Emissions or Omissions: How do firms' prospects under climate transition affect their equity returns?*

Joseph Noss[†1] and Zining Yuan[‡2]

[1]King's College London

[2]King's College London

April 30, 2025

Abstract

We investigate the relationship between firms' equity returns and potential changes in their profitability under a transition to net-zero emissions. To do so we use a new data set that enables us to estimate of how net-zero transition will change firms' profitability, based on estimated changes in demand for – and the cost of producing – their products. We find that higher emitting firms have higher stock returns. But stocks whose profitability is likely to increase under net-zero transition also earn returns that are slightly - yet statistically significant - higher than those whose profitability is likely to decrease. The latter result is less pronounced for firms with higher emissions, in countries with more stringent climate emissions-reduction policies. It is also less pronounced for firms that publicly disclose the degree to which they are exposed to risks or opportunities related to climate transition, or that disclose emissions reduction targets. This is consistent with an interpretation that whilst investors may demand greater compensation for holding higher emitting stocks, they do not demand greater compensation for holding those of firms at genuine risk from climate transition.

*We would like to thank David Aikman and attendees of the King's Business School 2024 for helpful discussion and comments. We acknowledge the support from the Qatar Centre for Global Banking & Finance. The authors declare that they have no relevant or material financial relationships to be disclosed.

[†]Email: joseph.b.noss@kcl.ac.uk

[‡]Email: zining.1.yuan@kcl.ac.uk

Keywords:Climate Transition, Stock returns, Sustainable Finance, Decarbonisation

1 Introduction

There are increasing concerns as to the effects of global warming due to human activity. This has led to efforts by policymakers – as well as wider shifts in consumer preferences, technology, and regulation – to curb carbon emissions. This in turn has led to discussion of climate transition risks: that is, the possibility that the profitability and value of some firms might change under a potential transition to a low-carbon economy.

This paper investigates whether firms' relative prospects under a potential transition to lower emissions are reflected in their stock prices. It does so using a new and novel measure, 'Climate Transition Value-at-Risk' (CTVaR), of the degree to which the value of firms is likely to change under a transition to lower emissions. This measure is based on in-depth firm-by-firm estimates of the impact of such a transition on demand for firms' products and services, their input costs and prices, and the subsequent effects on their profit margins. In doing so, it also accounts for a wide range of factors – including shifts in consumer behavior, technology and regulation – that might affect demand for firms' products under transition.

Existing attempts to examine the degree to which firms' transition risks are reflected in their equity prices have focused on firms' emissions. They examine whether the return on equities of higher emitting firms differ to those of lower emitting firms. One strand of literature finds that firms with higher emissions have higher stock returns than their lower emitting counterparts (e.g., Bolton and Kacperczyk (2021, 2023)[6] [5], Hsu et al. (2023) [12]. These authors argue that this is because investors demand greater compensation for holding stocks of firms that are higher emitting, due to the possibility that efforts to curb emissions might reduce their future profitability.

One draw back of this approach, however, is that firms' emissions may, however, be a poor proxy for their transition risk. Firms' individual emissions may not correspond to changes in demand for their products and services due to efforts to curb aggregate emissions at a global (or national) level. Some firms may currently have relatively high emissions; but might be likely to profit from the

longer-term transition to lower emissions globally – for example, if they are mining commodities for use in the generation and storage of renewable energy (Miller et al. (2023)[15], Boer et al. (2021) [4]. Other companies may create very few emissions as part of their own operations; but if they serve customers in high emitting sectors (e.g., providing services to oil companies), they may experience a sharp decline in revenues due to the transition. In addition, firms are likely to differ in the degree to which they are able pass any increase in the cost of emissions (e.g., due to the imposition of a carbon tax) on to their customers, thereby maintaining their profitability under climate transition. This is likely to depend on the relative competitiveness of different industries, as well as the ease with which consumers can substitute towards other, lower emitting, products and services. For example, higher emitting firms in less competitive industries might face relatively little reduction in demand for their products under a global reduction in emissions. Consumers are likely, for example, to continue to use long-haul air travel to some degree, and even if this means paying higher air fares.

In this paper, we provide new evidence on the link between firms' equity returns and prospects under transition, as measured by firms' CTVaR. To do so, we use series of pooled panel regressions of firms' monthly stock returns on CTVaRs, together with a host of other control variables and fixed effects. The hypothesis we seek to test is whether firms that are likely to reduce in profitability and value as a result of climate transition - that is have negative CTVaR - have higher equity returns. Such a negative correlation between firms' CTVaR and equity returns would be consistent with investors requiring greater compensation for holding stocks of firms more at risk from climate transition.

Our main finding is that of a small but highly statistically significant *positive* correlation between firms' stock returns and CTVaR; that is, firms whose profitability is likely to increase as a result of climate transition have higher equity returns than those for which it stands to decline. Specifically, we find that a one standard deviation increase in CTVaR is associated with a small (0.006 standard deviation) increase in monthly stock returns. This finding is consistent with the notion that firms' transition risk, as measured by CTVaR, is not reflected in their equity prices.

We also investigate the relationship between firms' emissions and stock returns. We find that the level of firms' emissions is also positively correlated with stock returns. In other words, whilst investors do not appear to have priced firms' prospects under transition according to CTVaR, they

nonetheless demand a premium for holding the equity of firms that are higher emitting. This suggests investors might be too fixated on emissions as a measure of climate transition risk, and fail – in their investment decisions – to account for the broader factors that influence firms prospects under transition.

We find that the scale and significance of this correlation between firms' equity returns and CTVaR is less for firms that are subject to greater pressures to align with climate transition. The correlation between CTVaR and stock returns is lower for firms in Europe and China jurisdictions that are subject to greater regulatory pressures to reduce their emissions and align with climate transition. Such regulatory pressures may increase investor focus on climate transition risks and opportunities, thereby increasing the degree to which firms' transition prospects are incorporated into their equity prices.

Furthermore, the scale and significance of the correlation between firms' CTVaR is also less for firms that consider and disclose their perceived risks and opportunities under climate transition. We find that the degree of correlation between equity returns and CTVaR is much lower for firms that consider and disclosure the nature of risks and opportunities that climate transition presents to their business, and for those firms that consider their products to enable transition in the wider economy. This is consistent with the notion that firms' consideration and disclosure of such risks and opportunities, together with the degree to which demand for their products may remain robust in transition, increases the degree to which this information is incorporated into their equity prices.

Finally, we find that the scale of the correlation between firms' CTVaR and equity returns is close to zero - albeit statistically significantly so - for firms that disclose emissions reduction targets, particularly those couched in terms of their intended reduction in absolute emissions. This is consistent with the notion that investors currently take firms' emissions as a proxy for their prospects under transition. Whilst emissions may be an imperfect proxy of such prospects, investors nonetheless come closer to pricing the pricing transition risk of firms that disclose an intention to reduce such emissions.

Our research contributes to the expanding literature on the intersection of firms' climate transition risk and stock market behaviour. As described above, one strand of literature, including that by [6] and [7], finds that firms with higher emissions have higher stock returns than their lower emitting

counterparts. These authors argue that this is because investors demand greater compensation for holding stocks of firms that are higher emitting, due to the possibility that efforts to curb emissions might reduce their profitability.

This result is contentious, however. Subsequent debate in the literature has queried whether the level of firms' emissions – rather than their intensity – is a correct reflection of firms' transition risk (Aswani et al. (2023) [1]). Other studies by (In et al. (2019) [13] and Pedersen et al. (2021)[18]) suggest that green firms outperform brown firms in equity markets. Questions have also been raised as to the econometric robustness of regressing firms' equity returns on their (unscaled) emissions whilst controlling for their size, since the latter two variables may be highly collinear.

Our findings shed new light on this debate in two respects. First, by using CTVaR as a measure of climate transition risk, we are able to overcome the debate as to whether the level or intensity of firms' emissions is a better proxy for their climate transition risk. Second, because our CTVaR data consider the full gamut of factors – including shifts in consumer behavior, technology and regulation – that might affect demand for firms' products under transition, they enable us to assess more accurately the degree to which equity prices affect firms' true prospects under transition. These data are proprietary, and their estimation based on expert judgement. But they may nonetheless provide an alternative estimate of the degree to which firms stand to lose or gain under climate transition, that is not based on their emissions.

This paper proceeds as follows. The next section (section reviews the existing literature on the relationship between firms' stock returns and emissions. Discussion of the limitations of firms' emissions as a proxy for their prospects under climate transition are given in Section 3, together with an introduction to the CTVaR data. Data on firms' equity returns, emissions and other control variables used in this analysis are described in Section 4. Section 5 introduces our methodology and results. A final section 7 concludes.

2 Review of the existing literature on the relationship between firms' equity returns and emissions

The literature posits two key reasons why there should be correlation between firms' emissions and stock returns. The first concerns transition risk. Increasing pressure by governments – and society at large – to decarbonise the global economy increase the risk to the cash flows – and hence the cost of capital – faced by higher emitting firms (Pastor et al., 2021)[17]. Such risk could emanate from the imposition of carbon taxes, or other measures to limit the quantity of emissions, which could increase firms' costs and reduce their profitability.

A second reason why emissions could relate to stock returns concerns investors' tastes. Pastor et al. (2021) [17] and Pedersen (2021) [18] argue that some investors may choose to divest from brown industries – not on the grounds of their risk, but because they cause harm to society. If enough investors avoid higher emitting stocks, then they should earn additional return in order to attract a smaller residual investor base.

An influential paper by Bolton and Kacperczyk (2021) [6]– on whose econometric methodology our work is based (see Section 5) – finds that US companies with higher levels of (and positive changes in) carbon emissions have higher realised stock returns. Their results are consistent with investors pricing climate transition risk – that is, requiring higher compensation for holding higher-emitting firms on the grounds of their risk. Other authors, such as Hsu et al.(2023)[12] and Pastor et al. (2021) [17] also document a strong association between firms' carbon emissions and their equity returns, arguing that this reflects the additional compensation required by investors in return for exposure to climate transition risks. Bolton and Kacperczyk (2023)[7] expand their previous study to firms globally, rather than just those in the US. They find that carbon premia related to the level of firms' emissions are higher in countries with stricter domestic climate policies, as these have increased investor awareness of climate change.

This empirical link between firms' emissions and stock returns is neither straightforward nor uncontentious, however. Aswani et al. (2023)[1] show that the carbon premium is insignificant when the intensity of firms' emissions – that is emissions scaled by firms' size – are considered,

rather than their absolute level. This finding is corroborated by Bolton and Kacperczyk (2021, 2023)[6][7], who also find no significant relationship between firms' equity returns and emissions. Other studies, such as Bauer et al. (2023)[3] and Pastor et al. (2021)[17] even find that equities of higher emitting firms have lower, rather than higher returns, than their lower emitting counterparts.

These findings have led to three key debates in the subsequent literature.

The first concerns whether the absolute level of firms' emissions properly captures firms' transition risks. If instead, transition risk reflects firms' emissions intensity – that is, emissions divided by some measure of their size, value or scale of production – then it is unclear whether any correlation between the absolute level of firms' (unscaled) emissions and equity returns can be taken as indicative of firms' transition risk. Bolton and Kacpercyzk (2021) [6] argue that the (unscaled) level of firms' emissions is a more suitable proxy for transition risk, because it directly captures the proportion of an economy's emissions for which a given firm accounts. In contrast, Aswani et al. (2023b)[2] argue the opposite: whilst society as a whole wishes to reduce the level of emissions, in so far as it wishes to do so whilst maintaining economic production, emissions intensity provides a better guide to firms' individual transition risk. If firms, in aggregate, produce a given value of goods or services, those firms with lower emissions intensity – that is fewer emissions per unit of production – are at less risk from transition.

This debate has also raised questions as to the robustness of certain econometric results. Bolton and Kacperczyk (2023)[5] argue that dividing emissions by firms' revenues causes 'noise' in the data, as firms' emissions intensity can change due to changes in firms' revenues that have little to do with either firms' emissions or productive output. Aswani et al. (2023)[1] acknowledge this. But they argue that by including firms' size as a control variable in their regressions of equity returns on the level of emissions, Bolton and Kacperczyk (2021)[6] introduce multicollinearity into their regressions, due to the way that the absolute level of firms' emissionsare are positively correlated with their size. This may cast doubt on the robustness of the relationship between the level of emissions and firms' revenues in the work of Bolton and Kacperczyk.

The second debate concerns differences between firms' emissions (whether scaled or not) provided by firms themselves, compared to those provided by third-party data vendors. Emissions data have expanded rapidly over the past fifteen years. But much of this expansion reflects an increase in

emissions data estimated by third-party vendors rather than that provided by firms themselves. Aswani (2023)[1] find that the carbon premium becomes insignificant when measured via emissions disclosed by firms rather than third parties. They argue that this may arise because estimated emissions may be a deterministic function of firms' size, sales growth and industry – rather than capturing genuine differences in their production processes and emissions efficiency. In contrast, Bolton and Kacperczyk (2023)[5] argue that this result is consistent with investors requiring a lower premium for holding firms that disclosure emissions, because the act of disclosure reduces uncertainty as to their future profitability.

This difference between firm-provided and vendor-calculated emissions also has implications for another result in the literature concerning the degree to which the relationship between firms' emissions varies over time and in response to the introduction of climate policy. Bolton and Kacperczyk (2023)[7] find that the relationship between the level of emissions and firms' equity returns is stronger after the formation of the Paris agreement in 2015. They attribute this finding to the notion that the introduction of tighter climate policies may increase the compensation investors require for holding the equity of higher emitting firms. This could be because the signing of the Paris Agreement resulted in more aggressive decarbonisation policies by governments. However, Aswani et al. (2024) [1] cast doubt on this result. They argue that this increase in the relationship between emissions and equity returns post-2015 may simply reflect an expansion of the number of firms in the sample, including those whose emissions are provided by third-party vendors.

The third contention is whether past realised equity returns are a good proxy for investors' expectations of firms' future equity returns cost of capital. The interpretation of higher equity returns conferring a risk premium in the eyes of investors for higher-emitting stocks contrasts with that in the ESG literature, where higher returns have been taken as evidence that firms' embracing of sustainability pays off – i.e., the sustainable behaviour is good for firm value, rather than exposing companies to additional risk (Gompers et a. (2003)[11], Boustanifar and Kang (2022) [8]). Zhang (2024)[19] finds that higher equity returns on higher emitting firms arise from forward-looking firm performance information contained in firms' emissions, rather than a risk premium in the eyes of investors. This study finds evidence that transition risk is at least partially reflected in equity prices, but that higher returns from higher-emitting firms are consistent with an ongoing transition – or set

of policy shocks – related to the transition to lower emissions.

3 Shortcomings of emissions as a measure of firms' transition risk and CTVaR

This section discusses the deeper shortcomings of emissions – whether unscaled or adjusted to effect firms' emissions intensity – as a measure of the degree to which firms' profitability might change under climate transition.

3.1 Emissions as a measure of transition risk

Recent regulatory initiatives have focused on firms' emissions as a measure of transition risk. Emissions are, for example, one of the metrics of climate-related risks that firms are required to report under various climate reporting regulations. These include climate disclosure rules issued by, for example, climate disclosure rules developed by both the US Securities Exchange Commission (SEC) and European Corporate Sustainability Reporting Directive (CSRD)[1], both of which require firms to disclose their emissions as the key metric with which to give investors information on companies climate-related financial risks. Similarly, central banks – such as the Bank of England, European Central Bank, and Federal Reserve Bank of New Year – have required firms to disclose their emissions as part of their stress tests to determine firms' exposures to climate transition risks. Part of the rationale for using emissions as a proxy for firms' transition risk is that any increase in the cost of emissions under transition will have a greater impact on the cots faced by higher-emitting firms, thereby resulting in a decline in their profitability. Such an increase in the cost of emissions could be brought about through the imposition of a carbon tax. It could also take the form of quantitative limits on firms' emissions, including those combined with carbon trading schemes that require higher-emitting firms to purchase carbon credits from their lower-emitting peers.

[1]See SEC (2024), 'SEC Adopts Rules to Enhance Climate-Related Disclosures', Press Release; and European Commission, 'Corporate Sustainability Reporting'.

3.2 Possible shortcomings of emissions as a measure of financial risk

Besides the debate in the academic literature described in the previous section, there are other shortcomings of emissions of as a proxy for firms' climate transition risk.

The first concerns emissions' backward-looking nature – that is, that they generally pertain to firms' past behavior and activities. They therefore give only limited insight into the future changes in firms' business models, and subsequent changes in emissions (see Kolbel et al. (2020)[14]). Future changes in firms' emissions can be a crucial determinant of the transition risks to which they are exposed. For example, a firm in an emissions intensive manufacturing sector (e.g., steel or cement) might have less (or little) exposure to transition risk it if takes steps to reduce its emissions – for example by switching to less emissions intensive energy sources and manufacturing processes.

Measure have been taken to provide investors with a more forward-looking guide to firms' future emissions. Several initiatives encourage firms to disclosure their strategies for reducing their emissions, with the aim of increasing transparency concerning their net-zero targets. These initiatives include those led by regulators: for example, the EU Corporate Sustainability Reporting Directive (CSRD) requires large companies to disclosure sustainability information, including their plans for reducing emissions. Other voluntary and market-driven frameworks, such as those formed by the Task Force on Climate-related Financial Disclosures, and Carbon Disclosure project, recommend – and provide platforms through which – firms can report their emissions reduction strategies and targets. The academic literature that relates emissions to firm equity returns attempts to account for the backward-looking nature of emissions. For example, Bolton and Kacperczyk (2021)[6] find that the equity returns of firms whose emissions are growing over time are greater than those for which they are shrinking. This provides some indication that investors pay attention to changes in firms emissions and use it as a yardstick for firms' transition risk.

Even if this issue were resolved, and emissions were readily available on a forward-looking basis, other reasons why emissions may be an imperfect measure of firms' exposure to transition risk:

First, firms' emission may not correspond to changes in demand for their products under a climate transition scenario. Some higher-emitting firms may continue to see robust demand for their products despite global attempts to reduce emissions. Miller at al (2023)[15] estimate the degree to

which demand for – and hence the price of – transition-critical commodities – are likely to increase as a result of climate transition. This is due to their role in supporting the manufacture of technologies that are likely to play a critical role in reducing emissions, including the manufacture of solar panels, batteries of electrical vehicles, and supporting the enhancement of electricity grids.

Conversely, other firms with relatively low emissions might see dwindling demand for their products and services. An example is a firm that is engaged in supply software products to oil and gas companies. Whilst this firm might have relatively low emissions, to the extent that the transition to lower emissions reduces demand for oil and gas, it might see a reduction in its profitability.

Second, firms differ in the degree to which any increase in the cost of their operations – including that brought about by a reduction in emissions (or increase in their cost, via a carbon tax) – is likely to impact to their profitability. Noss (2022)[16] discusses differences in the degree to which firms are able to pass such extra costs on to their costs on to their customers, in the form of higher prices for their products. This is likely to depend on the relative competitiveness of different industries, as well as the ease with which consumers can substitute towards other, lower emitting, products and services. For example, higher emitting firms in less competitive industries might face relatively little reduction in demand for their products under a global reduction in emissions. Consumers are likely, for example, to continue to use long-haul air travel to some degree, and even if this means paying higher air fares.

In summary therefore, whilst there is a clear need – and efforts being made – to reduce emissions on a global level, firms' individual emissions provide only an imperfect proxy of the degree to which this is likely to impact their profitability.

4 Data

This section introduces the other data used in this study . It begins by describing those on firms' Climate Transition Value-at-Risk, an alternative measure of how firms' profitability might change under a transition to lower emissions. It then goes on to describe data on firms' emissions, as well as those on firms' equity returns, as well as various other variables that reflect firms' individual that we use to control for other factors that influence firms' equity returns in our panel regressions.

4.1 Climate Transition Value-at Risk: CTVaR

Climate Value-at-Risk (CTVaR) attempts to offer an enhanced estimate of the degree to which firms' profitability – and the value of their equity – will change under climate transition. It is a propriety measure produced by WTW, available for around 3713 firms globally. For each firm, CTVaR consists of an estimate of the degree to which the value of firms' – and that of their equities – would change if investors were to align in a belief that the world would undergo a climate transition under which global temperatures increased to by less than 2°C.[2]

CTVaR is estimated not based on firms' emissions, but instead via an in-depth analysis of the impact of transition on demand for firms' products and services, their costs and prices, and the resulting effect on their profit margins. Precise details of its calculation for individual firms are proprietary; but a sketch of the methodology – based on publicly available information – is as follows:

- For each of 500 sectors in the global economy, the estimation begins by considering the likely change in demand for firms' products and services under climate transition. This includes changes due to changes in consumer preferences (for example, as consumers choose to shift towards less carbon intensive products, technology (as, for example certain industries witness a shift in demand for lower emissions technology such as electric vehicles). It also considers the effect of regulation, particularly where this requires some manufacturers (e.g., those in the fashion industry) to increase the durability of their products to lower emissions, resulting in a decrease in demand for products as their lifespan increases.

- It then assesses how residual demand for firms' products – over and above that resulting from the reduction in demand described above – will be decarbonized in order to achieve an overall reduction in emissions. This is based on estimates of the changes in manufacturing processes that will be required to meet residual consumer demand, whilst adhering to emissions targets. Such changes in manufacturing processes might include electrification (over the use of oil and gas, for example) or the introduction of sustainable aviation fuel.

[2] CTVaR differs to other measures of value-at-risk commonly used in finance. In particular, whereas VaR standardly estimates the change in a value of an asset with a given probability, CTVaR is the expected change in value under a given climate transition scenario. Mathematically the two have little in common.

- The next step is to consider who meets the cost of this decarbonization. Such costs might include additional investment required to adopt new technology or meet regulatory requirements (including the introduction of a carbon tax) or to adopt new technology. They might also include changes in operation costs, as firms adopt cleaner forms of energy.

  Firms in different sectors vary in the degree to which they pass through any chance in their costs to their customers. In most industries it is assumed that any increase (decrease) is costs is passed fully on firms' customers in the form of higher (lower) prices, meaning that firms' profit margins remain constant. That said, in some industries – such as those that are highly regulated, or in less competitive industries where firms have higher margins – firms may not change their prices and instead absorb more of the increase in their costs.

- The final step in the calculation is to consider the sum total of these estimated changes in demand – and on firms' prices and margins – on the profitability of each sector.

This process yields an estimate of the degree to which climate transition will change the profitability of firms in each sector, in aggregate.

Note that the change in demand estimated in the first step of the calculation is assumed to be fixed in the calculations of changes in costs and prices that follows. Put differently, changes in demand for firms' products are assumed to be an exogenous variable that is determined by scale of transition to lower emissions. Other variables that determine firms' profitability – that is, their costs and prices – are assumed to be affected by, but not themselves affect, changes in demand. This is a simplifying assumption given that, in reality, any change in price is likely to itself affect demand.

To calculate the effect of climate transition on individual firms, firms' activities are mapped to each of the 500 sectors considered above. The change in enterprise value of each firm is calculated as the sum of that of each of the sectors in which it is active, weighted by the revenue and profits it obtains from each. The impact on the value of firms' equities is calculated as the change in enterprise value, adjusted for the book value of firms' leverage.

4.2 Summary statistics of the CTVaR data

The CTVaR data consist of estimates of the impact on firms' equities were investors to align on a scenario in which any increase in global temperatures is limited to below 2°C. The data point for each firm consists of an estimate of the percentage change in each firms' equity price that would take place under this scenario. Unlike other data used in this study, data on firms' CTVaR is available only at a single point in time, at end-2022. The majority of firms in the sample are from North America and Europe, and a smaller number (172) from jurisdictions beyond this that are emerging markets.

Fig 1 shows the average level and dispersion (i.e., maximum / minimum and interquartile range) of estimates of CTVaR for all firms for which data are available. These are split by sector, as defined by their six-digit GICs code. The average exposure of firms in most sectors is negative, if generally close to zero; in other words, the average firm in most sectors is expected to decrease slightly in value as a result of transition. This reflects the aggregate capital investment required to maintain firms' profitability under net-zero transition. The average of exposure of firms in the energy sector is around -30%. One exception is the utilities sector, which includes firms engaged in renewable energy production, and where the average CTVaR is positive (i.e., these firms stand to gain from transition). There is considerable dispersion in the industrials and consumer discretionary sectors, which reflects differences in firms' industrial processes and ambition of their net zero targets.

CTVaR also varies across regions. As Fig 2 shows, a greater proportion of firms in North America have negative CTVaR compared to those in Europe. This might reflect the relative strength of policymakers' commitments to climate transition across these geographies. All-else-equal, a stronger (actual or perceived) commitment to climate transition in Europe might prompt a prevalence of firms with business models that are more likely to profit as a result of climate transition.

There is only limited correlation between the level of firms' emissions and CTVaR, as shown in Figure 3. As discussed above, some firms are high emitting but have positive climate transition

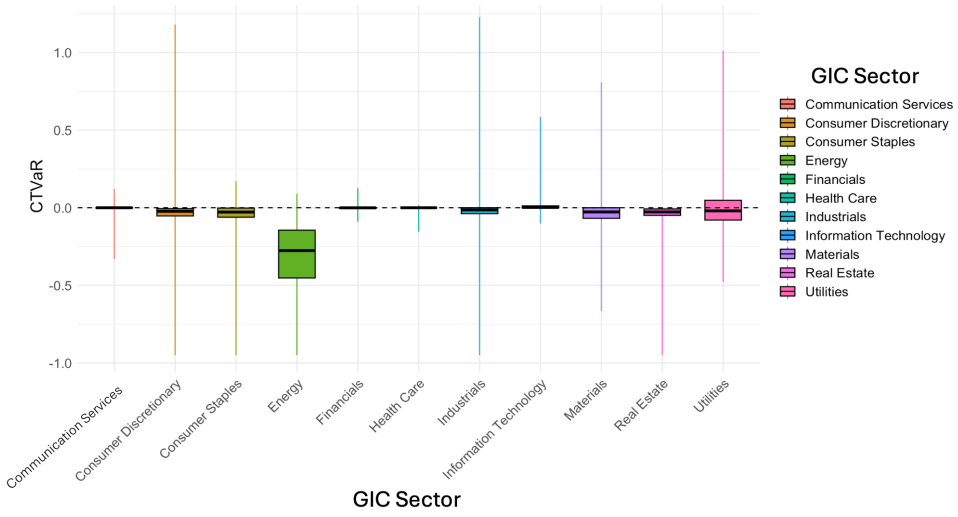


Figure 1: The average level and dispersion of firms' exposure to climate transition, by sector
The boxplot shows the minimum / maximum, 25 / 75th percentile and median exposure to climate transition for each sector

exposure. These include firms that are engaged in the extraction and manufacture of products and technologies that are likely to play a critical role in the transition to a lower carbon economy, even if their operations are themselves high emitting. One example, is the firm KGHM, which extracts and processes copper. Whilst this activity is relatively emissions intensive, the value of the firm may increase under transition as demand for copper – which is likely to play a key role in expanding and reconfiguring electricity grids – increases. Conversely, some firms are lower emitting but have negative transition exposure. Such firms include, for example, BW Offshore, which supplies services to oil and gas companies. While such firms are not, in themselves, high emitting, they nonetheless stand to lose a result of net-zero transition

4.3 Data on firms' emissions

Data on firms' emissions are taken from Trucost. These data conform to the Greenhouse Gas Protocol that distinguishes between three different sources of emissions: Scope 1 emissions, which are the direct emissions over the previous year produced by all entities directly controlled by the

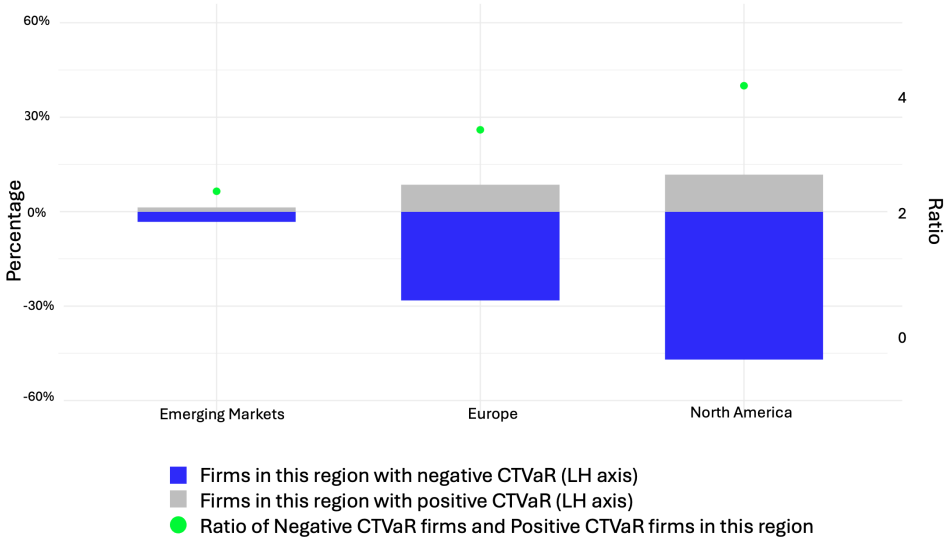


Figure 2: Proportion of firsm with positive/negaitve exposure to climate transition, and ratio of firms with negative exposure to those with positive exposure, by region

firm; Scope 2 emissions which are generated by the heat and electricity purchased and used by the firm; and Scope 3 emissions that are caused by the operations and products of the firm but occur from entities not owned or controlled by it (e.g., from its supply chain). Many of firms' Scope 3 arise from firms' purchase of goods and services, and their sold products[3].

Emissions of different scope differ in the degree to which they are reported. Scope 1 and 2 emissions are generally more widely reported, both because they are easier to measure also subject to stricter disclosure requirements. Summary statistics, including the number of firms reporting each scope of emissions – together with their average and median values, are reported in Table 1. These are similar – though not identical – to the summary statistics of the emissions data used by Bolton and Kacpercyzk (2021)[6]. We ascribe any differences to differences in the underlying sample of firms we are considering: whereas Bolton and Kacpercyzk (2021)[6] focus only on US firms, our sample both include firms' from other geographies.

Table 2 reports the correlation between firms' emissions and with CTVaR. Firms' Scope 1,2 and 3 emissions are positively correlated. Notably, emissions of all scopes have a small negative correlation with CTVaR.

[3]Reference latest CDP climate change report, and the proportion of emissions coming from these two scopes therein

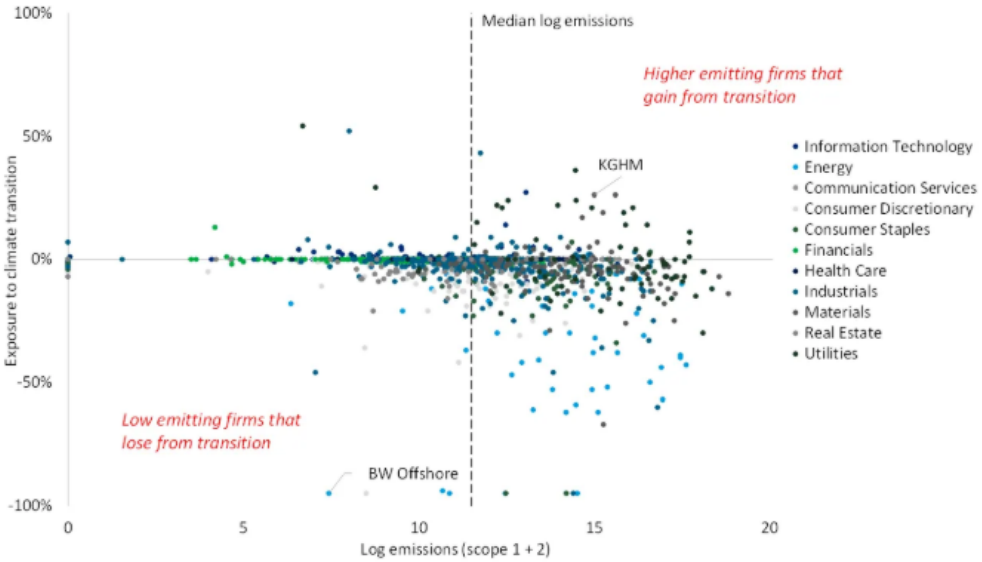


Figure 3: Firms' total emissions and CTVaR

4.4 Data on firms' equity returns and control variables

We also use monthly data on firms' equity returns between January 2005 and December 2023 from Compustat. This is combined with data on the following control variables:

- **LOGSIZE**, which is the natural logarithm of firm i's market capitalization (price multiplied by shares outstanding), which is observed on an annual basis at the end of each year t;
- **B/M**, which is the book value of each firm i divided by its market cap at the end of the year t;
- **LEVERAGE**, which is the book leverage of firm i at year t, measured by summing long-term debt, notes payable and long-term debt, divided by the book value of the firm's assets;
- **ROE**, which is the ratio of firm i's net yearly income divided by the value of its equity at year t;
- **MOM**, which is average stock return of firm i in the 12 months leading up to a given month t;
- **INVEST/A**, which is the ratio of firm i's capital expenditures (including its investments) divided by the book value of its assets at time t;
- **LOGPPE**, the natural logarithm of firm i's property plant and equipment;
- **BETA**, the market beta of firm i's stock in year t – that is, a measure of firm's sensitivity to changes in the value of equities market wide, calculated over a one-year period using daily data;

- **VOLAT**, which is the standard deviation of firm i's stock returns over the 12 months prior to month t;
- **SALESGR**, which is the annualized growth in sales revenue for firm i at time t, measured by the dollar change in annual revenue normalized by the previous month's market capitalization;
- **EPSGR**, which is the annualized growth in earnings-per-share, measured by the dollar change in annual EPS normalized by the firm's equity price.

These control variables match those used by Bolton and Kacpercyzk (2021)[6]. In keeping with their approach, and to eliminate the impact of outliers, we winsorise B/M, LEVERAGE and INVEST/A at the 2.5% level and MOM and VOLAT at the 0.5% level. Summary statistics broadly match the values reported by Bolton and Kacpercyzk (2021)[6].

Table 1: Emission Variables Summary Statistics 2005 - 2023

Variable	**Mean**	**Median**	**Std. Dev.**
Log (Carbon Emissions Scope 1 (tons CO_2e))	10.39	10.23	2.95
Log (Carbon Emissions Scope 2 (tons CO_2e))	10.50	10.56	2.30
Log (Carbon Emissions Scope 3 (tons CO_2e))	12.39	12.49	2.21
Carbon Intensity Scope 1 (tons CO_2e/USD m)/100 (winsorized at 2.5%)	1.79	0.13	7.55
Carbon Intensity Scope 2 (tons CO_2e/USD m)/100 (winsorized at 2.5%)	0.39	0.15	1.12
Carbon Intensity Scope 3 (tons CO_2e/USD m)/100 (winsorized at 2.5%)	1.59	0.88	1.93
GHG Direct Impact Ratio (winsorized at 2.5%)	0.70	0.05	2.83
GHG Indirect Impact Ratio (winsorized at 2.5%)	0.73	0.44	0.89

Table 2: Carbon emissions: correlations

	CTVaR	Scope 1	Scope 2	Scope 3	Intensity Scope 1	Intensity Scope 2	Intensity Scope 3
CTVaR	1.00						
Scope 1	-0.14	1.00					
Scope 2	-0.12	0.43	1.00				
Scope 3	-0.18	0.49	0.56	1.00			
Intensity Scope 1	-0.13	0.56	0.11	0.06	1.00		
Intensity Scope 2	-0.04	0.07	0.35	0.02	0.15	1.00	
Intensity Scope 3	-0.14	0.19	0.17	0.31	0.25	0.15	1.00

This table presents the cross-correlations among emission variables and CTVaR in the sample period 2005 - 2023.

To match these firms to those on firms' emissions and CTVaR using firms' ISINs. This leaves us with data on 3493 unique firms out of the 3713 firms available in the CTVaR data set.

5 Main methodology and results

This section describes the methodology used, and the results contained, in our study. We begin by replicating the results of Bolton & Kacpercyzk (2021)[6]; that is, those concerning the relationship between

firms' equity returns and the level (and intensity) of their emissions. We then go on to replace emissions with the CTVaR of the firms in the same regression, and examine how the relationship between equity returns and the CTVaR varies between firms that are subject to different intensities of climate policy (both over time and in different jurisdictions), as well as for firms that disclose different levels of climate readiness.

5.1 Relationship between firms' equity returns and emissions

We begin by examining the relationship between firms' equity returns and emissions. To do so, we replicate the methodology of Bolton and Kacperczyk (2023)[7], and carryout a pooled OLS panel regression of firms' equity returns on their emissions, along with the control variables described in the previous section. The regression specification is given by:

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{Emission}_{i,t} + \alpha_2 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \tag{1}$$

where $\text{RET}_{i,t}$ is the return on the equity of company i in month t, $\text{Emission}_{i,t}$ is a generic term for a variables representing different measures firms' emissions (both the log of the level of firms' scope 1, 2 and 3 emissions and the log of the total of these; as well firms' emissions intensities on a scope 1, 2, 3 and total basis). μ_t, ς_i and η_i are fixed effects that correspond to fixed effects over time (i.e., for each month), geography (North America, Europe, and emerging markets), and industry (by six-sector GICS code). To facilitate comparison of the explanatory power of the variables (both firms' emissions and, as described later in this section, CTVaR), all variables in all regressions are normalized.

Results are shown in Table 3 (specifications (1) to (8)). We find that the level of firms' emissions – of all scopes – have a small positive effect on firms' equity returns. Specifically, a one standard deviation increase in the level firms' emissions results in an increase in firms' equity returns of between 0.013 and 0.027 standard deviations, depending on the scope of emissions considered. These coefficients have high statistical significance. We also find that little relationship between firms' equity returns and emissions intensity – but for a small negative (but relatively insignificant in statistical terms) coefficient on the intensity of firms' scope 1 emissions.

Across both types of regressions – that on the level of emissions, and that on emissions intensity - the statistically significant coefficients on the control variables yield are of a sign that aligns with that documented in the wider asset pricing literature. The coefficients on LOGSIZE are negative, reflecting how larger firms empirically exhibit lower returns as they are typically more established, with less volatile expected cash flows and lower growth prospects. The coefficient on B/M is positive: 'value firms' higher book-to-

Table 3: Baseline regression of firm equity returns on emissions and control variables with time, industry and geographic fixed effects

Dept Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LOG (SCOPE 1)	0.013***								
	(0.004)								
LOG (SCOPE 2)		0.016***							
		(0.003)							
LOG (SCOPE 3)			0.027***						
			(0.004)						
LOG (TOT)				0.025***					
				(0.005)					
GHG INTENSITY SCOPE 1					-0.006*				
					(0.003)				
GHG INTENSITY SCOPE 2						0.001			
						(0.002)			
GHG INTENSITY SCOPE 3							0.000		
							(0.002)		
GHG INTENSITY TOT								-0.001	
								(0.002)	
CTVaR									0.006 ***
									(0.002)
LOGSIZE	-0.038***	-0.040***	-0.045***	-0.040***	-0.038***	-0.038***	-0.036***	-0.036***	-0.036***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.003)
B/M	0.024***	0.024***	0.023***	0.017***	0.024***	0.024***	0.018***	0.018***	0.025***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
LEVERAGE	-0.008***	-0.008***	-0.008***	-0.009**	-0.008***	-0.008***	-0.008**	-0.008**	-0.009***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
MOM	0.002	0.002	0.002	0.007*	0.002	0.002	0.007**	0.007**	0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
INVEST/A	-0.005*	-0.007**	-0.004*	0.001	-0.008***	-0.008***	-0.001	-0.001	-0.010***
	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)	(0.002)
ROE	0.033***	0.032***	0.032***	0.033***	0.033***	0.033***	0.034***	0.034***	0.038***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
LOGPPE	0.008*	0.006	0.001	-0.002	0.017***	0.016***	0.011*	0.011*	0.024***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)	(0.003)
Beta	-0.006*	-0.006*	-0.007*	-0.020***	-0.005*	-0.005*	-0.018***	-0.018***	0.006*
	(0.003)	(-0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)
VOLAT	0.024***	0.024***	0.025***	0.022***	0.023***	0.023***	0.021***	0.021***	0.016***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
SALESGR	0.018***	0.018***	0.018***	0.024***	0.019***	0.019***	0.025***	0.025***	0.020***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
EPSGR	0.059***	0.059***	0.059***	0.063***	0.059***	0.059***	0.063***	0.063***	0.052 ***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)	(0.003)	(0.002)
Year/month F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	291,075	291,323	291,419	152,192	291,419	291,419	152,192	152,192	400,436
R-squared	0.235	0.234	0.234	0.234	0.234	0.234	0.234	0.234	0.213

Notes: Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.
Standard errors, both here and in other results that follow, are clustered by firm and time, using the methodology of [9].

market ratios are empirically undervalued and have higher equity returns. Firms with higher profitability (represented by the ROE variable) demonstrate strong operational efficiency, thereby attracting investors and resulting in higher returns (see Fama and French (2015)[10]).

Our finding that firms with high levels of emissions – but not firms' with higher emissions intensity – have higher equity returns is consistent with that of Bolton and Kacpercyk (2021)[6]. These authors take this finding as consistent with the notion that investors demand additional compensation for holding the stock of firms with higher levels of emissions; that is, higher emitting stocks receive a 'carbon premium'.

As described in Section 2, these results have been subject to considerable debate in the literature. Discussion has focused on whether the level of firms' emissions, rather than their' emissions intensity, is a reasonable proxy for their prospects under transition. Questions have also been raised as the statistical robustness of controlling for firms' size in the regression, given that this variable is close to colinear with firms' (unscaled) emissions.

We do not opine on these debates here. Rather our intention in including these regressions is to gain some assurance that the nature of our data are similar in form to those used by Bolton and Kacpercyk (2021)[6]. This allows us to compare the relative impact of CTVaR on firms' equity returns versus firms' emissions, whatever the robustness of the latter result. It is to this that we now turn.

5.2 Relationship between firms' equity returns and CTVaR

We run an analogous regression to that in the previous sectoin, but replace the emissions of firm i with its CTVaR, that is CTVaR_i. The regression specification is similar to that in (1), but modified to reflect that our estimate of firms' CTVaR is available only at a fixed point in time (as of end-2022):

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{CTVaR}_i + \alpha_2 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \tag{2}$$

To reflect that fact that CTVaR varies by industry, and the controls variables vary over time, we continue to include the fixed effects capturing both firms' sector and time.

The result is shown in specification (9) of Table 3. CTVaR is positively associated with firms' equity returns. A one standard deviation increase in firms' CTVaR results in a small (0.006 standard deviation) yet statistically highly significant increase in firms' equity returns.

This result stands in marked contrast to that concerning the effect of emissions. Whereas investors receive a premium for holding higher emitting firms, they receive no such premium for holding stocks with lower CTVaR – that is, those that are estimated to reduce in profitability and value as a result of cliamte

transition. Indeed, if anything, investors appear to receive a positive - if very small - premium for holding stocks that are less exposed to transition risks (and have positive CTVaR). In other words, to the extent that CTVaR provides a more accurate assessment of the opportunities and risks embodied in climate transition, these do not appear to be priced by investors.

One explanation for this (albeit small) positive relationship between firms' CTVaR and equity returns might lie in the (albeit small) negative correlation between firms' CTVaR and emissions, discussed in the previous section. In other words, the positive correlation between returns and CTVaR might just be a reflection of how firms with higher CTVaR tend to be higher emitting, and higher emissions lead to higher equity returns.

To investigate this possibility, and as a robustness check, we run an additional set of regressions that includes both firms' emissions and CTVaR. This allows us to compare the relative impact of firms' emissions and CTVaR on equity returns. This regression takes the form:

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{Emission}_{i,t} + \alpha_2 \text{CTVaR}_i + \alpha_3 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \quad (3)$$

The results are shown in Table 4. CTVaR continues to have a small. positive and statistically significant impact on firms' stock returns when included in the regression alongside emissions. When CTVaR and the level of firms' emissions are included in the same regressions, the size of the impact of CTVaR on equity returns ranges from between around half to 75% of that of emissions (depending on the scope of emissions considered).

This result confirms that firms' CTVaR has small positive, yet statistically significant, impact on equity returns, over and above that driven by firms' emissions. Equity prices appear to exhibit both a carbon premium with respect to the level of firms' emissions, but do not price the risks and opportunities embodied in CTVaR.

One possible explanation for this result is that investors, in assessing future changes in firms' equities under climate transition, focus relatively narrowly on firms' emissions – rather than on their emissions intensity, or on the broader risk and opportunities captured by CTVaR. To investigate this, we explore the relationship between equity returns and CTVaR for firms with different levels of emissions. We do so by adding an interaction term – that is, the multiplicative product of CTVaR and different measures of emissions to (2):

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{Emission}_{i,t} + \alpha_2 \text{CTVaR}_i + \alpha_3 \text{CTVaR}_i * \text{Emission}_{i,t} + \alpha_4 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \quad (4)$$

Table 4: Regression of firms' equity returns on emissions and control Variables with CTVaR with time, industry and geographic fixed effects

Dept variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LOG (SCOPE 1)	0.014***							
	(0.004)							
LOG (SCOPE 2)		0.015 ***						
		(0.003)						
LOG (SCOPE 3)			0.028***					
			(0.004)					
LOG (TOTAL EMISSIONS)				0.027***				
				(0.005)				
GHG INTENSITY SCOPE 1					-0.005			
					(0.003)			
GHG INTENSITY SCOPE 2						0.001		
						(0.002)		
GHG INTENSITY SCOPE 3							0.000	
							(0.002)	
GHG INTENSITY TOT								0.000
								(0.002)
CTVaR	0.010***	0.009***	0.009***	0.014***	0.009***	0.009***	0.012***	0.012***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
LOGSIZE	-0.038***	-0.040***	-0.046***	-0.040***	-0.038***	-0.038***	-0.036***	-0.036***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
B/M	0.024***	0.024***	0.023***	0.017***	0.024***	0.024***	0.018***	0.018***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
LEVERAGE	-0.007***	-0.008 ***	-0.008***	-0.009**	-0.007***	-0.008***	-0.008**	-0.008**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
MOM	0.002	0.002	0.002	0.006*	0.002	0.002	0.007**	0.007**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
INVEST/A	-0.005*	-0.006**	-0.003	0.002	-0.007**	-0.008**	0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)
ROE	0.033***	0.033***	0.032***	0.033***	0.033***	0.033***	0.034***	0.034***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
LOGPPE	0.008*	0.007	0.002	-0.002	0.018***	0.016***	0.012*	0.012*
	(0.005)	(0.005)	(0.005)	(0.006)	(0.004)	(0.004)	(0.006)	(0.006)
Beta	-0.006*	-0.005*	-0.006*	-0.019***	-0.005*	-0.005*	-0.018***	-0.018***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
VOLAT	0.024***	0.024***	0.025***	0.022***	0.023***	0.023***	0.021***	0.021***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
SALESGR	0.018***	0.018***	0.018***	0.024***	0.019***	0.019***	0.025***	0.025***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
EPSGR	0.059***	0.059***	0.058***	0.063***	0.059***	0.059***	0.063***	0.063***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Year/month F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geography F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	291,075	291,323	291,419	152,192	291,419	291,419	152,192	152,192
R-squared	0.235	0.235	0.235	0.234	0.234	0.234	0.234	0.234

Results are shown in Table 5. The coefficient on CTVaR continues to be positive and statistically significant. But the coefficient on the interaction term, between CTVaR and the level of firms' emissions is negative, albeit of a smaller size. In other words, the degree to which firms' CTVaR increases their equity returns is less for firms with a larger level of emissions, and the market seems to price in more of their prospects under transition.

Table 5: Regression of firms' equity returns on with CTVaR, emissions and interaction terms with control variables and time, industry, and geographic Fixed Effects

VARIABLES	(1)	(2)	(3)
CTVaR	0.012***	0.025***	0.010***
	(0.003)	(0.004)	(0.003)
LOG (SCOPE 1)	0.014***		
	(0.004)		
LOG (TOTAL EMISSIONS)		0.028***	
		(0.005)	
GHG INTENSITY SCOPE 1			-0.001
			(0.002)
LOGSIZE	-0.038***	-0.041***	-0.036***
	(0.004)	(0.005)	(0.005)
B/M	0.024***	0.017***	0.018***
	(0.002)	(0.003)	(0.003)
LEVERAGE	-0.007***	-0.008 ***	-0.008***
	(0.002)	(0.003)	(0.003)
MOM	0.002	0.006**	0.007**
	(0.002)	(0.003)	(0.003)
INVEST/A	-0.005*	0.001	0.001
	(0.002)	(0.004)	(0.004)
ROE	0.033***	0.034***	0.034***
	(0.002)	(0.003)	(0.003)
LOGPPE	0.008*	-0.001	0.002**
	(0.004)	(0.006)	(0.006)
Beta	-0.006*	-0.019***	-0.018***
	(0.003)	(0.004)	(0.004)
VOLAT	0.024***	0.022***	0.022***
	(0.002)	(0.003)	(0.003)
SALESGR	0.018***	0.024***	0.025***
	(0.002)	(0.003)	(0.003)
EPSGR	0.059***	0.063***	0.063***
	(0.002)	(0.003)	(0.003)
CTVaR *LOG (SCOPE 1)	-0.004*		
	(0.002)		
CTVaR *LOG (TOT)		-0.013***	
		(0.003)	
CTVaR *GHG INTENSITY SCOPE 1			0.002*
			(0.001)
Year/month F.E.	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes
Geography F.E.	Yes	Yes	Yes
Observations	291,075	152,192	152,192
R-squared	0.235	0.234	0.234

As mentioned previously, it is not our aim to opine on the debate in the current literature as to whether the level of firms' emissions is taken by investors to be a proxy of firms' prospects under transition – nor whether this, or firms' emissions intensity, is a better measure of such prospects. But to the extent that the level of emissions is taken by investors to be a proxy for climate transition risk, the above result is consistent

with the notion that investors more carefully consider the transition prospects of higher-emitting firms, and hence these firms' CTVaR is better incorporated - or at least less unincorported - into their price.

5.3 Relative explanatory effect of CTVaR across jurisdictions

We compare the strength of the headline result in the precious section – that is the existence of a premium of firms with positive CTVaR – across firms subject to different strengths of climate policy. We do so by comparing the strength of the relationship between equity returns and CTVaR across different countries. Countries differ substantially in the extent of measures they are taking to reduce emissions. In particular, European countries have generally increased pressure on firms to decarbonize to a greater extent than the US.[4] To the extent that pressure on firms to act to mitigate climate change raises investor awareness of the transition risks faced by firms, one might expect our result to be weaker in the case of firms in Europe – where policies are more stringent – compared to in the US.

Results are shown in Table 6. The impact of CTVaR on firms' equity returns is smaller, and far less significant, for firms in Europe and China than for firms in the US and Emerging Markets.[5] That is, investors in these jurisdictions - whilst they do not receive additional compensation for holding equities of firms at risk from transition (i.e., with negative CTVaR), at least do not receive additional compensation for holding firms that standard to profit from it (i.e., those with positive CTVaR). This may be due to the greater strength of public perception regarding, and the urgency of public policy to accelerate, climate transition in Europe and China compared to the US and ohter emerging markets - a result consistent with that of (Bolton and Kacpercyzk (2023)[7]).

	(1) North America	(2) Europe	(3) Emerging Markets (ex. China)	China
CTVaR	0.007*	0.005	0.025**	0.003
LOGSIZE	-0.048***	-0.028***	-0.069***	-0.018
B/M	0.027***	0.019***	0.058***	0.098***
LEVERAGE	-0.004	-0.017***	-0.039*	0.037
MOM	0.002	0.013***	0.038***	0.037**
INVESTA	-0.012***	-0.011***	-0.009	0.036
LOGPPE	0.033***	0.013	0.069***	-0.086*
BETA	0.008	-0.011	0.028	-0.074***
VOLAT	0.021***	0.019***	-0.006	0.014
Observations	270,779	114,895	9,941	4,964
Adjusted R^2	0.232	0.212	0.188	0.341

Note: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 6: Regression of firm equity returns on CTVaR by Region, with Industry and Time Fixed Effects

[4] This is reflected, for example, in how European countries dominate the highest performing countries in the Climate Change Performance Index, whereas the US scores towards the bottom.

[5] Data on firms in emerging markets includes those in Peru, Hungary, Chile, South Africa, Mexico, United Arab Emirates, Clombia, Uruguay and Brazil.

6 The effect of firms' climate disclosures and transition plans

In this section, we assess whether firms' disclosure of the degree to which they are exposed to climate-related transition risks influences the relationship between their CTVaR and stock returns. To the extent that firms' disclosure of such risks and opportunities decreases the uncertainty faced by their investors, we might expect firms' CTVaRs to have a lower impact on their equity returns. This is because such disclosures might increase the degree to which such transition risks / opportunities were incorporated into firms' equity prices, thereby reducing the premium investors receive from holding stocks that benefit from transition. We also examine whether the existence and nature of firms' transition plans - that is, strategies disclosed by some firms through which they plan to align with global emissions reduction targets - influences this effect.

The spirit of this investigation is not novel. Bolton and Kacpercyzk (2023)[7], for example, find that the risk premium investors receive for higher emitting stocks is lower for those firms that disclose information on their emissions, rather than those firms for which these data being proxied by a third-party data vendor. But this result has also been subject to critique. For example, Asawni et al. question whether this difference in premium arises due to potential inaccuracies in the process through which third-party data vendors estimate emissions - i.e., as a function of firms' size, which itself correlates with emissions.

In contrast, our hope is that by combining voluntary firm disclosures from CDP with CTVaR we are able to obtain a cleaner read on the degree to which the relationship between firms' equity returns and transition risks varies with firms' disclosures. This is because CTVaR of a firm is calculated independently of its emissions, and so does not interact with other variables that appear in the regression (e.g., firm size).

6.1 Carbon Disclosure Project data

To do so we use data form the Carbon Disclosure Project (CDP) – a repository of information on the degree to which firms measure, manage and disclose climate risks. Firms across multiple jurisdictions contribute this information voluntarily via an annual survey conducted by the CDP. 4200 firms answered the survey at some point between 2011 and 2022, and the number of firms supplying responses has increased steadily over time.

From CDP surveys between 2011 and 2022, we select firms' answers to three questions that contain information on firms' transition risks. These are as follows:

- **RISKID**: Does your firm have a process for identifying climate-related risks?
- **OPID**:Does your firm have a process for identifying climate-related opportunities?

- **LowCarbon**: Does your firm classify any of its products publicly as low carbon, or as enabling a third party to avoid emissions?

We represent the answers to these questions via dummy variables that take the value 1 if firms respond positively to the question, and 0 if firms respond negatively. Firms that do not supply information are excluded from the subsequent analysis. Data are restricted to months between January 2011 and December 2022 – that is, those months in years for which CDP data are available.

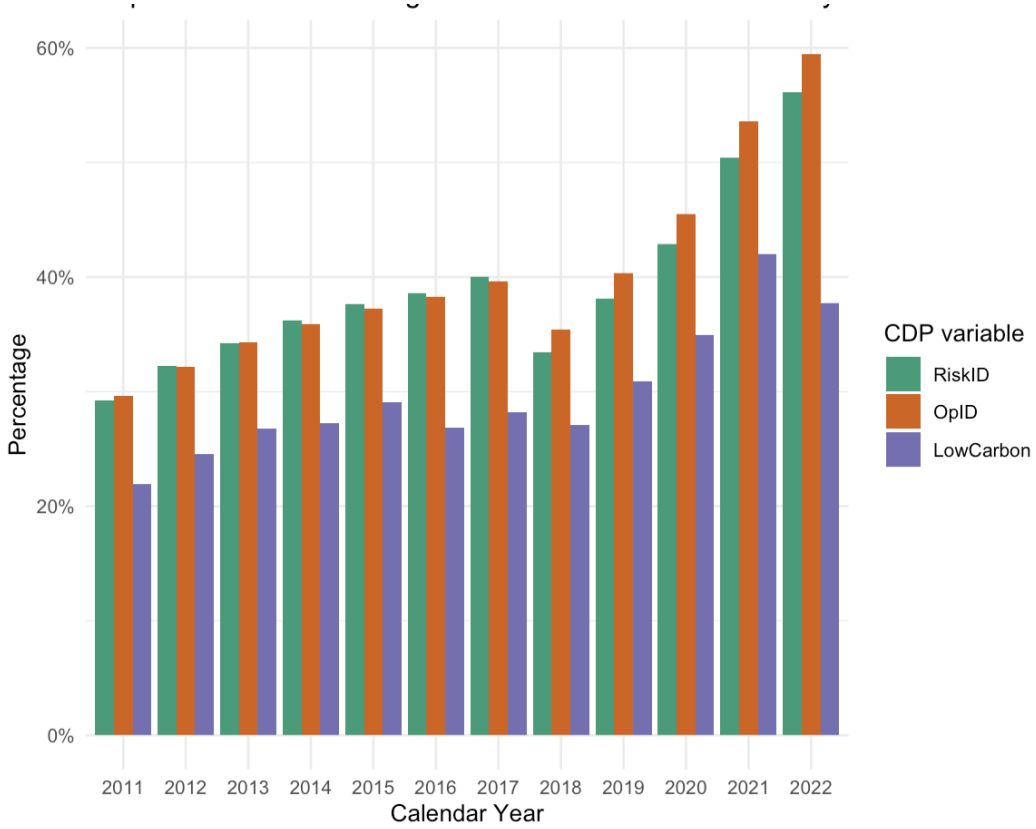


Figure 4: Proportion of firms answering positive to each CDP survey question, over time

The percentage of firms responding positively to each of the above questions is shown in 4. This has broadly increased over time, as firms' awareness of climate transition risks (and opportunities) - as well as the need to disclose these - has increased.

6.2 Impact of climate disclosures on the relationship between firms' CTVaR and equity returns

We begin by regressing firms' equity returns on their log total emissions as well as their CTVaR . These are analogous to the specifications in equations (1) and (2). The purpose of doing so is to check that the relationship between firms' equity returns, emissions and CTVaR for the subsample of data considered here (i.e., that between 2011 and 2022) is similar to that for the wider data set considered in previous sections.

Results are shown in Figure 7. Specifications (1) and (2) indicate that the relationship between firms' equity returns and both their emissions and CTVaR is similar to that in our baseline specification. A one standard deviation increase in firms' emissions / CTVaR results in a 0.022 / 0.019 standard deviation increase in their equity returns, both of which are highly statistically significant. Coefficients on control variables are also of a similar sign, magnitude and significance of those in our baseline specifications in Section 5.1.

We then include each of the dummy variables relating to the CDP data described above in turn, along with an interaction term - that is the multiplicative product of CTVaR and each dummy variable. The regression specification is:

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{CTVaR}_i + \alpha_3 \text{CTVaR}_i * D_{i,t} + \alpha_4 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \tag{5}$$

where $D_{i,t}$ is a dummy variable representing the response of firm i at time t to each of the above questions.

The inclusion of dummy variables representing the responses to the CDP survey yields remarkable results. The impact of CTVaR on the equity returns of firms that report having a process to identify climate-related risks and opportunities, is far less than for the rest of the same: a one standard deviation in CTVaR results in only a 0.004 standard deviation increase in their stock returns – found by summing the coefficients on CTVaR and that on the interaction term between CTVaR and the relevant dummy variable. This effect is statistically significant. This result is consistent with the notion that firms' act of considering transition risks and opportunities to their business, and disclosing these, drastically reduces the degree to which investors earn a premium on firms that stand to benefit from transition. In other words, the act of consideration and disclosure of these risks and opportunities by firms reduces market inefficiency and reduces the degree to which investors can gain from the degree they stand to profit from transition.

Finally, the inclusion of the dummy variable representing firms that report their products as low carbon – or enabling reduced emissions elsewhere in the economy – causes the impact of CTVaR equity returns to change sign. For firms reporting their products to be low carbon, a one standard deviation increase in their

	(1)	(2)	(3)	(4)	(5)
LOG (TOTAL EMISSIONS)	0.018***				
CTVaR		0.010***	0.045**	0.040***	0.021***
LOGSIZE	-0.030***	-0.036***	0.001	-0.003	0.001
B/M	0.005	0.014***	0.011**	0.009**	0.013***
LEVERAGE	-0.002	-0.001	0.003	0.003	0.003
MOM	0.0003	0.012***	-0.017***	-0.017***	-0.016***
INVESTA	0.012***	-0.005**	-0.011**	-0.012**	-0.013**
LOGPPE	-0.015**	0.011***	-0.003	0.001	-0.001
Beta	0.023***	0.020***	0.027***	0.026***	0.024***
VOLAT	0.037***	0.018***	0.045***	0.047***	0.045***
TP_RiskID			0.009		
TP_OpID				0.010	
TP_LowCarbon					-0.010
CTVaR:TP_RiskID			-0.041**		
CTVaR:TP_OpID				-0.036**	
CTVaR:TP_LowCarbon					-0.023***
Observations	119,949	251,768	60,560	60,945	65,463
R^2	0.223	0.190	0.264	0.266	0.261
Adjusted R^2	0.222	0.190	0.261	0.264	0.259

Table 7: Regression of firms' equity returns on CTVaR, and the interaction of CTVaR with dummy variables that represent positive responses of firms to CDP survey questions related to climate risks and opportunities

Note: *p<0.1; **p<0.05; ***p<0.01

CTVaR causes a 0.002 standard deviation decrease in their equity returns. Whilst this result is small, it is highly statistically significant. This result is consistent with investors in firms making these disclosures receiving lower returns for those more likely to profit from transition – or equivalently, a premium for those likely to reduce in profitability. It may for example be that firms making such a disclosure are subject to greater scrutiny by investors, meaning that information on their transition prospects is more likely to be reflected in their price.

In summary, these results are broadly consistent with the information contained within CTVaR being reflected in prices for firms that disclose information on the risk, and the additional return investors receive on CTVaR being less – or even negative – for firms that make such disclosures.

6.3 The impact of firms' transition plans on the relationship between their CTVaR and equity returns

CDP survey data also contains information on whether firms have published a climate transition plan, and the type of emissions reduction target this contains. In particular, data capture whether firms publish emissions targets based on an ambition to reduce their absolute emissions, or their emissions intensity (that is, their emissions divided by a measure of the size of their organisation or activities).

We therefore also investigate whether the relationship between firms' CTVaR and equity returns varies

according to the type of emissions reduction target they have disclosed.

As discussed in Section 2, there is an active debate in the literature as to whether firms' absolute emissions, or emissions intensity, constitutes a better measure of their exposure to climate transition risk. Once again, our aim is not to adjudicate on that question here - but rather to explore whether the nature of firms' targets affects the compensation investors demand for transition risk, as measured by CTVaR.

Figure 5 shows the proportion of firms with emissions reduction targets that report targets of different forms over time. The proportion of firms' reporting absolute emissions targets has increased over time. This may reflect the emphasise put on the absolute level of firms' emissions by some regulators - a phenomenon that [6] take as supporting investors' focus on the absolute level of firms' emissions.

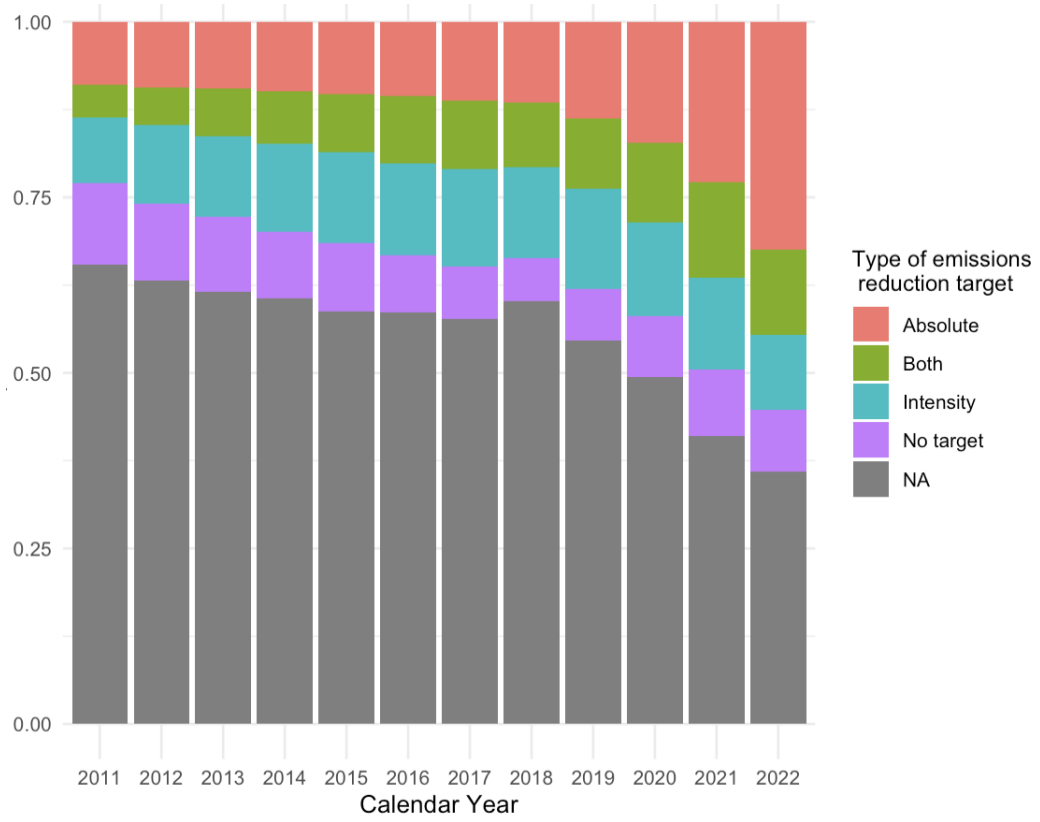


Figure 5: Proportion of firms answering positive to each CDP survey question, over time

We undertake further regressions similar to those in the previous section. These include the product of CTVaR and a dummy variable that captures the nature of firms' emissions target; that is:

- EmTargetAny - which takes the value 1 if a firm has an emissions reduction target of any form, and

0 otherwise;

- EmTargetAbsolute - which takes value 1 if a firm has an emissions reduction target stated in terms of the absolute level of emissions, and 0 otherwise;
- EmTargetIntensity - which takes value 1 if a firm has an emissions reduction target stated in terms of its emissions intensity, and 0 otherwise.

The regression specification is:

$$\text{RET}_{i,t} = \alpha_0 + \alpha_1 \text{CTVaR}_i + \alpha_3 \text{CTVaR}_i * D_{i,t} + \alpha_4 \text{Controls}_{i,t-1} + \mu_t + \varsigma_i + \eta_i + \varepsilon_{i,t} \tag{6}$$

where $D_{i,t}$ is a dummy variable representing the nature of firms' emissions target.

Results are shown in Table 8.

Once again, the first regression specification confirms the relationship between firms' CTVaR and equity returns for subsample of firms that report the nature of their emissions targets in the CDP data. As in our baseline specification, a positive CTVaR positively impacts firms' equity returns.

Specifications (2), (3) and (4) include the dummy variables capturing whether firms have an emissions target, and whether this is expressed as an absolute value of emissions or emissions intensity, respectively. The effect of CTVaR can be found by adding the coefficient on CTVaR and that on teh relevant interaction term.

The effect of CTVaR on firms that disclose an emissions target, or those that disclosure a target based on absolute emissions, is almost precisely zero. That is, a one standard deviation increase in CTVaR for these firms results in a (highly statistically significant) 0.001 standard deviation increase in their stock returns. In contrast, CTVaR continues to positively impact the equity returns of firms who disclose and emissions target in terms of emissions intensity.

This is consistent with the notion that firms' transition prospects are closer to being priced (or at least less mispriced) across those firms that disclose emissions reduction targets, at least those expressed in emissions intensity. This supports the hypothesis, expounded in [6], that investors are somewhat fixated with firms' emissions. Whilst, for the reasons we have discussed earlier in this paper, emissions give a misleading read on firms' prospects under transition, they may nonetheless increase the degree to which investors' consider - and demand differing degrees of compensation for - their prospects under transition.

	(1)	(2)	(3)	(4)
CTVaR	0.008***	0.017***	0.010***	0.010**
LOGSIZE	-0.047***	-0.012**	-0.012**	-0.012**
B/M	0.016***	0.017***	0.017***	0.017***
LEVERAGE	-0.002	-0.001	-0.001	-0.001
MOM	0.021***	-0.006	-0.006	-0.006
INVESTA	-0.012***	-0.015***	-0.014***	-0.014***
LOGPPE	0.024***	0.016**	0.015*	0.016**
Beta	0.012***	0.021***	0.021***	0.021***
VOLAT	0.012***	0.040***	0.040***	0.040***
EmTargetAny		-0.008		
EmTargetAbsolute			-0.002	
EmTargetIntensity				-0.009*
CTVaR:EmTargetAny		-0.016***		
CTVaR:EmTargetAbsolute			-0.009***	
CTVaR:EmTargetIntensity				-0.008
Observations	282,438	75,785	75,785	75,785
R^2	0.199	0.278	0.278	0.278
Adjusted R^2	0.198	0.276	0.276	0.276

Table 8: Regression results. Robust standard errors in parentheses.

Note: * p<0.1; ** p<0.05; *** p<0.01

7 Conclusion

This paper has considered the relationship between firms' equity returns and a new measure of firms' prospects under climate transition, CTVaR. This measure is based not on firms' emissions, but on granular estimates of the degree to which demand for firms' products, as well as firm profitability, is likely to change under transition. In considering this measure of climate transition risks / opportunities, rather than that based on emissions, we aim to skirt the controversies in the existing literature as to the suitability and robustness of the level of firms' emissions – versus firms' intensity – as a measure of transition risk.

We find that whilst stock returns appear to reflect a premium for higher emitting firms, so too are they higher for firms that estimated to profit from transition, according to our CTVaR data. The latter result is stronger for firms with higher emissions, for firms in jurisdictions with more accelerated climate transition policy, and for firms that have and disclose the degree to which they are exposed to risks and opportunities related to climate transition or emissions reduction targets. This is consistent with an interpretation that whilst investors may demand greater compensation for holding higher emitting stocks, they do not demand greater compensation for holding those of firms at genuine risk from climate transition. To the extent that – at least in the mind of investors – the level of firms' emissions does represent a proxy for firms' prospects under transition, our results are consistent with investors focusing (and requiring compensation for) this measure of transition risk, whilst not pricing in firms' prospects under transition as measured by CTVaR.

8 References

[1] Jitendra Aswani, Aneesh Raghunandan, and Shiva Rajgopal. "Are carbon emissions associated with stock returns?" In: *Review of Finance* 28 (Apr. 2023). DOI: 10.1093/rof/rfad013.

[2] Jitendra Aswani, Aneesh Raghunandan, and Shiva Rajgopal. "Are Carbon Emissions Associated with Stock Returns?—Reply*". In: *Review of Finance* 28.1 (May 2023), pp. 111–115. ISSN: 1572-3097. DOI: 10.1093/rof/rfad020. eprint: https://academic.oup.com/rof/article-pdf/28/1/111/56675782/rfad020.pdf. URL: https://doi.org/10.1093/rof/rfad020.

[3] Michael Bauer, Eric Offner, and Glenn D. Rudebusch. *The Effect of U.S. Climate Policy on Financial Markets: An Event Study of the Inflation Reduction Act*. Social Science Research Network, 2023. DOI: 10.2139/ssrn.4626499. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4626499 (visited on 12/04/2023).

[4] Lukas Boer, Andrea Pescatori, and Martin Stuermer. "Energy Transition Metals". In: *SSRN Electronic Journal* (2021). DOI: 10.2139/ssrn.3945524. (Visited on 05/31/2022).

[5] Patrick Bolton and Marcin Kacperczyk. "Are Carbon Emissions Associated with Stock Returns? Comment". In: *Review of Finance* 28.1 (May 2023), pp. 107–109. ISSN: 1572-3097. DOI: 10.1093/rof/rfad019. eprint: https://academic.oup.com/rof/article-pdf/28/1/107/56151330/rfad019.pdf. URL: https://doi.org/10.1093/rof/rfad019.

[6] Patrick Bolton and Marcin Kacperczyk. "Do Investors Care about Carbon Risk?" In: *Journal of Financial Economics* 142 (May 2021), pp. 517–549.

[7] Patrick Bolton and Marcin Kacperczyk. "Global Pricing of Carbon-Transition Risk". In: *Journal of Finance* 78 (Aug. 2023). DOI: 10.1111/jofi.13272.

[8] Hamid Boustanifar and Young Dae Kang. "Employee Satisfaction and Long-run Stock Returns, 1984-2020". In: *SSRN Electronic Journal* (2021). DOI: 10.2139/ssrn.3933687.

[9] A. Cameron, Jonah B. Gelbach, and Douglas Miller. *Robust Inference With Multiway Clustering*. 2011.

[10] Eugene F. Fama and Kenneth R. French. "A five-factor asset pricing model". In: *Journal of Financial Economics* 116 (Apr. 2015), pp. 1–22. DOI: https://doi.org/10.1016/j.jfineco.2014.10.010. URL: https://www.sciencedirect.com/science/article/pii/S0304405X14002323.

[11] Paul A. Gompers, Joy L. Ishii, and Andrew Metrick. *Corporate Governance and Equity Prices*. papers.ssrn.com, Sept. 2001. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=278920.

[12] PO-HSUAN HSU, KAI LI, and CHI-YANG TSOU. "The Pollution Premium". In: *The Journal of Finance* 78 (Feb. 2023). DOI: 10.1111/jofi.13217.

[13] Soh Young In, Ki Young Park, and Ashby Monk. *Is 'Being Green' Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns*. papers.ssrn.com, Apr. 2019. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3020304.

[14] Julian Kouml;lbel et al. "Does the CDS Market Reflect Regulatory Climate Risk Disclosures?" In: *SSRN Electronic Journal* (2020). DOI: 10.2139/ssrn.3616324. (Visited on 04/04/2021).

[15] Hugh Miller et al. "The Stumbling Block in 'the Race of our Lives': Transition-Critical Materials, Financial Risks and the NGFS Climate Scenarios(Matériaux critiques pour la transition, risques financiers et scénarios climatiques du NGFS)". In: *SSRN Electronic Journal* (2023). DOI: 10.2139/ssrn.4356692. (Visited on 03/18/2023).

[16] Joseph Noss. *Seeing through the smog: Towards a More Robust Measure of Climate Transition Risk*. Sept. 2022. URL: http://301.nz/Y5GtlnH4 (visited on 04/2024).

[17] Lubos Pastor, Robert F. Stambaugh, and Lucian A. Taylor. "Dissecting Green Returns". In: *SSRN Electronic Journal* (2021). DOI: 10.2139/ssrn.3864502.

[18] Lasse Heje Pedersen, Shaun Fitzgibbons, and Lukasz Pomorski. "Responsible Investing: The ESG-efficient Frontier". In: *Journal of Financial Economics* 142 (Nov. 2021). DOI: 10.1016/j.jfineco.2020.11.001. URL: https://www.sciencedirect.com/science/article/pii/S0304405X20302853.

[19] SHAOJUN ZHANG. "Carbon Returns across the Globe". In: *The Journal of Finance* (Oct. 2024). DOI: 10.1111/jofi.13402. (Visited on 12/21/2024).