Climate Transition Risk and Commercial Real Estate*

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ABSTRACT

Due to climate change, firms face growing uncertainty tied to the transition towards a low-carbon economy. This paper studies how real asset owners price climate transition risk using commercial real estate leases. Mapping firm carbon intensity to leases, I exploit the cross-sectional variation in firms with different levels of climate transition risk. I find novel evidence on asymmetric pricing of climate transition risk based on income exposure. Moreover, I document that green engagement by properties and landlords and local policy stringency affect climate transition risk premium. These suggest that awareness and local policy environment shape perceptions about climate transition risk.

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I. Introduction

As society commits to combating drastic climate change by reducing carbon emission and transitioning to a low-carbon economy, firms face increasing financial uncertainty from tightening regulation, intensifying litigation, shifting investor preferences, and changing customer taste. This uncertainty arising during the transition phase, referred to as climate transition risk or carbon risk, can produce shocks to firms' cash flows (Bolton and Kacperczyk, 2021; Giglio et al., 2021; Wang et al., 2022).[1] This risk is distinct from physical climate risk. A firm's exposure to climate transition risk is driven by the carbon emission or carbon intensity (carbon emission per revenue) from its business and production, not necessarily from exposure to physical climate change such as rising sea levels, flood risk, or hurricanes.[2] Therefore, firms, which have greater carbon intensity or face greater a challenge to transition away from carbon intensive activities, are exposed to higher climate transition risk. In the burgeoning climate finance literature, a central goal is to understand how financial market participants respond to the financial uncertainty given corporate climate risk exposure, especially climate transition risk (Engle et al., 2020; Krueger et al., 2020; Giglio et al., 2021; van Benthem et al., 2022; Bolton et al., 2022). While substantial progress has been made in learning how financial market players value climate transition risk,[3] there is a lack of consensus on whether and how such risk is priced in different asset markets.[4] Moreover, most existing studies have focused on the portfolio level pricing of climate transition risk. Thus, little is known at the underlying asset level, where asset owners and managers tend to engage in long-term contracts.

In this paper, I use commercial real estate (CRE) as the setting to address the impact of climate transition risk on real assets. I investigate whether and how real asset owners value the financial importance of climate transition risk via a set of commercial leases signed by firms with varying exposure to climate transition risk. Specifically, I study whether CRE owners price tenant firm climate transition risk by testing if higher climate transition risk tenants pay higher rent. Focusing on CRE in studying climate transition risk has several benefits. First, owners of CRE rely on long-term stable cash flows from tenants based on lease agreements. Long-term and low-turnover investors are documented as most likely to recognize climate risk (Krueger et al., 2020; Starks et al., 2017). CRE, which is usually traded infrequently and engages in multi-year lease contracts, forms a great testing field to empirically verify if and how long-term asset owners react to climate transition

[1] I use carbon risk and climate transition risk interchangeably in this paper.

[2] While the impact of firms' physical climate risk is also an important topic, it is beyond the focus of this paper.

[3] Giglio et al. (2021) provides a comprehensive review of initial effort in understanding pricing of both physical and transitional climate risk by different asset classes.

[4] Wang et al. (2022) covers a list of mixed evidences on impact of carbon risk on stock returns, and Cheong and Choi (2020) documents current studies on investigating climate transition risk premium in bond market, especially by green bonds.

risk.[5] Second, the current study of climate transition risk on stock and bond markets is primarily based on portfolio performances.

By focusing on the rent of leases that serves as the fundamental income engine for CRE assets, I am able to examine a direct channel to the pricing of climate transition risk on the underlying assets. The identification strategy relies on the following two observations. First, firms with higher exposure to climate transition risk face higher financial risk (Capasso et al., 2020; Ehlers et al., 2022; Seltzer et al., 2022). Since firms are tenants in commercial buildings, such financial risk arising from firms' climate transition risk also translates to uncertainty in tenants' future cash flow for CRE owners. Inspired by van Benthem et al. (2022), who identify the interaction between financial markets and energy firms, I illustrate the interaction of tenants and CRE owners with climate transition risk in Figure 1. CRE owners are expected to demand higher rent when signing leases with higher climate transition risk tenants as a way to compensate for tenants' future financial risk arising from climate transition. Second, landlords will only price in tenant climate transition risk if they believe that such risk is material and do expect uncertainty from climate transition to happen. Therefore, landlords may have only recently reacted to tenants' climate transition risk since concerns about transition risk are relatively new.

To leverage these two observations, I focus on CRE lease transactions, specifically, office leases by firms that disclose climate transition risk information prior to signing leases. I use a relative carbon intensity performance score within industry to measure tenant exposure to climate transition risk. Mapping firm level carbon intensity scores to office leases signed by the same firm, I compare rent of leases by tenants from the same industry facing different climate transition risk exposure, controlling for time, location, industry, and lease, building, and tenant characteristics using a standard cross-sectional hedonic framework.

My primary result suggests that landlords only consider tenant climate transition risk when a significant proportion of rental income is exposed to tenant climate transition risk. In the worst case scenario, where 100% of rental income is subject to one tenant - single tenant leases, landlords charge 10.3% rent premium for high climate transition risk tenant compared to low climate transition risk tenant. Even after considering the average single tenant discount, the rent is still 2.5% higher for a tenant with high climate transition risk. Along with the second identification observation, I also document that pricing of transition risk is subject to buildings' and landlords' involvement in green assessment, where tenants exposed to high climate transition risk in green buildings or buildings owned by ESG landlords are paying around 5.7 to 7.3% more per square foot for net effective rent

[5] Krueger et al. (2020) defines long-term investors as institutional investors with above 2-year holding period, whereas Starks et al. (2017) categorizes mutual funds with turnover ratio in the bottom 30th percentiles as long-term investors.

compared to tenants facing low transition risk in the same building.

I also demonstrate that the climate transition risk premium is prominent where climate policy related to emission is in place, which probably helps landlords to form the belief about future regulatory uncertainties and other changes related to climate transition. This provides a potential explanation for why, on average, I do not find a climate transition risk premium, as CRE owners rely on realized policy to form expectations about climate transition and related regulatory risk. Stronger results are also found when the state level climate policy is implemented earlier or with a more stringent timeline, suggesting the local policy environment could shape landlords' belief about climate transition risk since they see such risk is more likely to be realized.

This paper contributes to three strands of literature. First, it joins the emerging climate finance literature and expands the stream of studies on the pricing of firm climate transition risk by asset owners and managers (In et al., 2017; Bolton and Kacperczyk, 2023; Bernardini et al., 2021; Painter, 2020; Duan et al., 2021; Devine et al., 2022; Giglio et al., 2021) which largely focuses on portfolio level pricing and documents mixed evidence. For example, Bolton and Kacperczyk (2023) documents a globally recognized carbon risk premium using carbon emission levels and changes to measure transition risk. While Bernardini et al. (2021) found opposite results, suggesting additional returns from investing in more carbon-efficient portfolios measured by lower carbon intensity. Evidence in the bond market shows greater debate (Cheong and Choi, 2020). In addition to due to investor underreaction (Duan et al., 2021), mixed evidence could also arise because pricing is not studied at the asset level.

This paper drills down to the granular asset level to investigate how long-horizon asset owners value climate transition risk using office leases. It adds new evidence of asymmetrical and heterogeneous pricing of climate transition risk directly from the underlying asset owners. By focusing on the impact of climate transition risk from individual leases on CRE assets, this paper sets forth initial steps for the important future path of learning the extent of climate transition risk impact on asset prices mentioned by Giglio et al. (2021) in understanding the asset level risks.

Second, to my best knowledge, this paper is the first empirical study of the pricing of climate transition risk in commercial real estate using leases. It broadens the understanding of the important link between climate risk and real estate beyond physical climate risk and housing (Bernstein et al., 2019; Murfin and Spiegel, 2020; Baldauf et al., 2020; Keys and Mulder, 2020; Giglio et al., 2021; Addoum et al., 2021; Cvijanovic and Van de Minne, 2021; Bernstein et al., 2022; Ouazad and Kahn, 2022) to climate transition risk and CRE. It also joins the rising literature exploring the impact of climate change on commercial properties (Addoum et al., 2021; Holtermans et al., 2022, 2023) and serves as a complementary joint effort with Spanner and Wein (2020), which offers a pathway of carbon emissions at the property level using the Carbon Risk Real Estate Monitor

(CRREM) tool to understand the climate transition risk faced by commercial properties from carbon emissions at the property level. Within the real estate field, results found on heterogeneity pricing of tenant firm climate transition risk by green building owners also add new evidence to the rich green building literature (Eichholtz et al., 2010, 2009; Fuerst and McAllister, 2011; Reichardt et al., 2012; Chegut et al., 2014), showing risk management responses by green building landlords.

Finally, this study shines a light on the literature exploring the impact of firm and tenant characteristics on commercial properties (e.g.Liu and Liu (2013); Lu-Andrews (2017); Ambrose et al. (2018); Liu et al. (2019); Letdin et al. (2022)) from a new angle using corporate carbon intensity performance, beyond financial attributes. It extends the limited understanding of pricing of tenant risks from non-financial performances. The significant relationship found between firm carbon intensity scores and rent further highlights the impact of firm characteristics on asset owners and the importance of a detailed underwriting process.

The remainder of the paper is organized as follows. Section II introduces the firm level climate transition risk measure; Section III describes the data; Section IV illustrates the empirical method for identification and baseline specification; Section V reports the empirical results; and Section VI provides the concluding remarks.

II. Firm Climate Transition Risk

In this study, I use the monthly carbon intensity raw score (CI score) from Morningstar Sustainalytics to capture the tenant's climate transition risk exposure. Carbon intensity is carbon emission scaled by revenue. Recall that climate transition risk is the uncertainty to firms' finances associated with transitioning to low carbon society. Since one of the key efforts during this transition is to cut down the carbon emission, using firms' carbon emission performance to proxy for exposure to climate transition risk seems sensible.

The CI score is part of Sustainalytics' historical risk management raw scores, which considers the relative performance of a firm to its peer in managing individual material ESG related issues such as carbon intensity in the same industry.[6] Specifically, CI score compares a firm's carbon intensity[7] to its industry median carbon intensity at a given time. It ranges from 0 to 100. The lower the score, the higher the within industry carbon intensity. For example, a score of 0 means a

[6] There are 42 industries defined by Sustainalytics, which are peer groups based on firms' business models.

[7] The carbon intensity by Sustainalytics is defined as carbon emission in metric tons CO2e per million revenue dollar from Scope 1, 2, and 3 carbon emissions. Scope 1 emissions are direct emissions generated due to own operation and production. Scope 2 is emissions generated by purchased energy. Scope 3 emissions are other indirect emissions due to the business value chain. See `https://www.epa.gov/climateleadership/ghg-inventory-development-process-and-guidance` for more information.

firm's carbon intensity is the highest compared to the industry median in a given time, hence is the most emitter per dollar with the highest transition risk in that industry during that time. While a score of 100 means a firm's carbon intensity is the lowest compared to its industry median and the least emitter per dollar, therefore indicating the best performer in managing carbon intensity and facing the lowest transition risk in that industry at a given time. No score means carbon intensity is not a material issue to the firm given its industry. For example, in an online available ESG risk rating report by Sustainalytics for KONE Oyj[8] shown in Appendix Figure A.1, its CI score is 100 for 2018 because its carbon intensity was 13.2 metric tons CO2e per million dollars in USD, which is the furthest below its industry median of 27.2 metric tons CO2e per million dollars in USD in the same year.

While it is hard to find a perfect measure, there are several benefits of using the CI score to capture climate transition risk exposure. First, the CI score compares a firm's actual quantitative environmental output in carbon emission per financial unit. Since Sustainalytics pulls publicly available self-reported carbon intensity data, landlords are able to price that in, under an efficient market. It also avoids potential estimation bias (Kalesnik et al., 2022; Berg et al., 2019). Unlike ratings on other qualitative material ESG issues in terms of policy or programs, which are subject to proprietary algorithms, using carbon intensity relative performance resolves the challenge of idiosyncratic ESG rating due to rating agencies' proprietary methodologies. (Sautner et al., 2023; Engle et al., 2020) Second, I have considered another measure, the overall environmental score, E-score following Engle et al. (2020) and Seltzer et al. (2022)). However, it is a weighted average score of firms' management performance of all material environmental issues. Although it captures a firm's overall environmental preparedness, it is subject to the choice of underlying indicators and weights. Third, once again since reducing carbon emissions is one of the critical efforts needed during this transition and the battle with climate change, carbon emission intensity, which is what CI score assesses, seems to be a natural measure for climate transition risk exposure.

Table A.2 displays the number of North American firms covered and the summary statistics of firm level CI scores across 42 industries in the raw data.[9] I observe close to 2,000 US and Canadian firms that have CI scores available from 2009 to 2019. Looking across the industries by the average firm median monthly CI score, I find sectors with the lowest average CI score (highest climate transition risk) are Infrastructure and Homebuilders. These include firms that are big residential developers such as Lenar or Toll Brothers. This reinforces the well-reported fact that the building environment's large contribution to carbon emission and highlights the importance and urgency to

[8] KONE Oyj is a Finnish machinery company and one of the largest vendors supplying elevators and escalators. Note, this company is not in the historical raw score data set the sample uses since it is a European firm. It is used for illustration purposes since it is publicly available online.

[9] The distribution of CI scores by industry in the raw data is displayed in Appendix Figure A.2.

better understand climate transition risk in the built environment (e.g. Clayton et al. (2021) and Bienert et al. (2022)). The commonly expected carbon intensive industry such as Energy Services or Oil & Gas Producers falls into the lower quartile with the median of raw monthly firm CI score at 0.[10] Interestingly, I also find Media and Software & Services are among the lower score (high risk) industries, probably due to their high reliance on energy consumption to maintain big theme parks or data centers, which contributes to scope 2 emission specifically.Within each industry, most sectors have variation in scores from 0 to 100 showing the existence of both carbon intensive and less carbon intensive firms. In the last two columns, I count the number of firms in an industry with CI scores below (above) the overall median CI score of 20, indicating high (low) climate transition risk firms. The higher the percentage of firms facing high transition risk (High Risk (%)) in an industry, the riskier an industry is as there are more risky firms in that sector. This measure complements potential bias in an industry when there is one super low risk firm with many moderately high risk firms, vice versa.

III. Data

The primary sample relies on matching two datasets: CompStak, a proprietary crowd-sourced database of commercial real estate lease transactions[11] and Morningstar Sustainalytics, a leading third-party ESG data provider that reports firm ESG and carbon issue risk rating including carbon intensity score.[12] I explain the sampling process of each dataset and the merging procedure in the following section.

A. Commercial Real Estate Lease

In this empirical study, I focus on the CRE office leases for a few reasons. First, the office leasing market is one of the most important space markets with a diverse tenant pool. Almost all firms regardless of their industries would need office space for corporate operations. This helps to minimize the chances of using leases signed by tenants concentrated in a specific industry group that share similar climate transition risk exposure such as the case for the industrial leases. Second,

[10] The overall industry level average CI score spreads from 0 to 53 with 1st quartile at 23.5 and a median of 30.8. The firm level median CI score is around 20.

[11] Please find more information about CompStak on: https://www.compstak.com/

[12] The dataset used is the Sustainalytics Historical Raw Scores for North America with monthly ESG related issues raw management score including carbon intensity raw scores available from August 2009 to September 2019 for more than 4,000 North American firms accessed through Wharton Research Data Service (WRDS). A management score in general reflects how well a firm manages a given ESG related issue.The carbon intensity score (CI score) reflects the management performance of carbon emission by looking at its relative ranking of firm's actual carbon emission per revenue dollar (carbon intensity) to its industry level

office lease contracts tend to have a more straightforward rent schedule compared to leases for other property types such as retail. Retail leases usually consist of a base rent and a percentage rent that is tied to the sales revenue of a tenant (e.g. Benjamin et al. (1990) and Benjamin and Chinloy (2004)), but office leases typically do not have this feature. Third, office lease transactions are the most covered sector by CompStak, this helps to maximize the possible sample coverage.

I first collect a sample of office lease transactions[13] with tenant parent company names reported and signed between September 2009 and October 2019 from CompStak, when the earliest firm carbon intensity performance is available from Sustainalytics by at least one month prior. [14] For leases with missing tenant parent company names, I use the tenant name if reported. I delete leases that are signed before the building is completed. These are pre-leases, which are usually viewed as a different leasing market (Edelstein and Liu, 2016). Only about 1% of office leases signed during the sample period are pre-leased. To minimize the impact of outlier and uncommon leases, I require leases in the sample to 1) have a term between 1 month to a maximum of 240 months (20 years),[15] and 2) leased space of at least 500 square feet and no larger than 1,000,000 square feet, 3) located in a building with a minimum size of 3,000 square feet, 4) where the largest space size should not exceed its corresponding building size. Moreover, I remove leases with annual net effective rent per square foot below $1 or above $300. I further drop observations with inconsistent execution dates (signing date), commencement dates (start date), lease terms, and expiration dates (end date).

The final office lease sample contains 259,096 leases from 2,772 firms across more than 40 industries, representing close to 80% of non-preleasing office leases during the sample period across all 50 states and the District of Columbia.

B. Final Sample

Next, I map the office lease sample to monthly firm level carbon intensity performance (CI score) by firm name and year-month with a month lag to identify tenants' carbon intensity performance before leasing. I conduct an exact match of firm names after standardizing the firm names from Sustainalytics and tenant parent names in CompStak. I identify a matched observation if there is a firm has CI score a month before the lease execution month. Overall, I identified 802 unique firms out of 1,970 North American companies with available CI scores from Sustainalytics (40.7%) that signed more than 11,197 office leases in the United States between September 2009 and October 2019. Given leases by firms with and without CI scores may be fundamentally different, I focus on

[13] Office leases are defined as leases occupy office space in office buildings based on CompStak's definition

[14] Although in reality landlords and tenants may consider historical information older than a month, I assume landlords use the latest available information when assessing tenants.

[15] Lease term is defined as the maturity of a lease contract in months since the commencement date.

the sample of leases signed by firms with matched CI score.

The overall distribution of carbon intensity scores (or CI scores)[16] for firms in the sample is shown in Figure 2. The score is not continuous and tends to cluster around several values. I observe a large concentration of firms having carbon intensity scores from 0 to around 20. Since the sample median score is around 20 and the score is rather discrete, I use two measures to proxy firms' exposure to climate transition risk: 1) the absolute carbon intensity score, *CI Scores* with 0 refers to the firms with highest climate transition risk within an industry and time; 2) a categorical variable *TransRisk*, takes the value of 1 if a firm's carbon intensity score is or below 20, indicating high climate transition risk firms within an industry and time based on their actual carbon intensity, and 0 otherwise. Table A.3 documents the industry average CI scores of firms in the sample and the distribution of leases by CI scores for each industry is presented in Figure A.3. I noticed similar patterns of industries with high climate transition risk exposure as the raw data. There are some moves in the ranking depending on how many firms in each industry are matched and the proportion of high or low risk firms that are matched. Then, I plot the matched office leases by their climate transition risk on the map in Figure 3 Panel A. The geographic distribution of leases by high climate transition risk (high *TransRisk*) firms (in brown color) and low *TransRisk* firms (in light green color) is relatively spread out across the country.

I summarize the main statistics for matched office leases in Table I. The average office lease in the sample has an annual net effective rent of \$ 30.9/SQFT/year with a lease term slightly over 5 years, occupying about 14% of the space in an office building. The mean space size taken by a firm is 25,433 square feet (SQFT). About 2-3% of the leases are single tenant leases. Close to 18% of the leases are triple net leases (NNN leases) in the sample with on average more than 2 months free rent offered. More than 72% of the leases received TI, the tenant improvement allowance from landlords. In terms of the profile of office buildings studied, on average they are built in 1984 with a mean size of 320,049 square feet (SQFT). About 75% of them are class A buildings. This could be because, many of the firms with carbon emission intensity reported are large and public firms, who tend to occupy buildings with higher quality. Indeed, more than half of the leases are signed by publicly listed firms in the sample. Only 3% of them are Non-US firms. I also observe about 9.7% to 13.1% of the leases are held by landlords, who have ESG ratings or carbon intensity ratings (*ESG landlord* and *Carbon landlord*) by Sustainalytics.[17] When splitting the sample by tenant climate transition risk, about 5,226 office leases are signed by tenant firms with low *TransRisk* (CI score above 20) and about 5,971 by firms exposed to high *TransRisk* (CI score from 0 to 20).

[16] Carbon intensity score and CI score are used interchangeably in the following sections.

[17] ESG and Carbon landlords are identified if the landlord name matches with a firm name in Sustainalytics historical raw score data with an ESG issue score and a CI score, respectively.

IV. Empirical Method

The empirical strategy relies on the cross-sectional variation of climate transition risk exposure by tenant firms within the industry. I compare two leases signed at the same time, in the same location by tenants from the same industry but facing different climate transition risks. I employ a standard cross-sectional hedonic model to exploit this variation. More formally, I estimate the following ordinary least squares (OLS) regression to examine if CRE landlords price in tenant climate transition risk by charging high risk tenants higher rent:

$$Log(R_{i,c,t}) = \beta \, ClimateTransitionRisk_{c,t-1} + X_{i,t}\gamma + Z_b\delta + \Phi_c\phi + \tau_t + \kappa_s + \eta_j + \epsilon_{i,c,t} \qquad (1)$$

where $Log(R_{i,c,t})$ is the natural logarithm value of annual net effective rent per square foot of lease i signed by firm c at year month t and $\epsilon_{i,c,t}$ is an error term. $ClimateTransitionRisk_{c,t-1}$ is the climate transition risk exposure for firm c at t-1 using the two transition risk measures mentioned in Section III. The one-month lag reflects the fact that firm climate transition risk information is publicly available before the lease is signed. The coefficient of interest is β, which captures the marginal tenant climate transition risk effect on $Log(R_{i,c,t})$. When the absolute *CI score* is used, a negative coefficient of β is expected if landlords price in transition risk, as the lower the score, the higher the climate transition risk of tenants, the higher the rent expected. The opposite should be expected when *TransRisk* dummy is used as it indicates if a tenant is exposed to high climate transition risk or not(or has *CI score* no greater than 20 or not).

Accounting for other determinants of rent, $X_{i,t}$ is a matrix of lease characteristics, controlling attributes of leased space and contract terms for lease i when signing at time t. The parameter γ is a vector of corresponding coefficients. Z_b is a matrix of non-time varying building characteristics for each office building b that observed lease transactions in the sample. It controls for idiosyncratic building attributes and δ is a vector of coefficients for building characteristics on rent. As the type of tenants, such as firm ownership and size, could impact tenants' space choice, location preference, and lease terms negotiated, it is important to control for tenant characteristics other than its exposure to climate transition risk. CompStak reports whether the tenant is a publicly listed company, the country of the tenant headquarter, and tenant size by total employee numbers from a third-party data provider. I add Φ_c, a matrix of static tenant attributes for tenant firm c, to the equation to govern the potential effect of specific tenant characteristics and ϕ is the vector of coefficients.[18]

[18] I use the most recent tenant employee numbers as a proxy for tenant size.

Lastly, I control for year-month fixed effect (τ_t) and submarket fixed effect (κ_s) that captures time-specific trends and local market conditions respectively.[19] Later, I replace the submarket fixed effect with the property fixed effect, which further controls away potential sorting into different buildings within the same local neighborhood by tenants facing different climate transition risks. I also include tenant industry fixed effect η_j, which captures industry-specific heterogeneity that may affect rent. Although there might be variations in climate transition risk across industries, it will be hard to tease it out from other industry-wide factors that could influence rent. As a result, I choose to rule out potential industry level trends and focus on within-industry variation to identify the impact of tenant firm level climate transition risk on rent.

V. Empirical Results

A. Baseline

A.1. Pricing of Tenant Climate Transition Risk

I begin by exploring whether CRE owners price in tenant climate transition risk. On the one hand, asset owners, such as CRE landlords, may not have fully developed awareness and belief about climate change during the sample period. In this case, they may not factor tenant climate transition risk in rent. On the other hand, if CRE landlords anticipate that climate transition risk will materialize in the future, like other long-term investors, they are expected to charge a climate transition risk premium when signing long-term lease contracts. This premium would serve to compensate for the financial uncertainty that tenants may face during this transition.

Table II reports the OLS regression results of estimating Equation 1 across different specifications, exploring if tenant climate transition risk is priced in leases. In the odd-numbered columns, the absolute carbon intensity score, *CI Score*, is used and in the even-numbered columns, the binary *TransRisk* measure is used. The coefficient estimates of all control variables are presented in Table A.5.[20]

In column (1) and (2), I use the firm's *CI score* and *TransRisk* created based on the firm monthly score to capture the tenant's firm level climate transition risk before signing the lease. *TransRisk* of a firm has a value of 1 when the firm's previous month *CI score* is not greater than 20, indicating high climate transition risk exposure, and 0 otherwise. The coefficient estimates on both measures in column (1) and (2) carry the expected sign but are not statistically significant,

[19] Submarkets are areas or neighborhoods defined by brokers to signal their specialized local market coverage. It is the finest location variable I have observed in this data that has sufficient within location observations.

[20] Detailed definitions of key variables are documented in the Appendix Table A.1

suggesting that on average CRE landlords do not price in tenant climate transition risk at the firm level.

The *CI Score* is based on a firm's carbon intensity, which depends on both a firm's emission level and its revenue. Higher revenue tends to be associated with larger firm size. Given the same emission level, a larger firm size may lower the carbon intensity of a firm, and hence the transition risk. This is expected to have a downward impact on rent. Also, a larger firm may be safer from other business perspectives and have greater financial flexibility (Fazzari and Petersen, 1993; Lu-Andrews, 2017), which also suggests a negative relationship between tenant size and rent. Alternatively, large firm size could be positively related to emission level. The larger the firm, the greater the economic and business scale, hence the higher overall emission. This means that a larger firm size can increase a firm's carbon intensity, indicating a positive relationship between tenant size and rent.

In Table A.4, where I compare leases with low versus high *TransRisk*, I find that on average tenant size by employee number is smaller for high risk firms compare to those with lower risk. This seems to suggest that if there is a concern about the endogeneity of tenant size, one should expect to see an amplified effect by *TransRisk* without controlling for size. Nevertheless, to minimize the potential confounding effect from tenant attributes, I add controls for tenant size by tenant employee numbers in column (3) and (4), which follows the exact form of Equation 1. I also control for the type of tenants by if it is a publicly listed firm *Public tenant* and if it has a headquarters outside the US, *Non-US tenant*. The results stay the same and provide no evidence of average tenant climate transition risk premium by CRE landlords. The results of control variables are reported in the Appendix Table A.5.

Another potential argument is that tenants facing different climate transition risks may prefer to locate in different types of buildings within the same neighborhood. To address this, I conduct a within-property analysis by using a subsample of leases in which I observe at least two lease transactions in the same building in column (5) and (6).[21] I replace the submarket fixed effect with the property fixed effect. Here, I am comparing two leases by tenants from the same industry facing different climate transition risk leasing space in the same building. Similarly, I find that the null hypothesis still holds.

[21] The leases in the within-property sample by *TransRisk* across geographical location is presented in Panel B of Figure 3.

A.2. Other Factors on Office Rent

Across all six columns in Table II, I also see that rent for office leases is affected by various lease, building, and tenant characteristics shown in Appendix Table A.5.[22] The positive relationship between lease term in logarithm value, *Log(Term)*, recalls the positive lease term structure well documented in the literature (Grenadier, 1995; Gunnelin and Söderberg, 2003; Ambrose and Yildirim, 2008; Yoshida et al., 2016). Leases signed for larger space (*Log(Space size)*) have lower per square foot rent reflecting the economics of scale for landlords' fixed cost in operating and maintaining larger units once the lease is signed. This effect disappears in the within-building analysis probably because leases identified in the same building are 1) having a similar size than across buildings or 2) the leases for the same space occupied at different times. Triple net leases (*NNN leases*), where tenants pay insurance, maintenance, and utility expenses, experience lower rent compared to other lease types reflecting lower operating costs responsible by landlords. Lower rent for *Sublease* suggests the fact that the lease term is shorter by construction, the interior nature of subleasing or the urgency of the original tenant to rent out the space for cost recovery, hence weaker bargaining power. Interestingly, brand new leases are documented to carry a lower rent compared to leases signed as expansion, extension, or renewal, reflecting potential hold-up relationships between existing tenants and landlords or discounts to attract new tenants. I do not find the *Renewal option* significantly add value to office leases. The rent discount for *Free rent* months and the existence of tenant improvement, *TI*, are due to the typical deduction of lease concession terms when deriving net effective rent. Signing in advance (*Adv. sign*) does not lead to a significant difference in rent. This could be due to the benefit of early birds being more reflected in other forms, such as concession. Yet, landlords seem to charge a premium for being the first tenants in the building upon completion compared to later tenants based on the positive and statistically significant coefficient estimates on *New bldg lease*. Occupying space in different types of buildings does impact rent. Leases for space in Class A buildings (*ClassA Bldg*) have higher rent than those in other building classes, indicating the rent premium for higher building quality. Higher rent is observed for leases in larger buildings with positive and statistically significant coefficients on *Log(Bldg size)*. Static building characteristics dropped out when building fixed effect is included. I also control for building age with *Built Yr* dummy which is omitted from reporting for brevity. The positive relationship between the public tenant status, *Public tenant*) and rent, and the discount for foreign companies (*NonUs tenant*) are seen in all specifications except in (7) and (8) suggesting the potential space choice in more expensive buildings by publicly listed firms and US firms, respectively. Coefficients on the *Log(Tenant size)*, which is approximated by tenant

[22] More detailed definitions of control variables are documented in Appendix Table A.1.

employee number, are barely statistically significant. This is probably because the size effect is strongly correlated with other tenant characteristics, such as tenant's public status.

Overall, these results suggest that on average CRE landlords of office buildings have not charged a risk premium for tenants exposed to greater climate transition risk based on prior firm level carbon intensity performance within the industry during the study period. This is after controlling time and location, as well as lease, building, and tenant characteristics.[23] This finding is different from the carbon risk premium documented in the stock market literature(e.g.Bolton and Kacperczyk (2021),Engle et al. (2020)) and greenium in the bond market.[24]

B. Asymmetric Pricing of Tenant Climate Transition Risk by Tenant Concentration

In this section, I investigate if there is asymmetric pricing of tenant climate transition risk based on a lease's share in a landlord's overall rental income. Considering that many CRE owners, especially office landlords, own multi-tenant properties, they rely on rental income from a portfolio of leases. In a multi-tenanted building, there could be large leases signed by tenants occupying large proportion of space in the building and contributing to the majority of property rental income such as anchor tenants, while there could be other leases following major tenants to a building and contribute only a small fraction of the rental revenue. In such cases, landlords usually assess a lease by both its tenant profile and its proportional contribution to the overall rental income. Since leases may contribute differently, landlords may have different considerations on leases and view their associated risks differently based on leases' weights in overall income contributions. This should be more obvious for single-tenant property owners, whom rely on only one tenant for 100% of their rental income. Single-tenant property owners are expected to be more careful when underwriting a tenant in a single-tenant lease than if it is a tenant in a multi-tenant property lease.

There has been some literature looking at the impact of tenant portfolio and lease concentration within a property on value and risk. For example, Ambrose et al. (2018) finds highest tenant diversification is associated with higher mortgage risk compared to mortgages for single-tenant property, while moderate tenant diversification might be beneficial in lowering such risk provided anchor tenant leases do not expire before mortgage maturity. Although landlords are believed to benefit from positive externality with tenant diversification (e.g.Colwell and Munneke (1998)),

[23] I repeat the exercise of this table using the logarithm value of start rent as the dependent variable for robustness check in Appendix Table A.6. The results remain consistent.

[24] Cheong and Choi (2020) provides an in-depth summary of the bond greenium literature. However, there are also mixed results of carbon risk premium in the bond market, such as Duan et al. (2021) which documents carbon risk discount in the corporate bond market due to investors' underreaction.

large anchor tenants are usually offered with rent discount due to even larger positive externality they bring in (Pashigian and Gould, 1998) to attract demand, co-tenants and reduce vacancy risk. While such a phenomenon is more relevant in retail properties, a big-name tenant occupying a large portion of space within an office building could also help increase leasing probability and speed for landlords. Nevertheless, the documented benefits of having rental income concentrated on a few large leases are conditional on the leases being active. Upon expiration, landlords are naturally exposed to greater vacancy risk from those highly concentrated leases. As a result, they are expected to be more cautious when doing the underwriting and are more likely to be sensitive to tenant risk for leases consume a greater concentration of space within a property. Borrowing from this literature, a plausible hypothesis is tenant climate transition risk might be more likely to be priced in for leases taking a higher concentration of space in a building as greater proportion of income would be exposed to such risk.

To investigate this, I estimate the following equation by adding a measure of lease concentration and its interaction with tenant climate transition risk to Equation 1:

$$\begin{aligned} Log(R_{i,c,t}) = &\beta_1 ClimateTransitionRisk_{c,t-1} + \beta_2 LeaseConcentration_{i,t} \\ &+ \beta_3 ClimateTransitionRisk_{c,t-1} \times LeaseConcentration_{i,t} \\ &+ X_{i,t}\gamma + Z_b\delta + \Phi_c\phi + \tau_t + \kappa_s + \eta_j + \epsilon_{i,c,t} \end{aligned} \tag{2}$$

where *LeaseConcentration* is the logarithm of lease concentration ratio between lease space size and building size ranging from 0 to 1. Hence the *LeaseConcentration* is a non-positive variable capped at 0. The coefficients of interest here are β_1 and β_3. β_1 captures the rent difference between leases by high and low climate transition risk tenants when *LeaseConcentration* is 0. Since *LeaseConcentration* is the logged value of lease concentration ratio, when it equals to 0, the nominal lease concentration ratio equals 1, which is a single-tenant lease case. Hence, β_1 is measuring the rent difference between high and low climate transition risk tenants in single-tenant leases, where I expect to see a positive coefficient for transition risk rent premium. β_3 captures the differential impact of tenant climate transition risk on rent with a marginal change in *LeaseConcentration*. Given the nature of *LeaseConcetration* as a logged value of ration between 0 and 1, I expect as the *LeaseConcentration* decreases, the impact of tenant climate transition risk on rent becomes weaker.

Table III presents the OLS regression results of estimating the above equation. In column (1), I use the logarithm value of the ratio for lease space size to building size, *Log(LeaseCon)*, as the measure of lease concentration. The lower the logged ratio from 0, the lower the lease concentration of a lease. I then interact it with the dummy variable *TransRisk* to test any difference in pricing of climate transition risk as lease concentration changes. In column (2), I replace the logged lease concentration ratio with a dummy variable indicating 1 if a lease is signed by a single tenant, who occupies the entire building space, and 0 otherwise *SingleTenant*. I compare the pricing of tenant transition risk between single tenant leases and non-single tenant leases within the submarket.

Interestingly, I find a positive and significant coefficient of 0.032 on *TransRisk* alone in column (1). This means when the *Log(LeaseCon)* is 0, leases signed by high climate transition risk tenants are charged with 3.2% rent compared to leases by low-risk tenants. This is essentially the tenant climate transition risk premium for single tenant leases since a zero logged lease concentration ratio is when the lease space size to building size ratio equals 1. The interaction term is positive although weakly significant, it validates the positive relationship between *TransRisk* and lease concentration. The main effect of *Log(LeaseCon)* is negative and statistically significant at 1%. It implies that when lease concentration increases by 10%, rent decreases by 0.16%. The negative relationship between lease concentration and rent reflects the fact that tenants who have a higher concentration of space in a building are offered a rent discount, which is consistent with the favorite rent terms offered to larger tenants by space in the retail literature (Pashigian and Gould, 1998).

In column (2), I observe consistent results of tenant climate transition risk premium for single tenant leases. Specifically, I find a positive and statistically significant coefficient estimate of 0.103 on the interaction of *TransRisk* and *SingleTenant*, This means that landlords charge 10.3% higher in rent if a high transition risk tenant rather than a low transition risk tenant is the only tenant in the building. Even when factoring in the 7.8% rent discount for being a single tenant on average, the result still suggests that landlords require 2.5% rent risk premium for a high transition risk tenant compared to a low transition risk tenant from the same industry located in the same submarket. Since the coefficient on *TransRisk* alone is statistically insignificant in column (2), I do not find evidence that they differentiate tenants by climate transition risk for non-single tenant leases.

Overall, these results demonstrate an asymmetric pricing of tenant climate transition risk, where the climate transition risk is most recognized when it is a single-tenant lease where 100% of a building's rental income is exposed. This implies that landlords only factor tenants' exposure to climate transition risk in lease pricing when it impacts a sufficiently large share of CRE owner's rental income.

C. Heterogeneous Pricing of Tenant Climate Transition Risk

So far, the pooled regression results indicate that landlords on average do not price in tenant climate transition risk in the space market unless a significant proportion of rental income is exposed to transition risk. While landlords are expected to ask for compensation from high transition risk tenants, such pricing can only happen after they start to recognize tenant climate transition risk is material or after they expect climate transition risk will be realized. Then, when will such an expectation be formed and who will be the first mover? A plausible hypothesis is that only some building owners who have the relevant knowledge or experience would assess tenants on climate transition risk. For example, buildings that engage more in green assessment, such as certified green buildings or landlords who are subject to ESG disclosure or rating, may be more likely to be aware of tenant climate transition risk and demand compensation from high transition risk tenants for future financial uncertainties. In this section, I explore the heterogeneity of properties and landlords in the pricing of tenant climate transition risk.

C.1. Green Building

I first look at green buildings, which are buildings with environmentally friendly labels or certificates.[25] I collect data on the two most common green building certification organizations: LEED from US Green Building Council (USGBC) and Energy Star administered by US Environmental Protection Agency (EPA).[26] Then, I map office buildings certified during the sample period by LEED or Energy Star to buildings in the lease sample by geocoordinates.[27] If a matched address of a building is found in both the lease sample and the green building database, it means the building has been certified as a green building by at least one of the organizations.[28] Overall, I identified more than 40% of the unique office buildings in the sample (2,856 out of 6,488 unique office buildings) have ever been labeled as green buildings by Energy Star or LEED or both. More than half of the lease observations are located in the green buildings identified in my sample. There are about 1,388 sampled office buildings identified as LEED certified and 2,545 that are certified with Energy Star. This results in more than half of the office lease observations being located in a building that has ever been certified as a green building during the sample period. There are slightly fewer high *TransRisk* tenant leases in green buildings, but the differences are not economically significant as shown in the Appendix Table A.4. Nevertheless, I formally address the concern about the potential sorting effect to green buildings based on tenant characteristics by exploring within-property variations.

[25] It will be interesting to study how green buildings respond to other types of climate risks such as natural disaster and building level emission requirement. However, those are beyond the scope of this paper.

[26] For more information on LEED and Energy Star please refer to `https://www.usgbc.org/leed` and `https://www.energystar.gov/buildings/certified_buildings_and_plants` respectively.

[27] I also verify building type, built year, and building street addresses when an exact match is missing or duplicates are found.

[28] I also conduct a time-varying match by identifying a green building lease when a lease signed to a building with an unexpired green building label. However, this requirement is too restrictive and significantly reduces my sample size, so I use a static indicator variable for green buildings as long as the building has a matching address in both the lease sample and green building database during the sample period.

I replicate the specification in Equation 2 by replacing *LeaseConcentration* with green building indicator to examine potential heterogeneity in the pricing of climate transition risk by green building owners and non-green building owners. I also use building fixed effect instead of submarket fixed effect to compare leases within a property.[29] The OLS regression results are reported in Table IV. In column (1) and (2), I use a dummy variable of *GreenBldg* to indicate a value of 1 if a lease is signed to a building that has ever been certified by at least one of the green building organizations during the sample period, 0 otherwise. This is a static variable reflecting the green building certification history of a property. I interact this variable with *CI Score* (column (1)) and *TransRisk* (column (2)) respectively. While I do not find significant coefficient estimates on both the *CI Score* variable nor the interaction of *CI Score* × *GreenBldg* in column (1), which is probably due to the non-linear and discrete distribution of the score, I observe a moderately significant and positive coefficient of 0.04 on the interaction of *TransRisk* × *GreenBldg* in column (2). This implies that the rent differences between high and low transition risk tenants in green buildings are about 4% higher than in non-green buildings. I do not find significant rent differences between tenants' transition risk for non-green building leases since the coefficient estimates on *TransRisk* alone is statistically insignificant. Note that this result is after controlling for property fixed effect, which means it is free from the potential sorting to green buildings by tenant risk. Essentially, this is the rent premium asked by green building owners from high transition risk tenants compared to low transition risk tenants signed to the same building in addition to the documented average green building premium (Eichholtz et al., 2010; Wiley et al., 2010; Fuerst and McAllister, 2011).[30] Collectively, these findings suggest that green building landlords charge an average of 4% climate transition risk rent premium while non-green building landlords do not differentiate tenants by climate transition risk.

Then, I repeat this estimation by using the indicator for the Energy Star buildings (column (3) and (4)) and LEED buildings (column (5) and (6)) respectively in the remaining four columns of Table IV. I noticed that only the coefficient estimates on the interaction terms with *LEED* are statistically significant. Using the result from column (6), it implies that rent for high climate transition risk tenants is 5.9% higher than that for low climate transition risk tenants in LEED buildings. The moderately significant and negative coefficient on *CI Score* × *LEED* suggests there is a negative relationship between tenants' *CI Score* and rent for leases in LEED buildings, which confirms the climate transition risk premium at tenant firm level in LEED-certified buildings. Interestingly, I do not see similar results in Energy Star building leases and this is probably due to the different nature and emphasis of these two programs. Energy Star focuses solely on actual

[29] To allow within-property analysis, the within-property subsample is used in this test.

[30] The *GreenBldg* dummy variable is dropped out because of the inclusion of the building fixed effect.

building energy consumption in all fuel types and requires energy performance to be above peer group to be certified (minimum of 75 out 100 scores to be eligible). By definition, emission produced due to energy consumption (e.g. electricity purchases) is most relevant for scope 2 emission, while Sustainalytics *CI Score* covers all three scopes.[31] On the other hand, LEED contains four levels of certifications that assess more dimensions of a building's sustainability from location to indoor environment, in addition to energy and water use. It also evaluates reduction in contributions to climate change and carbon as part of its rating system. This makes it reasonable for owners of buildings that ever being certified for LEED to be more sensitive of climate transition risk, suggesting awareness matters for pricing of climate transition risk[32]

C.2. ESG Landlord

In a recent study by Krueger et al. (2020), institutional investors claim that their belief in the material impact of climate risk is especially driven by regulatory uncertainties, which is the main source of transition risk. Since many CRE owners are institutional investors, it is natural to expect institutional landlords to be more likely to price in the climate transition risk than private CRE owners. Moreover, this belief may be more prominent when landlords themselves are also assessed by environmental or carbon-related risk exposure since they will be naturally more aware of climate change and low-carbon transition.[33]

I explore this hypothesis by first identifying ESG landlords. I define a landlord as an *ESG-Landlord* if it has a matching name between a lease's current landlord name and a firm name in Sustainalytics historical ESG score dataset. For leases with multiple landlords, I separate the landlords to individual landlord companies and count a match when at least one of the landlords' names matches an ESG rated firm name in Sustainalytics. The *ESGLandlord* is a static dummy variable and takes the value of 1 when the landlord firm is a firm included in the Sustainalytics ESG rating during the sample period and 0 otherwise. Similarly, I also create a static dummy variable, *CarbonLandlord*, which indicates landlords that have *CI Score* by Sustainalytics during sample period as 1, and 0 otherwise. *ESGLandlord* differs from *CarbonLandlord* in a way that a firm may be rated by Sustainalytics on any ESG event, not necessarily on their carbon intensity performance because carbon intensity is either not material to those firms or they do not have carbon intensity information publicly available. Overall, I obtain about 171 office landlords (about 5% of landlords with available name information) with at least 1 owner having ESG score and 138

[31] The details on energy star certification criteria: `https://www.energystar.gov/buildings/building_recognition/building_certification`

[32] The details of LEED ratings are available at: https://www.usgbc.org/leed

[33] Engle et al. (2020) mention that ESG related rating may better capture climate risk related to regulatory uncertainties.

office landlords with at least 1 owner having CI score by Sustainalytics during the sample period.

Using specification similar to Equation 2 and using the within-property subsample, I report the OLS regression results in Table V. Column (1) and (2) test if *ESGLandlord* charge leases by high climate transition risk tenants higher rent by interacting *ESGLandlord* with *CI Score* and *TransRisk* respectively. Consistent with the conjecture that landlords assessed by ESG rating are likely to price in tenant climate transition risk, I find significant results on both interaction terms. The sign of coefficient on *CI Score* × *ESGLandlord* is negative, reflecting lower *CI Score* (higher risk) is associated with higher rent in ESG landlord buildings. The coefficient estimate on *TransRisk* × *ESGLandlord* is 0.057 and statistically significant at 5% level, reflecting that rent for leases by high transition risk tenants is 5.7% higher than that for low transition risk tenants in buildings owned by landlords with ESG rating. Since the coefficient estimates on *TransRisk* is not statistically significant, this implies that ESG landlords price in tenant climate transition risk by charging a 5.7% climate transition risk rent premium while there is no evidence supporting landlords without ESG rating do the same.[34]

In columns (3) and (4) of Table V, I find similar results for landlords with carbon intensity scores. The coefficient estimate on *TransRisk* × *CarbonLandlord* implies a climate transition risk rent premium of 7.3% in buildings by landlords with carbon rating. The results indicate an "empathy" effect from landlords, as they only consider tenant climate transition risk when they have relevant experiences (both landlords and tenants are subject to ESG and/or carbon rating). The greater magnitude of the coefficient of the *CarbonLandlord* × *TransRisk* supports this since both landlords and tenants go through the same experience: carbon intensity performance assessment. Surprisingly, there are a considerable amount of corporate real estate owners among the ESG or Carbon landlords identified in the sample. About more than 50% (65%) of identified ESG (Carbon) landlords are in non-real estate industries while the remaining are mostly Real Estate Investment Trust (REIT) firms.[35] This provides additional evidence to Krueger et al. (2020) that corporate asset owners are also sensitive to uncertainty arising from the climate transition.

D. Policy Environment

Climate transition risk is often associated with regulatory changes and uncertainties when moving towards a green economy, landlords in places with more ambitious transition goals are more likely to form expectations about uncertainties arisen from future carbon-related regulation changes.

[34] The *ESGLandlord* dummy variable is dropped out probably due to relatively stable building ownership during the study period.

[35] In the sample, I identified 81 unique landlords that have ESG ratings from Sustainalytics and 41 of them are not in real estate or home builder industries. Among the 57 carbon landlords identified in the sample, 37 of them are not from real estate industries. For those are in real estate industries they are mainly REITs.

A reasonable hypothesis arises: the tenant transition risk premium should be observed in places with existing carbon-related policies. The effect is expected to be more profound in places with tighter policies.

Although there is no federal-level regulation on carbon reduction targets by the sample period, I leverage state-wide green house gas (GHG) emission targets to examine the effect of policy existence and stringency on climate transition risk pricing. I hand collect information on the policy of statewide GHG emission targets from the Center for Climate and Energy Solutions (C2ES).[36] The key data points that I focus on include: 1) which state has a GHG emission reduction target in place, to identify states with and without a specific climate transition goal; 2) when the target is due, to measure the urgency and tightness of the policy. The earlier the due year, the tighter the target, the more strongly to believe policy associated uncertainties will realize; 3) when the target is set and released, to identify how early a state establishes a carbon policy. The earlier, the more active and knowledgeable a state is in terms of emission related policy and issues; and 4) if any state has achieved its goal to measure the impact of the actual realization a regulation change. When there are states that set interim targets at different points by year, I rely on the earliest stated checkpoint. For example, Pennsylvania (PA) sets the state level GHG reduction targets in 2019 to reduce GHG emissions by 80% below the 2005 level by 2050 with an interim due date of 2025 to reach 26% reduction below 2005 levels. I record 2025 as PA's first due date. There are other identification strategies that can be designed using this set of state GHG reduction policies. Due to the limited power of time series analysis using the *CI Score* data in my sample, I focus on the cross-sectional variation in these targets across states.

First, I overlay the map of the state GHG emission targets on the lease sample map in Figure 4. Overall, there are 25 states and the District of Columbia have set a statutory and/or executive GHG emission target as of 2022. Near 70% of the states that have a target in place have set it by 2019 (17 for the full sample and 16 for the within-property sample). In this study, I highlight the states that have an emission target released by 2019 (the last year in my sample) in green and overlay the dots of lease observations by climate transition risk to the full sample (Panel A) and the within-property sample (Panel B) on the state emission target map. I observe leases spread out in states with and without a target by 2019. I rely on that as an identification to test the impact of state climate policy on tenant transition risk premium in Table VI.

In column (1), I create a dummy variable *GHGPolicy*, which indicates 1 if a state has a GHG emission reduction target set by 2019 and 0 otherwise, and interact it with *TransRisk* to test the

[36] More information on C2ES: `https://www.c2es.org/about/`. The state GHG emission reduction target data is documented in their interactive map library: `https://www.c2es.org/document/greenhouse-gas-emissions-targets/`

impact of the existence of a state level climate policy directly related to carbon emissions. It is expected that landlords located in these states are more likely to factor potentially changing regulation and economic reformation into their expectations when moving towards the targets and hence price in tenant climate transition risk. Indeed, I find strong evidence supporting this conjecture, where on average landlords in states with a GHG reduction target charge high transition risk tenants 4.3% higher in rent than low transition risk tenants compared to landlords in states without a GHG reduction target by 2019.

Since the earliest due date to achieve the emission reduction target is 2020 among the identified states. With the average target set in year around 2015, I group states with such tight reduction timelines to represent the activist in GHG emission reduction. Asset owners in those states should face greater pressure to manage their emission level and are much more likely to believe the realization of associated uncertainties. I create the dummy variable of *GHGActivist* to indicate the five states with the earliest deadline (due in 2020) and compare the pricing of tenant climate transition risk between the activist states and all other states in column (2) of Table VI. The positive and statistically significant coefficient estimate on the interaction term of *TransRisk* and *GHGActivist* provides strong support on the tenant climate transition risk premium where climate policy is stringent and tight.[37] This is consistent with the stronger long-term carbon risk premium under tighter climate policy documented by Bolton and Kacperczyk (2023).

Among states with GHG reduction targets, California (CA) is the first state in the country to set this goal. CA released its state level targets in 2006 with a goal to reduce GHG emissions to the 1990 level by 2020. As a pioneer in setting climate transition targets in place for a long time, its people and businesses are expected to be better educated about climate issues and related changes and risks. It could also reflect the ambition a state has in the climate transition. Therefore, its people and businesses see that carbon related changes are more likely to happen at a faster pace. Furthermore, CA is the only state to have achieved its reduction goal in 2020. Although the target is achieved one year after the sample period, this still offers an opportunity to test the impact of actual realization of a policy change on the pricing of the climate transition risk. As such, I expect an even stronger premium in the pioneer state. I replace the *GHGActivist* dummy variable with *GHGPioneer* to indicate the state is the first to set a reduction target in the country, which is CA. The results shown in column (3) of Table VI confirm this. Leases by high climate transition risk in the pioneering state of emission reduction target policy are observed with an average of 7.5% rent premium compared to those in other states, which is the highest transition risk premium by magnitude across all coefficients on interaction terms in this table. More importantly, CA is

[37] I also conduct a robustness check in an unreported result by limiting the sample to states have emission targets by 2019 to compare the activist states and non-activist states. Results are consistent.

recorded as the only state that met its first target among other states with a similar due date of 2020. This suggests that the transition indeed happened, perhaps in a rigorous way. Therefore, landlords in the pioneer state price in climate transition risk. This reinforces the fact that CA is the pioneer state in emission reduction target, likely with a policy environment that shaped asset owners' and landlords' knowledge and beliefs about transition risk earlier and faster. If CA did not achieve its target, I may observe a weaker or no transition risk premium.

In all three columns, I do not observe any significant effect on *TransRisk* alone. This suggests that the transition risk is only recognized where a relevant policy is in place and policy tightness and policy environment are the main drivers. I also do not see the state policy variables in all columns as they are subsumed by the property fixed effect.

Overall, these findings provide strong evidence that local policy is a key to price transition risk, which policy tightness and environment shape landlords' belief in pricing tenant climate transition risk.

VI. Conclusion

Among the fast-growing research on pricing climate risk in financial assets, I focus on the real assets and conduct the first empirical analysis on CRE landlords' pricing of tenant climate transition in the space market by mapping firm level carbon intensity performance to office lease contracts in the United States between 2009 to 2019.

Comparing leases by tenants from the same industry facing different climate transition risk in the same location, I provide novel evidence that CRE landlords and asset owners only charge high climate transition risk tenants higher rent in single tenant leases. This implies asymmetric pricing of climate transition risk by landlords, where tenant risk only matters when it is big enough. Moreover, since many single tenant leases carry relatively longer terms (more than 5 years), it seems to suggest that landlords view transition risk as a long-term risk and manage the worst-case scenario by only charging tenants a risk premium when their rental income is 100% exposed to climate transition risk. When exploring the heterogeneity in office buildings, I document a transition risk rent premium in green buildings. Interestingly, the finding is only prominent among LEED-certified buildings, but not among Energy Star buildings. Given the distinctive emphasis between these two certifications, it seems that the pricing of tenant transition risk by building owners is more from a reputation and marketing consideration rather than direct energy consumption compensation. This consideration could be reasonable since the climate transition risk measured in this paper is for the entire tenant corporation not establishment specific.[38] However, I am limited with detailed on-site energy usage

[38] For example, a tenant could have very high carbon emission intensity for the entire firm leading to higher

data at the tenant level to verify the pricing channel by green building landlords. I also find climate transition risk premium for leases by landlords who have ESG rating and carbon intensity score, suggesting an "empathy effect" by landlords. It indicates that property owners factor in climate transition risk when they are assessed by similar risk measures. Leveraging the state level GHG reduction targets, I show the relevance of local climate policy in shaping asset owners' beliefs on climate transition risk and affecting how they evaluate tenant exposure to climate transition risk. The profound tenant climate transition risk premium for leases in states, where early GHG emission targets and more ambitious targets are implemented, demonstrate that climate policy stringency and environment matter for the pricing of transition risk by asset owners. These results offer an important initial step to learn how real asset owners and investors such as CRE landlords react to underlying tenant climate transition risk. It also forms the critical piece for understanding the climate transition risk that commercial real estate faces through its income in addition to the direct carbon exposure from its physical structure.

Overall, these findings suggest that tenant climate transition risk is considered only when it is closely relevant or sufficiently large for asset owners, such as CRE landlords. While transition risk seems to be less apparent, especially before actual policy or legislative shocks, it could evolve in a rapid and multiplicative manner once it materializes. Then, this would be impactful for real asset owners who are underprepared since leases tend to be long-term and hard to turn over or replace. It will be costly for landlords to recover from losing tenants due to unexpected shocks during the climate transition. Unexpected changes arising from shifting towards a low-carbon economy can also make it increasingly challenging for landlords to maintain their property value since building up a robust tenant portfolio takes time, especially when good quality tenants under this transition might be different and limited. This study serves as a reminder to CRE owners, asset managers, and investors to be more ready for the ongoing transition toward a carbon-constrained future. This paper does not call for an exclusion of all carbon intensive tenants but rather to encourage the understanding of tenant transition risk exposure and to reassess the scopes and dimensions for tenant underwriting and asset risk management in real assets during climate transition.

corporate financial risk but low carbon emission produced at the office space observed in the sample where the firm is leasing.

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Table I Summary Statistics of Office Leases

This table reports summary statistics on lease, building and tenant characteristics of unique office leases in the United States signed between September 2009 and October 2019 by firms with CI score reported a month prior in the sample. *Low TransRisk* refers to leases by tenants whose previous month carbon emission intensity score (*CI Score*) is above 20. *High TransRisk* refers to leases by tenants whose previous month carbon emission intensity score (*CI Score*) is no greater than 20. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm compared to its industry medium level. N stands for number of observations. SD stands for standard deviation. Definitions of key variables are available in the Appendix Table A.1.

Variables	N	Mean	SD	Low TransRisk(CI>20)	High TransRisk(CI<=20)
Lease Characteristics					
Execution year	11,197	2015	2.906	2014	2016
Expiration year	11,197	2021	4.416	2020	2022
Net effective rent	11,197	30.897	17.714	29.86	31.803
Start rent	11,197	32.238	17.446	31.293	33.065
Lease term	11,197	67.651	37.694	66.703	68.48
Space size (000 SQFT)	11,197	25.433	53.325	26.262	24.707
Adv.sign(=1)	11,197	0.873	0.333	0.862	0.883
NNN lease (=1)	11,197	0.178	0.383	0.175	0.181
Sublease (=1)	11,197	0.04	0.196	0.04	0.041
Free rent (month)	11197	2.737	3.659	2.729	2.744
TI (=1)	11,197	0.723	0.447	0.746	0.704
New lease (=1)	11,197	0.560	0.496	0.555	0.564
Renewal option (=1)	11,197	0.033	0.179	0.04	0.027
Lease concentration	11,197	0.14	0.222	0.143	0.138
New bldg lease (=1)	11,197	0.018	0.132	0.015	0.02
Building Characteristics					
ClassA bldg (=1)	11,197	0.745	0.436	0.747	0.743
Bldg size (000 SQFT)	11,197	320.049	414.585	328.51	312.643
Built year	11,197	1984	22.718	1984	1985
Tenant Characteristics					
CI Score	11,197	35.875	39.014	72.56	3.767
Single tenant (=1)	11,197	0.026	0.158	0.026	0.025
Public tenant (=1)	11,197	0.551	0.497	0.566	0.538
NonUS tenant (=1)	11,164	0.03	0.171	0.042	0.019
Tenant employee (000)	9,777	59.394	114.489	61.600	57.404
Landlord Characteristics					
ESG landlord (=1)	11,197	0.131	0.338	0.139	0.124
Carbon landlord (=1)	11,197	0.097	0.296	0.103	0.092
Landlord number	11,188	1.134	0.386	1.138	1.130
N (total = 11,197)				5,226	5,971

Table II Tenant Climate Transition Risk and Office Rent Build Table

This table reports OLS regression results of *Log(Net effective rent)* on tenant climate transition risk at firm level using the cross-sectional office leases by tenants with the previous month firm *CI Score* signed between September 2009 to October 2019 in the United States across different specifications. In column (1), (3) and (5), I use tenant firms' monthly *CI Score* to proxy tenant climate transition risk. *CI Score* ranges from 0 to 100 with 0 representing the worst carbon intensity performance (highest climate transition risk exposure) and 100 referring to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within the industry. In column (2), (4) and (6), I use *TransRisk* to measure tenant climate transition risk. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not higher than 20, and 0 otherwise. All columns have year-month fixed effect, location fixed effect and tenant industry fixed effect. In column (3) and (4) I add tenant attributes as control variables. In column (5) and (6), I replace the submarket fixed effect with the building fixed effect *Bldg FE* to control for location by using a subsample of leases with at least two lease observations in each building (Within Property Sample). Definitions of key variables are available in the Appendix Table A.1. Results of control variables are reported in Appendix Table A.5. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

	CI Score	TransRisk	CI Score	TransRisk	CI Score	TransRisk
Dep.Var.=Log(Net Effective rent)	(1)	(2)	(3)	(4)	(5)	(6)
CI Score(0=High Risk)	−0.00003		−0.00002		0.00001	
	(0.0001)		(0.0001)		(0.0001)	
TransRisk(1=High Risk)		0.007		0.007		0.011
		(0.006)		(0.007)		(0.009)
Lease & Building Controls	Yes	Yes	Yes	Yes	Yes	Yes
Tenant Controls	No	No	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Submarket FE	Yes	Yes	Yes	Yes	No	No
Tenant Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Bldg FE	No	No	No	No	Yes	Yes
Observations	11,197	11,197	10,933	10,933	6,876	6,876
Adjusted R^2	0.724	0.724	0.725	0.725	0.815	0.815

Table III Asymmetric Pricing of Tenant Climate Transition Risk and Tenant Diversification

This table reports OLS regression results of *Log(Net effective rent)* on tenant climate transition risk and its interaction with measures of lease concentration using the cross-sectional office leases by tenants with firm level *CI Score* signed between September 2009 to October 2019 in the United States. Column (1) reports the results of interacting *TransRisk* and *Log(LeaseCon)*. Column (2) reports the results of interacting *TransRisk* and *SingleTenant*. *Log(LeaseCon)* is the logarithm value of lease concentration, which is a ratio of space size to building size between 0 and 1. *SingleTenant* is a dummy variable, which is 1 for a lease signed by one tenant occupying the entire building size, and 0 otherwise. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not higher than 20, and 0 otherwise. *CI Score* ranges from 0 to 100 with 0 representing the worst carbon intensity performance (highest climate transition risk exposure) and 100 referring to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within the industry. All columns include a battery of lease, building and tenant control variables, year-month fixed effect, submarket fixed effect and tenant industry fixed effect, and coefficients of control variables and fixed effects are not reported. Definitions of key variables are available in the Appendix Table A.1. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

Dep.Var.=Log(Net Effective rent)	(1)	(2)
TransRisk(1=High Risk)	0.032**	0.005
	(0.015)	(0.007)
Log(LeaseCon)	−0.016***	
	(0.004)	
SingleTenant(=1)		−0.078***
		(0.027)
TransRisk x Log(LeaseCon)	0.008*	
	(0.004)	
TransRisk x SingleTenant		0.103***
		(0.039)
All Controls	Yes	Yes
Year-Month FE	Yes	Yes
Bldg FE	Yes	Yes
Submarket FE	Yes	Yes
Tenant Industry FE	Yes	Yes
Observations	10,933	10,933
Adjusted R^2	0.725	0.725

Table IV Pricing Tenant Climate Transition Risk and Green Building Certificate

This table reports OLS regression results of *Log(Net effective rent)* on tenant climate transition risk and its interaction with green building indicators using the cross-sectional office leases by tenants with firm level *CI Score* signed between September 2009 to October 2019 in the United States in a within-property subsample. Column (1) and (2) reports the results of interacting firm level climate transition risk measures with *Green Bldg*. *Green Bldg* is a static dummy variable, indicates 1 for a lease in a building that has ever earned a green building certificate (LEED or Energy Start) during the sample period and 0 otherwise. In column (3) and (4), green building status is indicated by a static dummy variable, *Energy Star*, which is 1 if a lease is in a building ever certified as an Energy Star building during the sample period, 0 otherwise. In column (5) and (6), green buildings are measured by status of ever being certified as *LEED* buildings during the sample period and 0 otherwise. Odd-numbered columns use *CI Score* as the climate transition risk measure. Even-numbered columns use *TransRisk* as the climate transition risk measure. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within the industry. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not higher than 20, and 0 otherwise. All columns include a battery of lease and tenant control variables, year-month fixed effect, building fixed effect and tenant industry fixed effect, and coefficients of control variables and fixed effects are not reported. Definitions of key variables are available in the Appendix Table A.1. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

	All Green Bldg		Energy Star Bldg		LEED Bldg	
	CI Score	TransRisk	CI Score	TransRisk	CI Score	TransRisk
Dep.Var. = Log(Net Effective rent)	(1)	(2)	(3)	(4)	(5)	(6)
CI Score(0 = High Risk)	0.0002		0.0001		0.0002	
	(0.0002)		(0.0002)		(0.0001)	
CI Score x GreenBldg	−0.0003					
	(0.0002)					
TransRisk (1=High Risk)		−0.017		−0.003		−0.015
		(0.015)		(0.013)		(0.011)
TransRisk x GreenBldg		0.040**				
		(0.018)				
CI Score x EnergyStar			−0.0001			
			(0.0002)			
TransRisk x EnergyStar				0.022		
				(0.016)		
CI Score x LEED					−0.0004**	
					(0.0002)	
TransRisk x LEED						0.059***
						(0.016)
All Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Bldg FE	Yes	Yes	Yes	Yes	Yes	Yes
Tenant Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,876	6,876	6,876	6,876	6,876	6,876
Adjusted R^2	0.815	0.815	0.815	0.815	0.815	0.816

Table V Pricing Tenant Climate Transition Risk and ESG Landlord

This table reports OLS regression results of *Log(Net effective rent)* on tenant climate transition risk and its interaction with landlord indicators using the cross-sectional office leases by tenants with firm level *CI Score* signed between September 2009 to October 2019 in the United States in a within-property subsample. Column (1) and (2) reports the results when interacting climate transition risk with *ESGLandlordESGLandlord* is a dummy variable, takes value of 1 if at least one of the landlords is ever being matched to a firm with ESG scores by Sustainalytics, 0 otherwise. A List of ESG Landlords identified in the sample is documented in Appendix Table **??**. Column (3) and (4) reports the results when interacting climate transition risk with *CarbonLandlord*. *CarbonLandlord* is a dummy variable, takes value of 1 if at least one of the landlords is ever being matched to a firm with CI scores by Sustainalytics, 0 otherwise. A List of Carbon Landlords identified in the sample is documented in Appendix Table **??**. Odd-numbered columns use *CI Score* as the climate transition risk measure. Even-numbered columns use *TransRisk* as the climate transition risk measure. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within industry. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not higher than 20, and 0 otherwise. All columns include a battery of lease and tenant control variables, year-month fixed effect, building fixed effect and tenant industry fixed effect, and coefficients of control variables and fixed effects are not reported. Definitions of key variables are available in the Appendix Table A.1. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

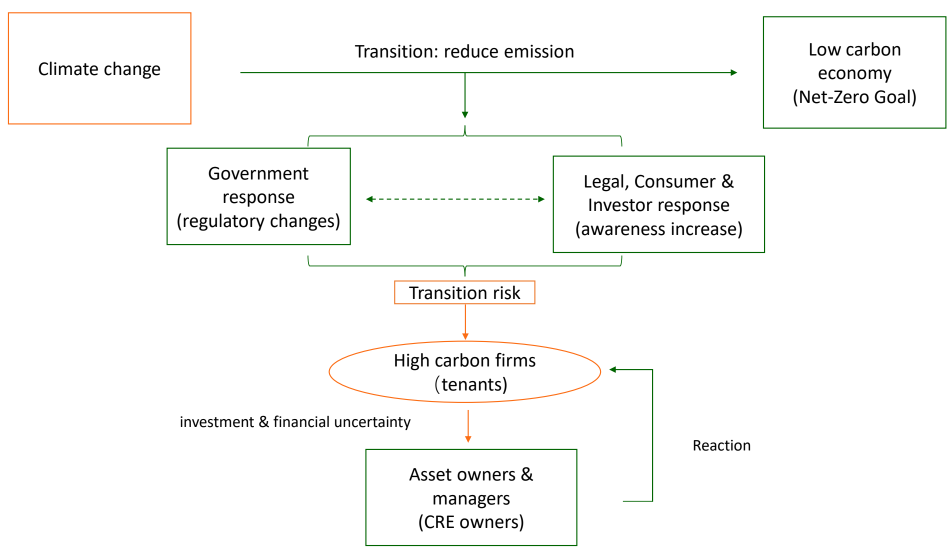
	ESG Landlord		Carbon Landlord	
	CI Score	TransRisk	CI Score	TransRisk
Dep.Var.= Log(Net Effective rent)	(1)	(2)	(3)	(4)
CI Score(0 = High Risk)	0.0001		0.0001	
	(0.0001)		(0.0001)	
TransRisk (1=High Risk)		0.001		0.002
		(0.009)		(0.009)
CI Score x ESGLandlord	−0.001*			
	(0.0003)			
TransRisk x ESGLandlord		0.057**		
		(0.024)		
CI Score x CarbonLandlord			−0.001**	
			(0.0004)	
TransRisk x CarbonLandlord				0.073**
				(0.028)
All Controls	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes
Bldg FE	Yes	Yes	Yes	Yes
Tenant Industry FE	Yes	Yes	Yes	Yes
Observations	6,876	6,876	6,876	6,876
Adjusted R^2	0.815	0.816	0.815	0.816

Table VI Pricing Tenant Climate Transition by State Climate Policy

This table reports OLS regression results of *Log(Net effective rent)* on tenant climate transition risk, *TransRisk* and its interaction with different local policy environment measures using the cross-sectional office leases by tenants with firm level *CI Score* signed between September 2009 to October 2019 in the United States in a within-property subsample. Column (1) reports results for the interaction with *TransRisk* and *GHG Policy*. *GHG Policy* is a static dummy variable, indicating 1 for states have released state level GHG reduction target by 2019, 0 otherwise. Column (2) reports the results for the interaction with *GHGActivist*, which is 1 if a lease is in a state that has a target of reducing state level GHG emission by 2020, 0 otherwise. Column (3) reports the results for the interaction with *GHGPioneer*, which takes value of 1 if a lease is signed at a state that is the first in the country to set the state level GHG reduction target, and 0 otherwise. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not higher than 20, and 0 otherwise. All columns include a battery of lease and tenant controls, year-month fixed effect, building fixed effect and tenant industry fixed effect, and coefficients of control variables and fixed effects are not reported. Definitions of key variables are available in the Appendix Table A.1. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

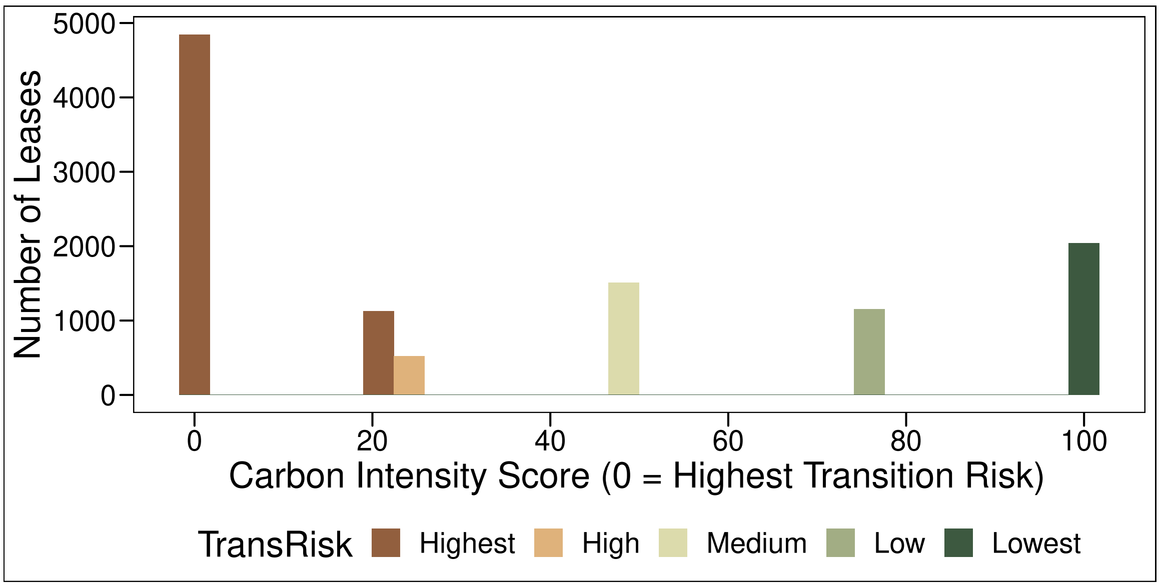
Dep.Var. = Log(Net Effective Rent)	(1)	(2)	(3)
TransRisk(1=High Risk)	−0.007	−0.012	−0.009
	(0.011)	(0.011)	(0.011)
TransRisk x GHGPolicy	0.043***		
	(0.016)		
TransRisk x GHGActivist		0.056***	
		(0.017)	
TransRisk x GHGPioneer			0.075***
			(0.017)
All Controls	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes
Bldg FE	Yes	Yes	Yes
Tenant Industry FE	Yes	Yes	Yes
Observations	6,876	6,876	6,876
Adjusted R^2	0.816	0.816	0.816

Figure 1. Interaction of Tenant Firm Climate Transition Risk and CRE owners



This figure illustrates the key components of climate transition risk and the interaction between high carbon firms, who are tenants in commercial real estate (CRE), and asset managers and owners, like CRE landlords and owners.

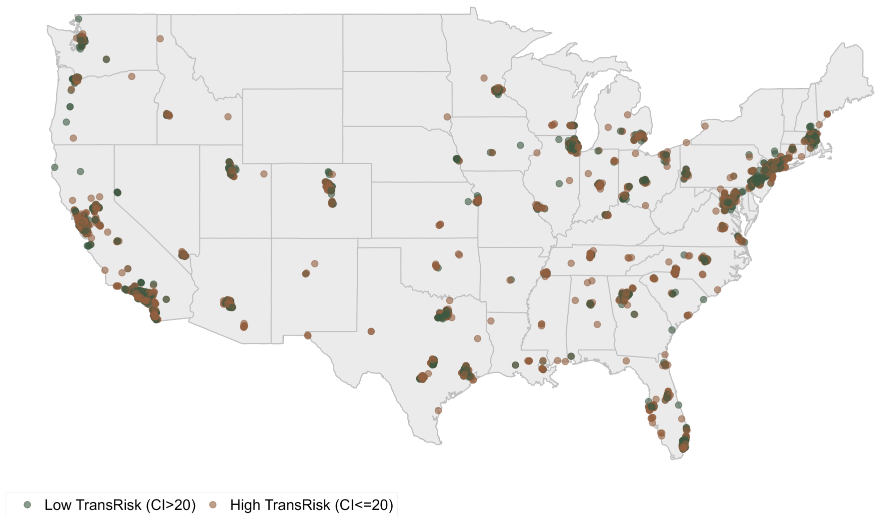
Figure 2. Distribution of Lease Carbon Intensity Score



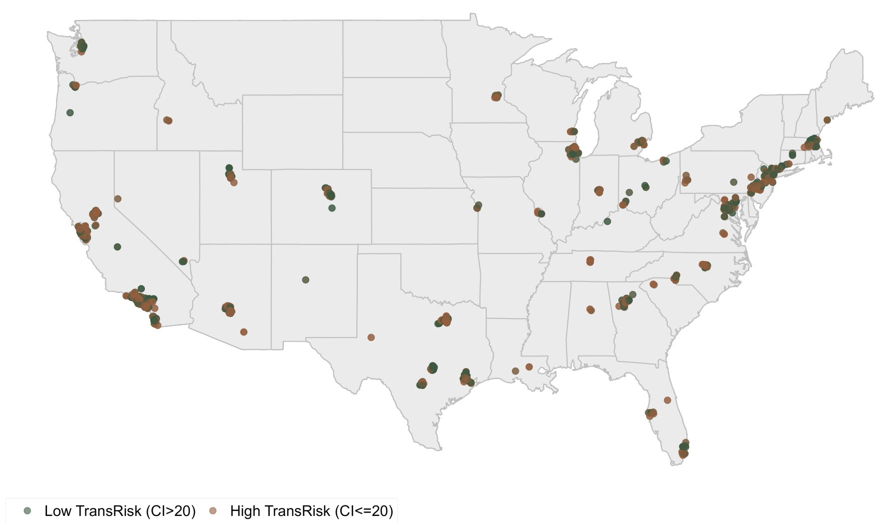
This figure displays the distribution of tenant firm carbon intensity score (*CI Score)* for office leases in the sample signed during September 2009 to October 2019 in the United States. A score of 0 referring to the worst carbon intensity performance within an industry, facing highest climate transition risk, and 100 being the best carbon intensity performance with lowest climate transition risk exposure in that industry. Dark brown color indicates the highest climate transition risk. Dark green represents the lowest climate transition risk.

Figure 3. Lease by Tenant Climate Transition Risk in US

Panel A: Full Sample



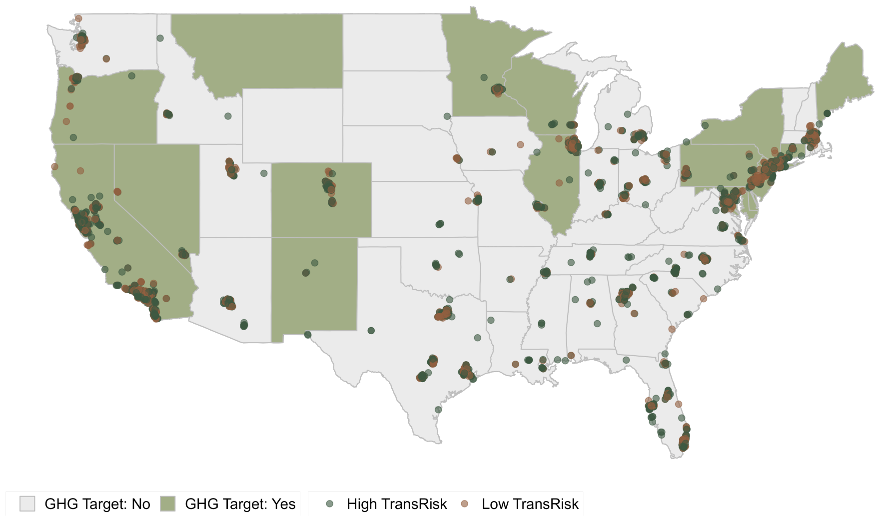
Panel B: Within-Property Subsample



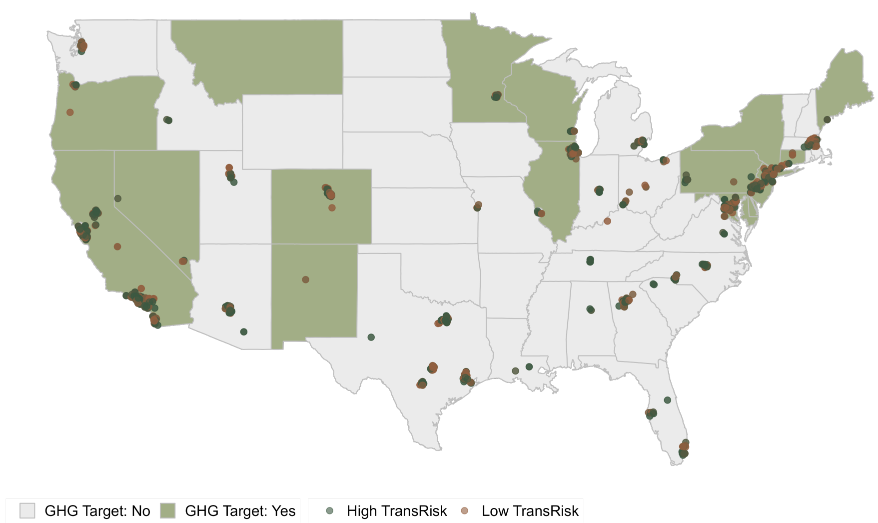
These figures display the geographical location of office leases executed from September 2009 to October 2019 in the sample by previous month tenant climate transition risk level. Panel A shows the geographical location of office leases in the full sample by *TransRisk*. Panel B shows the geographical location of office leases in the within-property subsample by *TransRisk*. Each dot represents a lease observation. Brown color dots illustrate leases by tenants with a *CI Score* no greater than 20, representing high transition risk within an industry. Green dots are the leases by tenants with a *CI Score* above 20, indicating low climate transition risk within an industry. *CI Score* ranges from 0 to 100 with 0 representing the worst carbon intensity performance (highest climate transition risk exposure) and 100 referring to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within the industry.

Figure 4. Tenant Climate Transition Risk and State Climate Policy

Panel A: Full Sample



Panel B: Within-Property Subsample



These figures illustrate the geographical location of office leases executed between September 2009 to October 2019 in the sample by states with GHG emission reduction targets and states without GHG emission reduction targets. Panel A shows the geographical location of office leases in the full sample by *TransRisk* and state level GHG reduction policy. Panel B shows the geographical location of office leases in the within-property subsample by *TransRisk* and state level GHG reduction policy. States released a statutory or executive GHG emission target by 2019 is filled in green color and the remaining stays as grey color. Each dot represents a lease observation. Brown color dots illustrate leases by tenants with a *CI Score* no greater than 20, representing high climate transition risk within an industry. Green dots are the leases by tenants with a *CI Score* above 20, indicating low climate transition risk within an industry. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within industry.

Appendix A

Table A.1 Variable Definition

This table documents the definition of key variables for lease, building and tenant characteristics used in the regressions.

Variable	Definition
Lease Characteristics	
Log(Net Effective Rent)	Logarithm of annual net effective rent per square feet
Log(Term)	Logarithm of lease term
Log(Space size)	Logarithm of space size in square footage
Adv. sign (Yes = 1)	Dummy variable indicating a lease is signed before the commencement date as 1, 0 otherwise
NNN lease(Yes = 1)	Dummy variable indicating triple net lease as 1, 0 otherwise
Sublease(Yes = 1)	Dummy variable indicating sublease as 1, 0 otherwise
Free rent	Free rent months given
TI(Yes = 1)	Dummy variable indicating tenant improvement allowance is given as 1, 0 otherwise
New lease(Yes = 1)	Dummy variable indicating lease is signed as brand new lease as 1, 0 otherwise
Renewal option(Yes = 1)	Dummy variable indicating lease has a renewal option as 1, 0 otherwise
Lease concentration	A ratio of space size to building size bound between 0 o 1
New bldg lease(Yes = 1)	Dummy variable indicating lease is signed when a building is completed as 1, 0 otherwise
Log(LeaseCon)	Logarithm of lease concentration ratio, where lease concentration ratio is a ratio between 0 to 1 of lease space size to building size
Building Characteristics	
ClassA bldg(Yes=1)	Dummy variable indicating a building is a class A building as 1, 0 otherwise
Log(Bldg size)	Logarithm of building size in square footage
Built year	The year when a building is built
GreenBldg (Yes=1)	Dummy variable indicating a building is ever certified as a green building during the sample period as 1, 0 otherwise
EnergyStar (Yes=1)	Dummy variable indicating a building is ever certified as an Energy Star building during the sample period as 1, 0 otherwise
LEED (Yes=1)	Dummy variable indicating a building is ever certified as a LEED building during the sample period as 1, 0 otherwise
Tenant Characteristics	
SingleTenant	Dummy variable indicating a tenant has space size equals to building size, 0 otherwise
Public tenant	Dummy variable indicating lease is signed by a publicly listed company as 1, 0 otherwise
NonUS tenant	Dummy variable indicating a tenant's headquarter country is not United Stated as 1, 0 otherwise
Log(Tenant size)	Logarithm value of tenant employees for a firm
CI Score	The carbon intensity score of a firm, ranging from 0 to 100 measuring the relative carbon emission per revenue of a firm in its industry in a given time. The lower the score the higher carbon intensity relative to the industry median, the higher the climate transition risk
TransRisk (1=High Risk)	Dummy variable indicating a firm has a CI score of no greater than 20 as 1, representing high climate transition risk exposure, 0 otherwise
Landlord Characteristics	
ESGLandlord (Yes=1)	Dummy variable indicating a landlord has ever had an ESG management performance raw score by Sustainalytics during the sample period as 1, 0 otherwise
CarbonLandlord (Yes=1)	Dummy variable indicating a landlord has ever had a CI score by Sustainalytics during the sample period as 1, 0 otherwise
Market Characteristics	
GHGPolicy (Yes=1)	Dummy variable indicating a state has implemented a state level GHG reduction target by 2019 as 1, 0 otherwise
GHGActivist (Yes=1)	Dummy variable indicating a state has the first due date of the state level GHG reduction target by 2020 as 1, 0 otherwise
GHGPioneer (Yes=1)	Dummy variable indicating a state is the first in the country to set the state level GHG reduction target as 1, 0 otherwise

Table A.2 Carbon Intensity Performance Score by Industry (Raw Data)

This table reports the industry level summary statistics of raw firm level carbon intensity scores (*CI Score*) for 1970 North American firms during August 2009 to September 2019 from Sustainalytics. Ave.CI is the average of all firms' median monthly score in each industry Med.CI is the median of all firm monthly scores in each industry. SD.CI is the standard deviation of all firm monthly scores in each industry. Min.CI is the minimum of all firm monthly scores in each industry. Max CI is the maximum of all firm monthly scores in each industry. HighRisk (%) is the percentage share of monthly firm score within 0 - 20 out of all firm scores in each industry. LowRisk (%) is the percentage share of monthly firm score above 20 out of all firms scores in each industry.

Industry	No.Firm	Ave.CI	Med.CI	SD.CI	Min.CI	Max.CI	HighRisk(%)	LowRisk(%)
Transportation Infrastructure	1	0.0	0.0	-	0	0.0	100.0	0.0
Homebuilders	7	13.6	0.0	19.3	0	50.0	71.4	28.6
Refiners & Pipelines	52	16.2	20.0	18.8	0	75.0	86.5	13.5
Retailing	70	16.9	0.0	23.0	0	100.0	77.1	22.9
Media	52	17.7	0.0	26.2	0	100.0	82.7	17.3
Banks	133	19.4	20.0	26.1	0	100.0	78.2	21.8
Real Estate	151	19.9	20.0	23.5	0	100.0	87.4	12.6
Textiles & Apparel	19	21.1	20.0	28.7	0	100.0	73.7	26.3
Energy Services	28	21.8	0.0	35.6	0	100.0	71.4	28.6
Software & Services	123	21.9	20.0	25.8	0	100.0	75.6	24.4
Traders & Distributors	17	23.4	20.0	23.8	0	87.5	76.5	23.5
Transportation	36	23.8	20.0	31.1	0	100.0	69.4	30.6
Machinery	43	24.5	20.0	26.2	0	100.0	72.1	27.9
Consumer Services	50	24.8	20.0	29.7	0	100.0	76.0	24.0
Telecommunication Services	32	25.9	10.0	34.2	0	100.0	62.5	37.5
Commercial Services	34	26.3	0.0	38.2	0	100.0	70.6	29.4
Oil & Gas Producers	102	27.2	20.0	30.3	0	100.0	61.8	38.2
Steel	9	27.8	0.0	38.4	0	100.0	55.6	44.4
Household Products	16	28.1	20.0	34.7	0	100.0	68.8	31.2
Diversified Financials	119	28.8	20.0	34.5	0	100.0	66.4	33.6
Paper & Forestry	12	30.4	22.5	30.6	0	100.0	50.0	50.0
Chemicals	53	31.2	20.0	38.6	0	100.0	64.2	35.8
Healthcare	102	33.2	20.0	34.9	0	100.0	65.7	34.3
Insurance	87	34.1	20.0	37.0	0	100.0	63.2	36.8
Aerospace & Defense	39	34.2	20.0	35.4	0	100.0	64.1	35.9
Consumer Durables	15	34.7	25.0	38.8	0	100.0	46.7	53.3
Building Products	4	35.0	20.0	44.3	0	100.0	75.0	25.0
Semiconductors	45	35.2	20.0	39.7	0	100.0	57.8	42.2
Automobiles	22	35.7	25.0	37.0	0	100.0	45.5	54.5
Electrical Equipment	10	36.0	20.0	40.1	0	100.0	60.0	40.0
Utilities	99	37.3	20.0	42.8	0	100.0	58.6	41.4
Pharmaceuticals	119	37.5	20.0	34.8	0	100.0	56.3	43.7
Containers & Packaging	24	38.4	28.8	38.5	0	100.0	50.0	50.0
Food Products	76	39.0	25.0	36.3	0	100.0	43.4	56.6
Construction & Engineering	10	42.0	10.0	50.3	0	100.0	60.0	40.0
Food Retailers	25	44.0	25.0	38.8	0	100.0	44.0	56.0
Technology Hardware	64	44.4	20.0	43.6	0	100.0	53.1	46.9
Auto Components	14	48.9	50.0	40.0	0	100.0	42.9	57.1
Construction Materials	5	50.0	50.0	50.0	0	100.0	40.0	60.0
Diversified Metals	19	52.4	50.0	46.5	0	100.0	42.1	57.9
Industrial Conglomerates	8	53.1	62.5	50.8	0	100.0	37.5	62.5
Precious Metals	24	53.1	50.0	37.1	0	100.0	25.0	75.0
Overall	1,970							

Table A.3 Carbon Intensity Performance Score by Industry

This table reports the industry level summary statistics of carbon intensity scores (*CI Score*) of leases by 802 North American firms signed during August 2009 to September 2019 in my sample. Ave.CI is the average carbon intensity score of all leases in each industry. Med.CI is the median carbon intensity score of all leases in each industry. SD.CI is the standard deviation carbon intensity score of all leases in each industry. Min.CI is the minimum carbon intensity score of all leases in each industry. Max CI is the maximum carbon intensity score of all leases in each industry. HighRisk (%) is the percentage share of leases with carbon intensity score within 0 - 20 out of all leases in each industry. LowRisk (%) is the percentage share of leases with carbon intensity score above 20 out of all leases in each industry.

Industry	No. Lease	No. Firm	Ave.CI	Med.CI	SD.CI	Min.CI	Max.CI	HighRisk(%)	LowRisk(%)
Automobiles	10	2	2.00	0.0	6.32	0	20	100.00	0.00
Homebuilders	246	6	8.60	0.0	16.10	0	100	90.70	9.35
Steel	18	4	9.44	0.0	24.30	0	100	83.30	16.70
Building Products	4	4	10.00	10.0	11.50	0	20	100.00	0.00
Banks	685	32	17.30	0.0	27.20	0	100	67.20	32.80
Telecommunication Services	326	17	19.10	0.0	26.60	0	100	64.40	35.60
Construction Materials	7	4	20.00	0.0	36.50	0	100	85.70	14.30
Energy Services	48	15	20.90	0.0	34.60	0	100	75.00	25.00
Media	517	25	23.20	0.0	32.70	0	100	67.90	32.10
Consumer Services	324	22	25.00	0.0	37.20	0	100	67.90	32.10
Paper & Forestry	3	1	25.00	25.0	0.00	25	25	0.00	100.00
Textiles & Apparel	55	9	25.00	0.0	39.10	0	100	65.50	34.50
Retailing	451	33	25.10	20.0	31.80	0	100	65.40	34.60
Refiners & Pipelines	52	14	29.30	20.0	35.90	0	100	69.20	30.80
Diversified Metals	5	2	30.00	25.0	27.40	0	75	20.00	80.00
Traders & Distributors	19	6	30.80	20.0	30.10	0	100	52.60	47.40
Transportation	153	13	31.90	20.0	37.80	0	100	58.20	41.80
Software & Services	1740	89	33.30	20.0	36.20	0	100	54.40	45.60
Precious Metals	8	4	34.40	37.5	32.60	0	75	37.50	62.50
Machinery	120	20	35.80	25.0	36.70	0	100	49.20	50.80
Healthcare	639	51	35.90	20.0	39.00	0	100	56.50	43.50
Insurance	1230	37	36.10	20.0	42.70	0	100	60.50	39.60
Commercial Services	578	21	36.80	20.0	43.00	0	100	60.60	39.40
Utilities	131	31	38.70	25.0	38.10	0	100	42.00	58.00
Diversified Financials	1310	48	41.00	50.0	39.10	0	100	44.00	55.70
Construction & Engineering	72	6	42.20	10.0	48.10	0	100	59.70	40.30
Pharmaceuticals	322	48	44.20	50.0	36.50	0	100	38.50	61.50
Real Estate	303	43	44.30	20.0	44.10	0	100	53.50	46.50
Oil & Gas Producers	132	30	46.40	50.0	38.10	0	100	36.40	63.60
Food Retailers	53	11	47.50	50.0	43.20	0	100	43.40	56.60
Chemicals	70	18	48.10	25.0	42.80	0	100	47.10	52.90
Household Products	55	9	48.50	50.0	42.70	0	100	38.20	61.80
Industrial Conglomerates	47	3	49.70	50.0	44.10	0	100	40.40	59.60
Semiconductors	283	25	51.30	50.0	38.70	0	100	29.30	70.70
Food Products	166	28	55.70	50.0	34.20	0	100	21.10	78.90
Electrical Equipment	46	5	56.50	75.0	41.00	0	100	41.30	58.70
Technology Hardware	420	35	56.80	75.0	42.50	0	100	36.70	63.30
Auto Components	12	3	57.90	50.0	31.30	0	100	16.70	83.30
Aerospace & Defense	480	17	58.00	75.0	34.50	0	100	20.20	79.80
Consumer Durables	46	7	62.50	75.0	41.40	0	100	21.70	78.30
Containers & Packaging	13	5	71.20	75.0	32.00	0	100	7.69	92.30
Overall	11,197	802							

Table A.4 Summary Statistics of Office Leases by Tenant Climate Transition Risk

This table compares the key summary statistics of lease, building and tenant characteristics of unique leases by tenants with firm level carbon intensity score (*CI Score*) signed between September 2009 and October 2019 in the United States in the sample by tenant climate transition risk exposure. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm compared to its industry medium level. *Low TransRisk* refers to leases by low climate transition risk tenants whose previous month *CI Score* is above 20. *High TransRisk* refers to leases by high climate transition risk tenants whose previous month *CI Score* is no greater than 20. N stands for number of observations.

Variables	Low TransRisk (CI>20)	High TransRisk (CI<=20)	Difference	t-stat	d-stat
Lease Characteristics					
Lease term	66.703	68.48	1.777	2.49	0.047
Space size (000 SQFT)	26.262	24.707	-1.555	-1.54	-0.029
Adv. sign (=1)	0.862	0.883	0.021	3.291	0.062
NNN lease (=1)	0.175	0.181	0.005	0.699	0.013
Sublease (=1)	0.04	0.041	0.001	0.292	0.006
Free rent (month)	2.729	2.744	.015	0.217	0.004
TI (=1)	0.746	0.704	-0.042	-4.914	-0.093
New lease (=1)	0.555	0.564	0.008	0.858	0.016
Renewal option (=1)	0.04	0.027	-0.013	-3.793	-0.072
Lease concentration	0.143	0.138	-0.006	-1.325	-0.025
Single tenant (=1)	0.026	0.025	-0.001	-0.485	-0.009
New bldg lease (=1)	0.015	0.02	0.006	2.195	0.042
Building Characteristics					
ClassA bldg (=1)	0.747	0.743	-0.004	-0.434	-0.008
Bldg size (000 SQFT)	328.51	312.643	-15.867	-2.021	-0.038
Bldg yr	1984	1985	1.098	2.552	0.048
Green bldg (=1)	0.552	0.528	-0.024	-2.554	-0.048
LEED bldg (=1)	0.305	0.289	-0.016	-1.866	-0.035
ES Bldg (=1)	0.497	0.471	-0.025	-2.694	-0.051
Tenant Characteristics					
CI Score	72.56	3.767	-68.793	-195.773	-1.763
Public tenant (=1)	0.566	0.538	-0.028	-2.999	-0.057
NonUS tenant (=1)	0.042	0.019	-0.023	-7.06	-0.134
Tenant employee (000)	61.6	57.404	-4.196	-1.81	-0.037
Landlord Characteristics					
ESG landlord (=1)	0.139	0.124	-0.015	-2.353	-0.045
Carbon landlord (=1)	0.103	0.092	-0.011	-1.965	-0.037
Landlord number	1.138	1.13	-0.009	-1.165	-0.022
N (total = 11,197)	5,226	5,971			

Table A.5 Tenant Climate Transition Risk and Office Rent: Control Variable

This table reports OLS regression results of control variables in Table II. Column (1) to (6) report the coefficient estimates for control variables of OLS regression results on firm level tenant climate transition risk across different specifications. *Built Yr* dummies are controlled and omitted from reporting for brevity. Odd-numbered columns use *CI Score* to measure tenant climate transition risk. *CI Score* ranges from 0 to 100. The lower the score, the higher the risk. Even-numbered columns use *TransRisk* to measure tenant climate transition risk. *TransRisk* is a dummy variable, indicating 1 for high climate transition risk tenant and 0 otherwise. Definitions of control variables are available in Appendix Table A.1. The robust standard errors clustered at the lease level are reported in parentheses.The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

	CI Score	TransRisk	CI Score	TransRisk	CI Score	TransRisk
Dep.Var.=Log(Net Effective rent)	(1)	(2)	(3)	(4)	(5)	(6)
Log(Term)	0.070***	0.070***	0.070***	0.070***	0.053***	0.053***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.010)	(0.010)
Log(Space size)	−0.011***	−0.011***	−0.011***	−0.011***	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)
NNN lease(=1)	−0.180***	−0.180***	−0.181***	−0.181***	−0.083***	−0.083***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.018)	(0.018)
Sublease(=1)	−0.095***	−0.095***	−0.096***	−0.096***	−0.118***	−0.118***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.023)	(0.023)
New lease(=1)	−0.059***	−0.059***	−0.059***	−0.059***	−0.059***	−0.059***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)	(0.008)
Renewal option(=1)	−0.009	−0.009	−0.009	−0.009	0.009	0.009
	(0.016)	(0.016)	(0.016)	(0.016)	(0.021)	(0.020)
Free rent	−0.016***	−0.016***	−0.016***	−0.016***	−0.016***	−0.016***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
TI(=1)	−0.070***	−0.070***	−0.071***	−0.071***	−0.077***	−0.077***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.010)	(0.010)
Adv.sign(=1)	0.011	0.011	0.008	0.008	−0.010	−0.010
	(0.008)	(0.008)	(0.009)	(0.009)	(0.011)	(0.011)
New bldg lease(=1)	−0.009	−0.009	−0.009	−0.009	0.097**	0.096**
	(0.030)	(0.030)	(0.030)	(0.030)	(0.043)	(0.043)
ClassA Bldg(=1)	0.128***	0.128***	0.128***	0.128***		
	(0.009)	(0.009)	(0.009)	(0.009)		
Log(Bldg size)	0.029***	0.029***	0.028***	0.028***		
	(0.005)	(0.005)	(0.005)	(0.005)		
Public tenant(=1)			0.016***	0.017***	0.011	0.011
			(0.006)	(0.006)	(0.010)	(0.010)
NonUS tenant(=1)			−0.053***	−0.051***	−0.007	−0.003
			(0.017)	(0.017)	(0.027)	(0.027)
Log(Tenant size)			0.0005	0.001	−0.005*	−0.004
			(0.002)	(0.002)	(0.003)	(0.003)
Built Yr	Yes	Yes	Yes	Yes	Yes	Yes
Tenant Controls	No	No	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Submarket FE	Yes	Yes	Yes	Yes	No	No
Tenant Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Bldg FE	No	No	No	No	Yes	Yes
Observations	11,197	11,197	10,933	10,933	6,876	6,876
Adjusted R^2	0.724	0.724	0.725	0.725	0.815	0.815

Table A.6 Robustness Check: Tenant Climate Transition Risk and Office Start Rent

This table reports OLS regression results of *Log(Start rent)* on tenant climate transition risk at firm level using the cross-sectional office leases by tenants with firm level *CI Score* signed between September 2009 to October 2019 in the United States across different specifications. In column (1), (3) and (5), I use tenant firm's monthly *CI Score*. *CI Score* ranges from 0 to 100 with 0 represents the worst carbon intensity performance (highest climate transition risk exposure) and 100 refers to the best carbon intensity performance (lowest climate transition risk exposure) of a firm within industry. In column (2), (4) and (6), I use *TransRisk* to measure tenant climate transition risk. *TransRisk* is a dummy variable, which is 1 representing high transition risk exposure if a tenant's previous month firm *CI Score* is not greater than 20, and 0 otherwise. All columns have year-month fixed effect, location fixed effect and tenant industry fixed effect. In column (3) and (4) I add in tenant attributes as control variables. In column (5) and (6), I replace submarket fixed effect with building fixed effect to control for location using the within-property subsample. All columns have a battery of lease and building controls, and year-month fixed effect, and coefficients of control variables and fixed effects are not reported. Definition of key variables are available in Appendix Table A.1. The robust standard error clustered at the lease level are reported in parentheses. The stars ***, **, * denote statistical significance at the 1%, 5%, and 10% level, respectively.

	CI Score	TransRisk	CI Score	TransRisk	CI Score	TransRisk
Dep.Var.=Log(Start rent)	(1)	(2)	(3)	(4)	(5)	(6)
CI Score(0=High Risk)	0.00002		0.00002		0.00005	
	(0.0001)		(0.0001)		(0.0001)	
TransRisk(1=High Risk)		0.001		0.002		0.003
		(0.006)		(0.006)		(0.007)
Lease & Building Controls	Yes	Yes	Yes	Yes	Yes	Yes
Tenant Controls	No	No	Yes	Yes	Yes	Yes
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Submarket FE	Yes	Yes	Yes	Yes	No	No
Tenant Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Bldg FE	No	No	No	No	Yes	Yes
Observations	11,197	11,197	10,933	10,933	6,876	6,876
Adjusted R^2	0.758	0.758	0.759	0.759	0.855	0.855

Figure A.1. Sample Report of Carbon Intensity Score

SUSTAINALYTICS ESG RISK RATING REPORT KONE Oyj

Appendix

Management Details

E.1.7.0 - GHG Reduction Programme

100	20.00%	20.0
Raw Score	Weight	Weighted Score

The company has a strong programme

Criteria

- ✓ Policy commitment to reduce GHG emissions
- ✓ GHG reduction targets and deadlines
- ✓ GHG emissions monitoring and measurement
- ✓ Managerial responsibility for GHG emissions
- ✓ Initiatives to reduce GHG emissions
- ✓ Regular GHG audits or verification

Sources

KONE Code of Conduct; accessed 8 December 2020

KONE Sustainability Report 2019 (FY2019)

The company provided feedback on 8 January 2021

E.1.8 - Renewable Energy Programmes

100	5.00%	5.0
Raw Score	Weight	Weighted Score

The company has set quantitative targets at group level and has set a clear deadline for reaching these targets

KONE aims to increase the share of green electricity to 50% by 2021 (onsite production or purchased renewable energy).

Sources

KONE Sustainability Report 2019 (FY2019)

E.1.9 - Carbon Intensity

100	15.00%	15.0
Raw Score	Weight	Weighted Score

The company's carbon emissions intensity is well below the industry median

Company Corporate Website
https://www.kone.com/en/Images/pdf_sustainability_report_2018_tcm17-83612.pdf

	2018
Carbon Intensity (t/million USD)	13.2
Industry Median	27.2

E.1.10 - Carbon Intensity Trend

50	17.50%	8.7
Raw Score	Weight	Weighted Score

The company's carbon intensity trend has remained relatively stable (+/- 10% inclusive) over the last 3 years

Company Corporate Website
https://www.kone.com/en/Images/pdf_sustainability_report_2018_tcm17-83612.pdf

	2018
Carbon Intensity Trend (%)	-0.6

E.1.11 - Renewable Energy Use

40	12.50%	5.0
Raw Score	Weight	Weighted Score

Between 5% and 9.9% of the company's primary energy use comes from renewable energy sources

In FY2019, approximately 5% of the total company's energy consumption came from renewable energy sources.

Sources

KONE Sustainability Report 2019 (FY2019)

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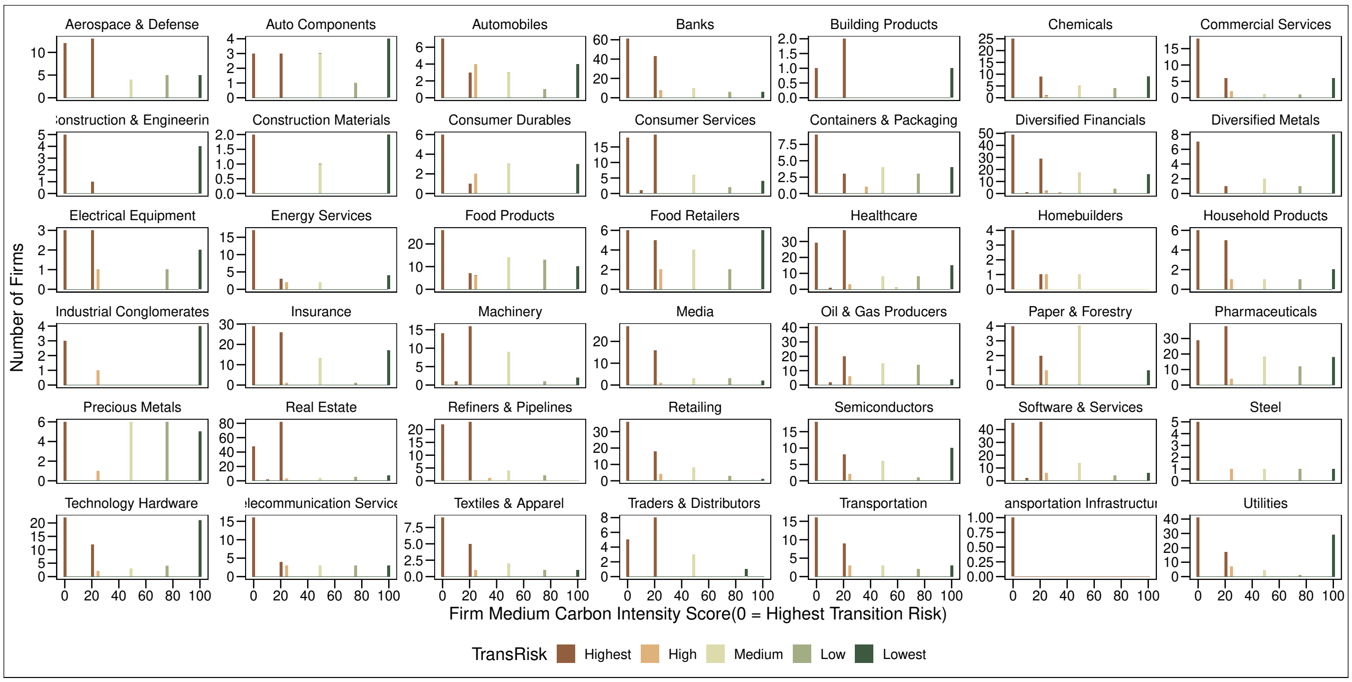
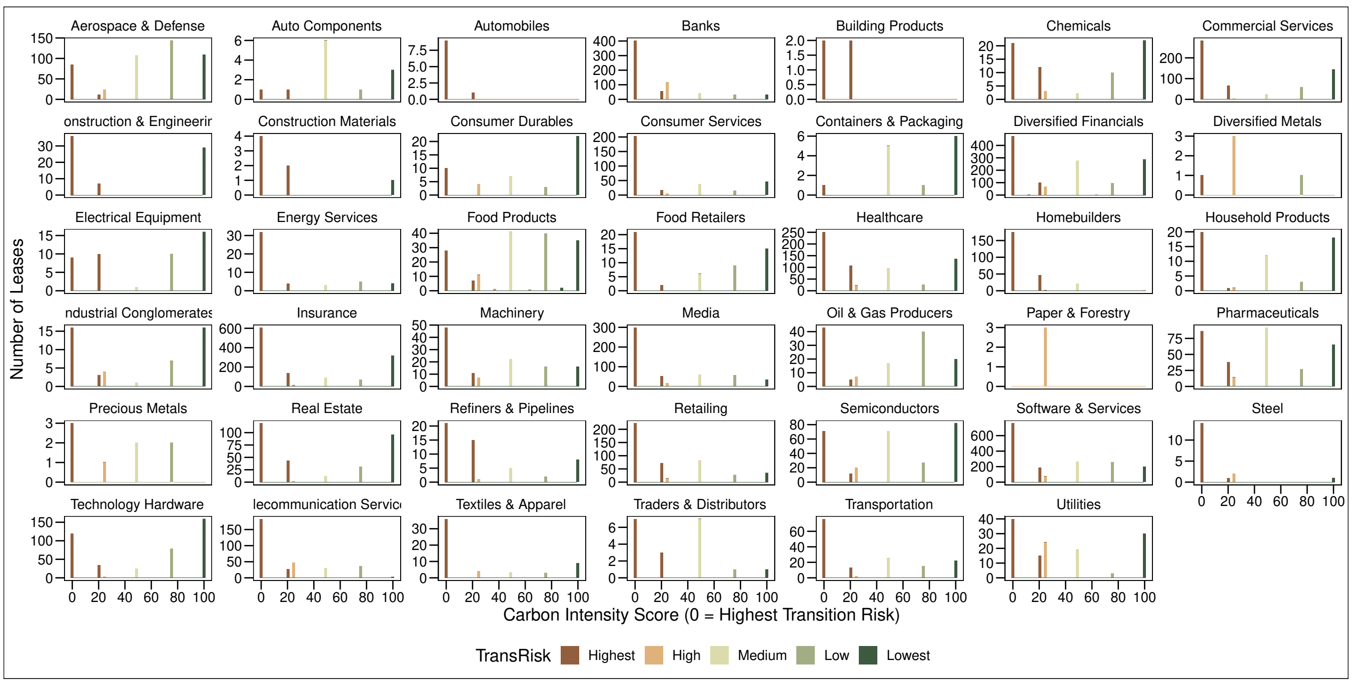
This figure illustrates part of a sample risk rating report including carbon intensity score for KONE Oyj, obtained from `https://www.sustainalytics.com/docs/default-source/meis/kone_oyj_riskratingsreport_18032021.pdf`. Item E.1.9 documents how the CI score (carbon intensity raw score) is determined. Note, this company is not in the sample given it is an European firm. This is included for illustration purpose of the *CI Score* methodology.

Figure A.2. Distribution of Firm Carbon Intensity Score by Industry (Raw)



This figure illustrates the distribution of firm median monthly carbon intensity score (*CI Score*) across industries during August 2009 to September 2019 in the raw data by Sustainalytics. A score of 0 referring the worst carbon intensity performance within an industry, facing highest climate transition risk and 100 being the best carbon intensity performance with lowest climate transition risk exposure in that industry. Dark brown color indicates the highest climate transition risk. Dark green represents the lowest climate transition risk.

Figure A.3. Distribution of Firm Carbon Intensity Score by Industry in Sample



This figures display the distribution of tenant firm carbon intensity score (*CI Score*) across industries for office leases signed during September 2009 to October 2019 in the United States in my sample. A score of 0 referring the worst carbon intensity performance within an industry, facing highest climate transition risk, and 100 being the best carbon intensity performance with lowest climate transition risk exposure in that industry. Dark brown color indicates the highest climate transition risk. Dark green represents the lowest climate transition risk.