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Pricing or panicking? Commercial real estate markets and climate change

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Abstract

This paper provides the first study of climate risk pricing in euro area commercial real estate markets. We pay particular attention to changes in risk pricing over time, as a sudden market shift may significantly amplify the financial stability and macroeconomic implications of these risks. We find evidence of investors applying a penalty to buildings exposed to physical risk and that this penalty has increased significantly over the 2007-2023 period we study, particularly for properties exposed to risks associated with climate change. This change in pricing appears to have occurred in an orderly manner, with no implications for liquidity in the market for high risk buildings. In contrast, while pricing of transition risk has also increased over the period studied, towards the end of our sample the market response to transition risk appears to be playing out via market liquidity. This indicates that older buildings - which are more exposed to transition risks - may already be at risk of becoming "stranded assets".

Keywords: Climate Change, Commercial Real Estate, Financial Stability
JEL codes: R33, Q51, G2

Non-Technical Summary

This paper provides the first study of climate risk pricing in the euro area commercial real estate (CRE) market, focusing on its largest segment - the office market. We study the exposure of euro area office markets to climate risk, how investor pricing of these risks has developed over time and implications for market liquidity. We find evidence of investors applying a penalty to buildings exposed to physical climate risks and that this has increased significantly over the 2007-2023 period we study. This adjustment appears to have occurred in an orderly fashion, without disruptions to market liquidity for high risk buildings. We also find evidence of increased pricing of transition risks over the sample we study. However towards the end of our sample the market response to transition risk appears to be playing out via liquidity, suggesting that older buildings may already be at risk of becoming "stranded assets".

The potential impact of climate change on CRE prices has a number of direct financial stability and macroeconomic implications. Falling CRE values will have implications for the resilience of the firms, funds and insurers who own these assets, with knock-on effects on the credit risk of associated debt exposures. Where CRE is used as collateral, falling values will further increase the exposure of lenders to losses and reduce borrowers' access to credit, potentially amplifying the macroeconomic impact of climate events.

However, the timing and nature of this adjustment will also determine its consequences for the real economy and financial system. Existing work on climate change and financial stability repeatedly emphasises the lower costs of a gradual transition, whereby both policy makers and markets adapt gradually to the reality of climate change - for example via a gradual pricing of risks as information and data becomes available. In contrast a sudden, disorderly transition whereby the market has not adapted until it is forced to by a sudden event will likely have more damaging consequences. For example, via falling market liquidity due to uncertainty or the creation of "stranded assets" which investors struggle to sell at any price. Indeed climate stress testing for the euro area consistently finds significantly higher bank capital losses from sudden, disorderly transitions (ECB/ESRB, 2020, 2021a, 2022).

In recent years a range of factors may have encouraged market players to increasingly account for climate risk when pricing buildings. These include intensification of climate risks and increased awareness of them, facilitation of pricing via improved data availability, increasing concerns regarding insurance gaps and - in the case of transition risk - the intensification of climate regulations. However, real estate markets have a long history of failing to correctly price risks, often with significant implications for the wider financial system and real economy (Claessens et al., 2009; Jordà et al., 2015), so this change in pricing over time is far from guaranteed.

To measure exposure to physical risk we use the Four Twenty Seven micro data set, which provides risk scores for six physical risk hazards - Fires, Heat stress, Water stress, Sea level rise, Earthquakes and Floods. As expected there is clear heterogeneity in exposure of office markets to these risks across the euro area, with southern European markets registering a higher level of exposure than northern Europe. We then then match this data with a large data set of CRE transactions, covering euro area office markets between 2007 and 2023 and use simple hedonic regressions to study the role of physical risks in pricing. Our findings indicate that investors are able to identify high risk buildings and do apply a discount to them.

We then study variation in pricing over time and find a significant increase in penalty between the beginning and end of our sample. Comparison of pricing across different types of risks again points to climate change concerns as a driving factor. While investors have increased discounts for risks most associated with climate change - such as heat stress and rising sea levels - there is no evidence of investors increasing discounts for risks less associated with climate change, namely earthquake risk.

Investor concerns regarding climate risk may affect the price of exposed buildings but also their liquidity, with the potential for exposed assets to become un-sellable or "stranded". We find that approximately a quarter of transacted offices in our sample have at least one high physical risk score. In a scenario where owners of high risk buildings were increasingly struggling to find buyers we would expect this share to decrease over the period studied due to longer selling times or failed attempts to sell buildings. However, high risk buildings account for a stable share of transactions over the period we study. This finding is confirmed by a simple logit model which accounts for confounding factors. This suggests that the increased pricing of climate risks by investors over our sample period has played out in a relatively orderly manner, without implications for the liquidity of high risk buildings.

CRE markets are also highly exposed to transition climate risk. Real estate is a significant carbon emitter - with one third of the EU's energy related greenhouse gas emissions estimated to come from buildings. This has created both direct and indirect links between climate policies and real estate markets. Direct policy interventions include requirements that buildings meet certain energy efficiency criteria. Indirectly, corporate carbon disclosure regulations encourage firms more broadly to reduce carbon emissions and as a result also increases demand for energy efficient office space. As before, we would expect this to result in a premium for highly energy efficient offices which strengthens over the period we study, particularly in its final years as firms come to terms with the increased likelihood and stringency of this type of regulation.

Unfortunately, we do not have building-level data on energy efficiency ratings in our transactions data set. However, we do use building age and time since last renovation as a proxy. Descriptive statistics show a clear divergence between prices of buildings below and above the 5 year age cut-off in the final years of our sample. Again we use hedonic regressions to account for confounding factors. We find that the premium for young buildings is significantly higher at the end of our sample than at the start, with a 18pps increase in premium over the 2007-2023 period.

To our surprise, we do not see a particularly pronounced increase in premium in the final years of our sample. This is despite the intensification of climate legislation over this period and increased focus on this risk by major market players. Our final piece of analysis suggests that investor concerns regarding transition risk may now be playing out via the liquidity channel. By applying a similar logit model we show a clear shift in market activity away from older buildings from 2018 onwards. This suggests that owners of older buildings may indeed be struggling to find buyers as concerns regarding exposure to climate policies increase. This suggests that the "stranded asset" problem arising from transition risk may already be beginning to take hold in euro area CRE markets.

Taken together these results show that euro area CRE markets have a significant exposure to climate risks. From a policy perspective, this underlines the importance of considering macroprudential tools to increase the resilience of the financial system to these risks and avoid its weaknesses amplifying the economic effect of climate shocks (see ECB/ESRB (2022)). It also underlines the importance of continuing work to close data gaps which hinder our analysis of CRE markets, particularly in relation to energy efficiency of the stock of buildings.

1 Introduction

Real estate markets play a central role in both the real economy and the financial system. Real estate is an important asset on the balance sheets of households, firms, funds and insurers, is widely used as collateral and its past cyclical fluctuations have had clear links with both recessions and financial crises (Claessens et al., 2009; Jordà et al., 2015). In addition to cyclical challenges, real estate markets also currently face a range of significant structural challenges (see Ryan et al. (2023)). In particular, real estate is highly exposed to both physical and transition risks arising from climate change. The implications of these risks are not only long term but will likely intensify in the coming years. Understanding if and how the market is adjusting to these challenges is crucial to our understanding of their ultimate implications for financial stability and wider economic activity.

This paper provides the first study of climate risk pricing in the euro area commercial real estate (CRE) market, focusing on its largest segment - the office market. We study the exposure of euro area office markets to climate risk, how investor pricing of these risks has developed over time and implications for market liquidity. We find evidence of investors consistently applying a penalty to buildings exposed to physical climate risk from 2012 onwards. This adjustment appears to have occurred in an orderly fashion, without disruptions to market liquidity for high risk buildings. We also find evidence of increased pricing of transition risks over the sample we study. However towards the end of our sample the market response to transition risk appears to be playing out via liquidity, suggesting that older buildings may already be at risk of becoming "stranded assets".

The potential impact of climate change on CRE prices has a number of direct financial stability and macroeconomic implications. Falling CRE values will have implications for the resilience of the firms, funds and insurers who own these assets, with knock-on effects on the credit risk of associated debt exposures. Where CRE is used as collateral, falling values will further increase the exposure of lenders to losses and reduce borrowers' access to credit, potentially amplifying the macroeconomic impact of climate events.

However, the timing and nature of this adjustment will also determine its consequences for the real economy and financial system. Existing work on climate change and financial stability repeatedly emphasises the lower costs of a gradual transition, whereby both policy makers and markets adapt gradually to the reality of climate change - for example via a gradual pricing of risks as information and data becomes available. In contrast, a sudden and disorderly transition whereby the market has not adapted until it is forced to by a sudden event, will likely have more damaging consequences. For example, via sharp drops in market liquidity due to uncertainty or the creation of "stranded assets" which investors struggle to sell at any price. Indeed climate stress testing for the euro area consistently finds significantly higher bank capital losses from sudden, disorderly transitions (ECB/ESRB, 2020, 2021a, 2022).

To our knowledge we are the first to study whether CRE investors' pricing of risks points toward such a gradual adjustment or not, with the real estate climate literature typically focusing on response to specific climate events or regulations. This issue may be particularly relevant to CRE markets as their opacity and illiquidity may make sudden repricing particularly disruptive. In recent years a range of factors may have encouraged market players to increasingly account for climate risk when pricing buildings. These include intensification of climate risks and increased awareness of them, facilitation of pricing via improved data availability, increasing concerns regarding insurance gaps and - in the case of transition risk - the intensification of climate regulations. However, real estate markets have a long history of failing to correctly price risks, often with significant implications for the wider financial system and real economy (Claessens et al., 2009; Jordà et al., 2015), so this change in pricing over time is far from guaranteed.

Thus we test first for variation in prices across buildings associated with high and low levels of climate risk and then we test variation in these premia (penalties) over the course of our sample. If investors are gradually increasing their pricing of climate risk - facilitating a more orderly transition - we would expect increasing price penalties associated with both physical and transition risk exposure over the course of the 15 years we study.

To measure exposure to physical risk we use the Four Twenty Seven micro data set, which provides risk scores for six physical risk hazards - Fires, Heat stress, Water stress, Sea level rise, Earthquakes and Floods. As expected there is clear heterogeneity in exposure of office markets to these risks across the euro area, with southern European markets registering a higher level of exposure than northern Europe. The Greek market is most exposed with the average office building classified as having a Medium Risk exposure. We then match this data with a large data set of CRE transactions, covering euro area office markets between 2007 and 2023. Descriptive results suggest that investors may be increasingly accounting for these risks in their pricing of offices over time, with a clear divergence between average prices of buildings with and without at least one high risk score over the period studied.

While a useful starting point, simple descriptive statistics will not account for a range of confounding factors which could drive this descriptive result. To address this we run a series of transaction-level hedonic regressions which control for the role of aggregate price dynamics, cross-country price differentials, central business district location and regional economic dynamics. Our findings indicate that investors are able to identify high risk buildings and since 2012 have been consistently applying a price discount to these buildings. We find that the average discount applied to a high risk building has increased by 24pps over the 2007-2022 period. To our knowledge this is the first time that the presence of market pricing of physical climate risks in euro area CRE markets has been shown. This result is robust to a battery of further checks which account for variation in market risk appetite, the geographic heterogeneity of the sovereign debt crisis and variations in price premia applied to prime building locations.

Of course, it remains possible that increased pricing of risks is driven by factors not related to climate change concerns, such as improvements in data availability. While repricing for these reasons would still benefit market stability and serve to reduce the likelihood of sudden disruptive repricing, comparison of pricing across physical risk types provides some interesting insights. We compare changes in pricing across physical risk types which are associated with climate change - such as heat stress and rising sea levels - with those around risks which are not typically associated with climate change, namely earthquake risk. Our results again point to climate change concerns as a driving factor. While investors have increased discounts for risks most associated with climate change, there is no evidence of investors increasing discounts for buildings exposed to earthquake risk.

Investor concerns regarding climate risk may affect the price of exposed buildings but also their liquidity, with the potential for exposed assets to become un-sellable or "stranded". Indeed ECB/ESRB (2022) flag that an abrupt market-wide reassessment of climate risk pricing could result in severe firesale activity where all holders of a given asset simultaneously seek to reduce exposure but are unable to find a willing buyer. In their review of the literature on climate change and real estate Clayton et al. (2021) highlight this liquidity angle as being particularly understudied, with almost no examination in the context of commercial real estate.

While typical liquidity indicators like bid-ask spreads are not widely available for CRE markets, we can examine variation in the share of market activity occurring in high risk areas. In a scenario where there is falling liquidity in the market for high risk buildings and owners of high risk buildings are increasingly struggling to find buyers, we would expect this share to decrease over the period studied due to longer selling times or failed attempts to sell buildings. However, high risk buildings account for a stable share of transactions over the period we study. This finding is confirmed by a simple logit model which accounts for confounding factors. This suggests that the increased pricing of climate risks by investors over our sample period has played out in a relatively orderly manner, without implications for the liquidity of high risk buildings.

CRE markets are also highly exposed to transition climate risk. Real estate is a significant carbon emitter - with one third of the EU's energy related greenhouse gas emissions estimated to come from buildings. This has created both direct and indirect links between climate policies and real estate markets. Direct policy interventions include requirements that buildings meet certain energy efficiency criteria. Indirectly, corporate carbon disclosure regulations encourage firms more broadly to reduce carbon emissions and as a result also increase demand for energy efficient office space. As before, we would expect this to result in a premium for highly energy efficient offices which strengthens over the period we study, particularly in its final years as firms come to terms with the increased likelihood and stringency of this type of regulation.

Unfortunately, we do not have building-level data on energy efficiency ratings in our transactions data set. However, we do use building age and time since last renovation as a proxy. Descriptive statistics show a clear divergence between prices of buildings below and above the 5 year age cut-off in the final years of our sample. Again we use hedonic regressions to account for confounding factors. We find that the premium for young buildings is significantly higher at the end of our sample than at the start, with a 18pps increase in premium over the 2007-2023 period. Despite there being no correlation between the likelihood of a building being exposed to physical climate risk and the likelihood of it being old, the timing of this change closely mirrors that of our physical risk pricing dynamics, again pointing to climate change concerns as the driver of this dynamic. This result is again robust to a range of further tests which account for variation in market risk appetite, the geographic heterogeneity of the sovereign debt crisis, variation in heating costs, variation in premia associated with prime location and variation in construction activity.

To our surprise, we do not see a particularly pronounced increase in premium in the final years of our sample. This is despite the intensification of climate legislation over this period and increased focus on this risk by major market players. Our final piece of analysis suggests that investor concerns regarding transition risk may now be playing out via the liquidity channel. By applying a similar logit model we show a clear shift in market activity away from older buildings from 2018 onwards. This suggests that owners of older buildings may indeed be struggling to find buyers as concerns regarding exposure to climate policies increase. This suggests that the "stranded asset" problem arising from transition risk may already be beginning to take hold in euro area CRE markets. Indeed market activity levels for CRE markets in general have dropped to record low levels since the beginning of the ECB's rate hike cycle (see Ryan et al. (2023)). If this is coupled with a shift towards young buildings in the remaining transaction activity, building owners are likely facing extreme difficulty in selling older assets.

Taken together these results show that euro area CRE markets have a significant exposure to climate risks. From a policy perspective, this underlines the importance of considering macroprudential tools to increase the resilience of the financial system to these risks and avoid its weaknesses amplifying the economic effect of climate shocks (see ECB/ESRB (2022)). It also underlines the importance of continuing work to close data gaps which hinder our analysis of CRE markets, particularly in relation to energy efficiency of the stock of Europe's buildings.

The rest of this paper is structured as follows: the next section discusses transmission mechanisms which link climate change with financial stability via real estate markets. Section 3 provides an overview of related literature. Section 4 provides an overview of our data sets. Section 5 discusses physical risk and Section 6 discusses transition risk. Both risk sections first provide descriptive statistics, then market pricing regression analysis and then market activity regression analysis. Section 7 concludes.

2 Climate change, commercial real estate and financial stability

As a market for physical assets, CRE markets are directly exposed to physical climate risks via the potential for buildings to be damaged or destroyed during climate events. Real estate is also a significant carbon emitter - with estimates that one third of the EU's energy related greenhouse gas emissions come from buildings [1] and in cities this figure can be as high as 60% (JLL, 2023). For owners of older or less energy efficient buildings, this creates the risk that buildings may be affected by legislation aiming to reduce real estate emissions. Indeed, the Paris Agreement mandates that greenhouse gas emissions from buildings must be reduced to zero by 2050, with ambitious targets set for 2030.[2]

Where climate events - be they natural disasters or major legislative changes - result in widespread, negative shocks to CRE values this will have a number of significant and simultaneous financial stability implications. First, this will have implications for the resilience of firms which own these assets, with potential knock-on effects for credit risk in the banking system. It will also have implications for the resilience of funds and insurers with large CRE holdings. Second, CRE is widely used as collateral by firms when they borrow - indeed Horan et al. (2023) estimate that almost 40% of euro area collateralised loans to firms are collateralised by CRE. These two effects combined give rise to "wrong way risk", whereby a large physical risk event would be associated with both rising probability of default and falling collateral values - pushing up loss given default - at the same time (see ECB/ESRB (2021a)).

In the case of physical events, this shock to the financial system via CRE markets would occur at the same time as a significant wider shock to economic activity arising from the climate event. This may reduce the financial system's capacity to absorb losses arising from the CRE shock. Where the financial system is unable to absorb losses in an orderly fashion, it may in turn amplify the economic shock arising from the climate event, for example via a sharp reduction in credit provision. Even when the resilience of the financial system is not threatened, large shocks to CRE values may still have implications for credit supply and therefore wider economic activity via the collateral channel. These effects may also play out via market liquidity, with the pool of potential buyers for affected assets shrinking and owners of these assets struggling to sell assets, even at discounted values. This will also have direct implications for financial stability - for example, affecting banks' capacity to sell recovered collateral and funds' capacity to raise cash through asset sales.

While much of the literature has focused on the effects of climate events themselves, investors should have some awareness of which properties are more or less exposed to climate risks risks. As a result we would expect investors to at least partially price these risks in advance of a climate event occurring. Moreover, there are a number of factors which could result in a strengthening of market pricing of this risk over time. First, as markets - and societies more broadly - become increasingly aware of the reality of climate change, this updating of beliefs may also feed into investors' pricing of risk when valuing and purchasing properties. This may be triggered in particular by both major climate events or landmark political events related to climate change, which both raise investors awareness of physical climate risks and provide greater credibility to the possibility of legislative actions. The literature identifies the Paris Agreement as a landmark event in this regard (see next Section).

[1] Estimates from the European Commission available here.

[2] As part of the European Green Deal, the European Commission proposed plans in July 2021 to achieve a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels. To meet this goal, the EU aims to reduce buildings' greenhouse gas emissions by 60%, their energy consumption by 14%, and the energy consumption of heating and cooling by 18%. See European Commission.

Regarding physical risks, continued high global carbon output and rising frequency of severe climate events have likely increased the risks from climate change to real estate markets over the period studied, which we would expect to result in greater awareness of these risks by investors. Moreover, rising concerns regarding the capacity for buildings exposed to climate risk to be insured may also feed into pricing. ECB/ESRB (2021a) highlight that only 35% of economically relevant climate losses are estimated to be currently insured in the EU.

Regarding transition risks, following the EU Energy Performance of Buildings Directive, a number of euro area governments have begun implementing policies which require buildings to be of a certain energy efficiency standard. Most notably, Dutch legislation came into force in January 2023 which requires an energy efficiency class of A, B or C for office buildings. By 2030 office buildings must have an energy efficiency rating of A (Hogan and Lovells, 2023).[3] More broadly, companies are increasingly required to disclose their carbon emissions. In March and April 2022 alone, three major corporate disclosure proposals were released globally: the EU's Corporate Sustainability Reporting Directive (CSRD), the U.S. Securities and Exchange Commission's (SEC) Climate-Related Disclosure requirements and the International Sustainability Standards Board (ISSB). In response many companies are pledging to reduce their carbon output and one way they can do this is by moving into more energy efficient offices. Cushman and Wakefield (2023) flag similar implications from carbon taxes.

Widespread discussion of these risks by industry players suggests that markets are fully aware of the risks arising from incoming legislative change and therefore we should expect price changes to begin before policies are introduced (Cushman and Wakefield, 2023; McKinsey, 2022; JLL, 2021, 2023). Indeed, Cushman and Wakefield (2023) estimate that up to 74% of the European office stock risks obsolescence due to the combination of a shift towards remote working and increasing concerns regarding energy efficiency and climate change. In relation to the implications of SEC corporate carbon disclosure rules for real estate markets McKinsey (2022) state that "*the Great Repricing will happen whether the SEC's proposed rule becomes reality sooner, later, or not at all*" although they do state that major pieces of legislation will likely accelerate the process.

The financial stability implications of this time component of market pricing are important. Indeed much of the existing work on the financial stability and real economy implications of climate change stresses the increased risks associated with a disorderly vs. an orderly transition to the reality of climate risks (ECB/ESRB, 2020, 2021a, 2022). We would argue that this element is particularly important in illiquid and opaque markets like CRE.

On one hand, increased penalisation of climate risk exposure in CRE markets as awareness of climate risks increases will have all of the financial stability implications laid out above. However if markets ignore these risks, this could result in sudden, large jumps in pricing and large drops in liquidity when the market is suddenly forced to adjust. Both the pricing and liquidity shocks may also be amplified by significant uncertainty, as investors struggle to quickly price an unfamiliar risk. Moreover, where market prices have not reflected exposure to climate risks, this may result in excessively low risk weights on banks' CRE exposures and insufficient provisioning for associated losses. Large, sudden jumps in pricing and spikes in market uncertainty may also expose real estate funds to large widespread redemptions which funds will may struggle to meet as market illiquidity will impede asset sales. Finally, large sudden shocks to CRE values will have significant implications for the resilience of firms which own these assets, particularly where previous underpricing of climate risks has allowed them to build up excessive leverage.

As a result, given the reality of the risks to CRE markets posed by climate change, a gradual increase in pricing over time is likely the most positive outcome from a financial stability perspective (ECB/ESRB, 2020). Indeed climate stress-testing of the financial system finds that losses are more contained in "gradual adjustment" scenarios than in those whereby sudden and

[3] A number of cities - such as Paris - have also committed to net zero carbon policies (JLL, 2023).

disorderly adjustment is made (ECB/ESRB, 2021a, 2022).

3 Related literature

The existing literature regarding the pricing impact of climate change in real estate markets primarily focuses on the impact of specific climate events - both natural disasters and specific regulatory changes. The literature on commercial real estate is significantly less well developed than for residential, however Fisher and Rutledge (2021), Cvijanovic and Van de Minne (2023), Addoum et al. (2024) and Holtermans et al. (2023) all show that physical climate events have clear, immediate pricing impact which tends to fade in the years following a natural disaster. In terms of transition risk, Akhtyrska and Fuerst (2024) find that the implementation of the Minimum Energy Efficiency Standard (MEES) had a direct impact on UK office rents. Eichholtz et al. (2010), Eichholtz et al. (2013), Kok and Jennen (2012), Fuerst and McAllister (2011a), Fuerst and McAllister (2011b), Fuerst and Van de Wetering (2015) and Chegut et al. (2014) also show a general link between energy efficiency and building returns in the US, UK and Netherlands.

The literature also shows that prices in areas with similar climate risk profiles may change after a given climate event in a nearby region. For example, Addoum et al. (2024) find that flood-risk-exposed properties in Boston saw slower price growth after Hurricane Sandy. McCoy and Walsh (2018) find a similar dynamic for wildfires. This suggests that we may not need a climate event to occur in a given location for prices to be affected by investors' concerns regarding climate change - investors are aware that certain areas are more prone to climate events than others. Indeed for residential markets Baldauf et al. (2020) find that in Florida neighbourhoods characterised by greater climate change belief there is also greater evidence of physical risk pricing.

However, beyond the real estate literature, we can find a number of papers which examine the adaption of financial markets to a growing awareness of climate change via pricing. Many of these papers find a clear change in pricing in the period surrounding the Paris Agreement in 2015. Specifically, Delis et al. (2024), Ehlers et al. (2022) and Seltzer et al. (2022) find evidence of banks, syndicated loan markets and corporate bond markets beginning to price firms' exposure to both physical and transition risk following the Paris Agreement. Ginglinger and Moreau (2023) find that firms exposed to physical climate risk also reduced their leverage following the Paris Agreement and Ramadorai and Zeni (2024) show that firms reported an increased belief regarding the impact of climate regulation. Fontana et al. (2025) show that euro area banks began pricing physical climate risks in their mortgage portfolios following the Agreement.

A number of further papers indicate that by simply focusing on natural disasters and individual legislative changes, we may miss important elements of CRE markets' climate pricing. Large CRE transactions - such as those included in our data - are carried out by sophisticated institutional investors. Choi et al. (2020) show that while retail equity investors respond to daily extreme weather changes with changes in investment decisions, institutional investors do not respond to these short term shocks. Schlenker and Taylor (2021) also provide evidence that prices of financial derivatives whose payouts are based on future weather outcomes more closely align their expectations with scientific projections than recent weather observations.

Thus in our analysis we want to examine changes in CRE markets over an extended period of time, as opposed to following specific climate events - such as natural disasters or regulatory changes. Understanding these aggregate dynamics is an important aspect of understanding how climate change is affecting CRE markets as a whole, which in turn is crucial for understanding macroeconomic and systemic risk implications. In this regard the literature - particularly on commercial real estate - is quite sparse and this is the gap in the literature our work aims to fill.

A recent paper which is arguably the most similar to ours is Sirmans et al. (2025) in which the authors examine physical climate risk pricing in US commercial real estate markets. They find evidence of investors pricing these risks (beyond studying response to specific climate events). They also find that in areas where there is a greater awareness of climate risks this pricing effect is stronger. However, they do not study variation in pricing over time. As a result our papers can be considered useful complements to one another.

Furthermore Turnbull et al. (2013) argue that liquidity must be studied alongside prices to fully capture the effects of flood risk on housing markets. They find both discounts and longer selling times for homes in parts of Louisiana most exposed to physical climate risk. In their comprehensive review of the literature on real estate and climate change Clayton et al. (2021) flag this as a particularly understudied topic, particularly in commercial real estate markets. This is another gap in the literature that we help to fill by examining whether or not increased awareness of climate risks has affected the liquidity of more exposed buildings.

Finally, the existing literature on physical risk pricing in commercial real estate markets is primarily focused on US markets. To our knowledge we are the first to study physical climate risk pricing in commercial real estate markets in Europe.

4 Data

4.1 Property transaction prices and characteristics

To understand pricing dynamics over time we use a large data set of euro area CRE transactions starting in 2007. Specifically we use the RCA data set provided by MSCI which contains transaction-level data for large CRE transactions. The data includes property characteristics such as the type of building transacted (e.g. Office, Retail, Industrial), its size, price, age, latest renovation date, location and a flag showing whether or not the building is located in a central business district (CBD). The three most crucial pieces of information throughout our analysis are price, exposure to physical climate risk and exposure to transition climate risk. We use price per square foot as our standard price measure. Price values outside of the 5th and 95th percentile values by country and year are windsorised. For simplicity we focus on office buildings throughout our analysis, as they are the largest and historically most important investment market in euro area CRE, although future work could extend our analysis to other parts of the euro area CRE market.

The data set comprises of large CRE transactions, covering mostly deals valued at 10 million euros or more. As a result the buyers and sellers in question are typically large institutional players. Just less than 60% of transactions have investment funds as buyers, a further 20% have firms, pension funds and insurers account for about 10% of purchases and the final 10% is a mix of other buyer types. Buyers are also geographically diverse, with approximately half coming from the same country as the asset being bought, just over 10% coming from another part of the euro area and the rest coming from outside the euro area (see Ryan et al. (2022)).

4.2 Measuring physical risk

The RCA data set provides the location for each transacted building - via zip code, longitude/latitude, postal code and city name - so we can study how physical risk may be priced in these transactions by matching the RCA data with another data set providing estimates of exposure to physical risk for different parts of the euro area.

As in Fontana et al. (2025) and Alogoskoufis et al. (2021) we use the Four Twenty Seven database which provides measures of climate-related exposures and threats facing real estate, corporate facilities, infrastructure, and other real assets. It should be noted that this data set does not have a time component, so exposure to physical risk for a given location will not vary over time in our analysis. Data is provided at the building-level, with additional information on the location and type of building provided.

Scores are provided across six hazard types: Floods, Heat Stress, Earthquakes, Water stress, Sea level rise and Wildfires.[4] Indicators integrate information on both current hazard frequency and intensity, and projected changes until 2040 and are derived from a combination of peer-reviewed climate model-based datasets and environmental datasets. Wildfire, temperature and precipitation-based indicators are based on outputs from the NASA NEX-GDDP project. Indicators are based on a comparison of model results for the periods 1975-2005 and projections for 2030-2040, with projections based on the highest emission pathway. Flood, hurricane, sea level rise and water stress indicators build on data from the World Resources Institute Aqueduct tool and simulated high resolution flood data builds on analysis from the flood analytics provider Fathom (see ECB/ESRB (2021b) for further discussion).

Risk scores for each hazard can take a value between 0 and 100. Five risk levels are assigned to these: No risk, Low risk, Medium risk, High risk and Red flag. The translation from risk scores to levels is, however, not homogeneous across hazards as score thresholds can vary. To create numeric scores which are comparable across hazards we assign values 0-4 to the levels of each hazard, where 0 is assigned in the case of a No risk level and 4 in the case of a Red flag.

We match the two data sets by constructing average risk scores for buildings in a given area in Four Twenty Seven and then studying transactions of all the buildings in this area in RCA. Thus we calculate average and maximum risk scores at the postal code and city level. Trying to match individual buildings across the two data sets would be a sub-optimal approach as neither data set covers the full population of buildings in a given region and so trying to match the two results in quite a small sample size. In contrast, by using Four Twenty Seven to produce regional estimates, we are able to use almost our entire transaction data set.

We first merge the aggregated Four Twenty Seven data with RCA by postal code. With this first step we are able to match 70% of our RCA transactions sample with an estimate of physical risk exposure for the postal code where the building is located. Using the remaining unmatched sample we repeat this process at town/city level. This provides a town/city level estimate of physical risk for a further 28% of our full RCA sample. Combined we are able to merge 98% of all RCA transactions in this way, leaving us with 24,386 out of the 24,912 office transactions over the 2007-2023 period, across all 20 euro area countries and Bulgaria for our physical risk analysis.

4.3 Measuring transition risk

Unfortunately our RCA transactions data set does not include information on buildings' energy efficiency, which would be the ideal measure of a building's exposure to transition risk. However, building age is available for 64% of our sample and older buildings are likely to require more extensive renovation to meet energy efficiency standards, so we use this as a proxy for energy efficiency. Indeed, ONS (2022) find that a property's age is the single biggest factor in predicting its energy efficiency. Of course, once renovation has been undertaken we would expect a building to have a reduced exposure to transition risk. For 17% of the sample the date of latest renovation is also provided.

[4] In this case Heat stress refers to the danger of experiencing excess heat and Water stress to the danger of experiencing water shortage.

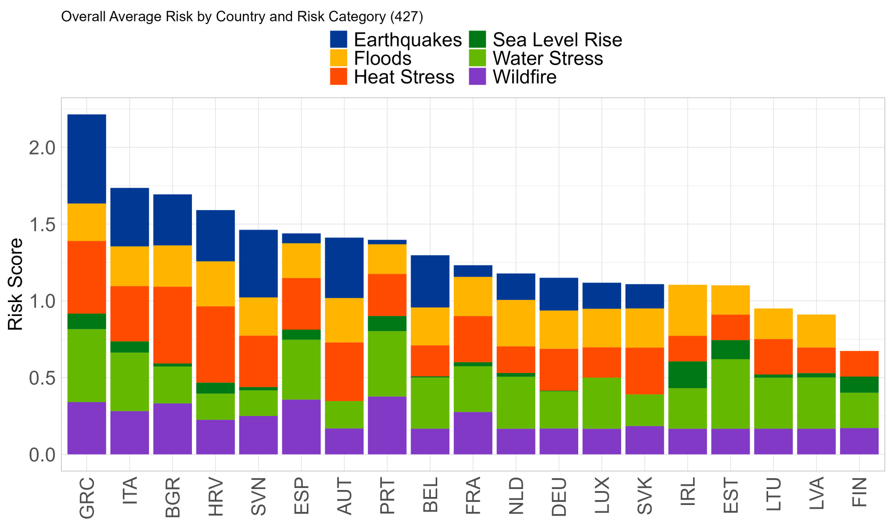
Using these two variables we construct a variable aiming to reflect a building's exposure to transition risk: We start by calculating the number of years since the last renovation, where this data is available. For transactions where renovation date is not provided we calculate the number of years since the building's construction. For the rest of the paper we will refer to this as our *age* variable. Where the resulting building age is greater than 30 years we remove the transaction from our data set, due to the high likelihood that the building as been renovated over the past 30 years but this information has not been provided. This leaves us with 15,184 transactions for our transition risk analysis over the 2007-2023 period, across all 20 euro area countries and Bulgaria.

5 Physical risk

5.1 Descriptive statistics

As the exposure of euro area CRE markets to climate change risks has not been systematically studied before, we begin with simple descriptive analysis before moving on to more formal regressions.

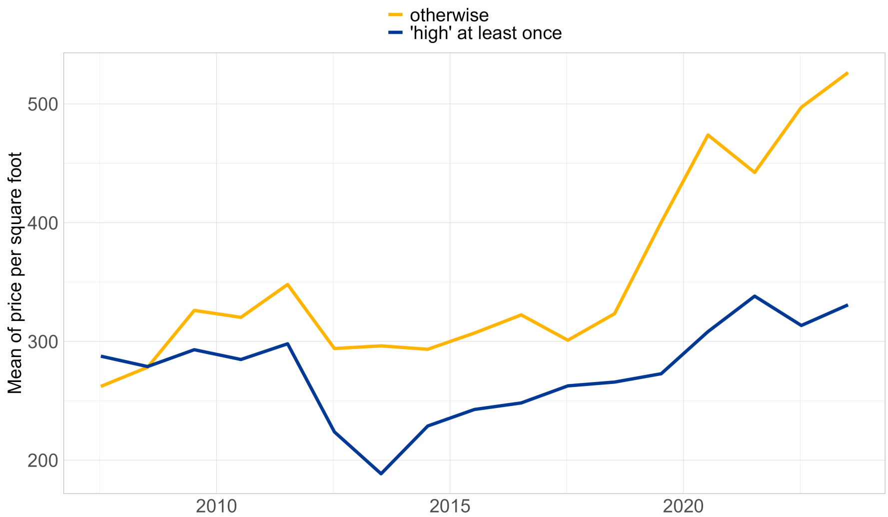
Figure 1: Physical risk exposures of national office markets display clear cross-country heterogeneity in risk exposure



Note: This chart aggregates risk scores for buildings identified as offices in the Four Twenty Seven data set so it should reflect risk scores for the euro area's stock of offices. When the excercise is repeated with transaction-level data from RCA (capturing the flow of market activity) results are largely unchanged. To allow for aggregation we translate risk scores into numeric values. 0= No risk; 1 = Low risk; 2 = Medium risk; 3 = High risk; 4 = Red flag

First, in Figure 1 we aggregate risk scores from the Four Twenty Seven data set at the country-level, establishing the average aggregate physical risk score across offices in a given country and the contribution of each type of physical risk to this score. As we would expect, we find significant cross-country heterogeneity in physical climate risk across the euro area's stock of office buildings. Risks are highest in a number of Southern European countries - notably Greece - and lowest in some of Europe's smaller Northern economies. In Greece the average risk score of 2 aligns with a Medium risk level, indicating significant exposure of the Greek office market to climate change risks. At the other end of the spectrum, the aggregate Finish risk score of below 1 means that the average Finnish office has a risk score between Low and No risk. A large share of the variation across countries appears to be driven by variation in heat stress, exposure to earthquakes and water stress.

Figure 2: Average prices over time show a clear divergence between properties with at least one risk flagged as at least high and the rest of the market

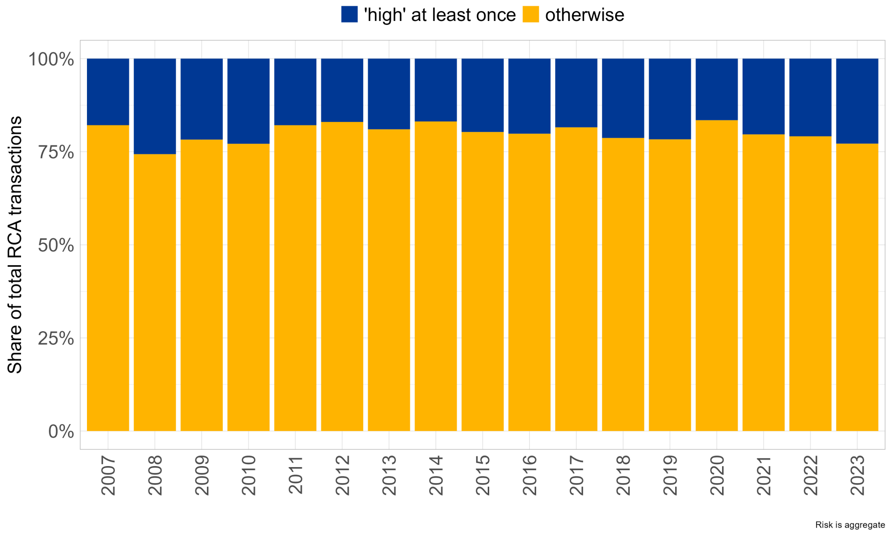


Note: This chart shows a simple average of transacted office prices in terms of price per square foot. The sample is split between offices with at least one physical risk score equal to High or Red Flag and the rest of the market

Next we examine dynamics over time in pricing of buildings which are and are not exposed to high levels of physical risk. Figure 2 tracks the mean price of buildings which do and do not have at least one High or Red Flag risk score across the all of the physical risk categories. There is a clear divergence towards the end of the series, with buildings exposed to physical risk largely excluded from the rapid price growth experienced in the market in the years prior to 2020. A possible explanation is that, as awareness of climate risks have risen, investors have increasingly accounted for this in building prices. Of course this result could also be driven by other factors, such as a shift in market activity towards parts of the euro area which are characterised by both higher office prices and low physical risk. We will aim to control for these factors in our regressions.

As flagged in the literature, investors' response to climate risk could show up in pricing but also in market liquidity, with owners of high risk assets struggling to sell assets due to a shrinking pool of buyers. Figure 3 looks at the share of transacted offices in the euro area in each year which have at least a high score for any physical risk. There is no sign of a reduction in the share of market activity occurring in these areas over time, suggesting that increased awareness of physical climate risks has not yet left investors in a position where they simply cannot sell exposed buildings. In the next section we will also examine this again using regressions to account for potential confounding factors. The fact that about a quarter of transacted buildings in each year have a high or very high risk score, underlines again that euro area CRE markets have significant physical climate risk exposures.

Figure 3: Almost a quarter of transacted offices in the euro area have at least a high risk score in at least one physical risk category



Note: This chart shows the share of annual office transactions with at least one High or Red Flag risk score.

5.2 Market pricing

While these descriptive charts are a useful first step, they are subject to a range of potential confounding factors - such as higher real estate prices in Northern European countries which also happen to have lower exposure to physical climate risk. Our regression analysis aims to control for these using a simple hedonic regression method. In Equation 1 we regress log of price per square foot on a range of fixed effects capturing factors which are likely to be correlated with both a building's price and its exposure to physical climate risk. These include year fixed effects which should capture the overall trend in price growth over time, country fixed effects to capture variation in prices across the euro area and a dummy which equals one if the building is in the central business district (CBD). We capture exposure to physical risk with a dummy which equals one if the building is in a location which has at least one physical risk score with a High or Red Flag risk level. We cluster errors at the postal code level and will continue to do this throughout our regression analysis.

$$log(pricesqft_{i,t}) = \alpha + \beta_1 year_t + \beta_2 country_j + \beta_3 CBD_i + \beta_4 physicalrisk_{i,t} + \epsilon_{i,t} \quad (1)$$

Table 1: Regressing price per square foot on our physical risk dummy and a range of control variables provides evidence of investors pricing physical risk from 2015 onwards

	Baseline (1)	GDP per capita (2)	2015 split (3)	2015 split & GDP/cap (4)	Dynamic controls (5)	Drop GR, PT, ES (6)
High risk	-0.09**	-0.04	-0.03	-0.01	-0.01	0.01
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
CBD	0.52***	0.48***	0.52***	0.48***	0.48***	0.49***
	(0.06)	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)
GDP per capita		2.14***		2.14***	2.15***	2.17***
		(0.28)		(0.14)	(0.15)	(0.15)
High risk × 2015 dummy			-0.09***	-0.04*	-0.04*	-0.06**
			(0.02)	(0.02)	(0.02)	(0.03)
GDP growth					-0.01**	-0.01**
					(0.00)	(0.00)
Pop. growth					-0.02	-0.04*
					(0.02)	(0.02)
House price growth					0.01***	0.01***
					(0.00)	(0.00)
R^2	0.43343	0.49245	0.43428	0.49259	0.49422	0.50276
Observations	23,357	20,835	23,460	20,835	20,835	19,538
Year fixed effects	✓	✓	✓	✓	✓	✓
Country fixed effects	✓	✓	✓	✓	✓	✓

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Note: Dependent variable is log of price per square foot. High risk dummy equals one for transactions with at least one physical risk category equal to High Risk or Red Flag. All growth variables are entered as nominal annual growth rates. CBD is a dummy which equals one when an office is in a physical risk district. The 2015 dummy equals one for all years from 2015 onwards. Data covers 2007-2022.

Results in Table 1 show that we have a negative and highly statistically significant coefficient for this physical risk score dummy - indicating that investors do appear to penalise buildings with high physical risk exposure. However, as a further check we add a control for annual, regional (NUTS2) GDP per capita. While this is not a variable that would typically be included in this type of hedonic approach, we believe it is an important control variable to account for the possibility that - within countries - areas with higher exposure to physical risk are less economically developed and therefore have lower real estate prices. Indeed we find that once this control is added the coefficient for our physical risk variable halves in size and become statistically insignificant. This suggests that while buildings in high risk areas are typically cheaper, this is in large part due to local economic conditions.[5]

Of course it is possible that this insignificant finding is due to us examining average effects over the full time time period studied. The literature on financial market pricing of climate risks widely emphasises the 2015 Paris Agreement as an event which increased markets' awareness of risks arising from climate change, with a number of papers marking this as the point when financial markets began actively pricing these risks. In particular, the Paris Agreement stands out as having placed a particular emphasis on the role of the financial system in tackling challenges arising from climate change and we might expect this to also affect the buyers in our sample who largely come from the financial sector. Moreover, the literature highlights a number of events occurring earlier in 2015 in the build up to the Paris Agreement which emphasised the importance of climate change risks for the financial system - these include direction by G20 finance ministers in April to the Financial Stability Board (FSB) to consider how the financial sector could take account of the risks climate change poses to the financial system, a high profile speech by Mark Carney - then Chair of the FSB - laying out links between climate change risks and financial stability[6] and the beginning of concrete work by the FSB to tackle climate risks in the financial system via the creation of disclosure task force on climate-related risks.[7].

Thus we interact our high risk dummy with a dummy which equals 1 in all years from 2015 onwards. We find a negative and statistically significant result both with and without our GDP per capita control. This provides preliminary evidence that investors do appear to be accounting for climate risks at least since the time period surrounding the Paris Agreement - in line with what the literature has shown for wider financial markets. Again the inclusion of GDP per capita as a control variable halves the coefficient size but the coefficient does remain statistically significant to 10 per cent.

We add a number of further control variables to test the robustness of this result. While our year fixed effects will account for fluctuations in aggregate euro area macroeconomic activity and real estate prices over time, we add annual regional GDP and population growth controls to account for the fact that economic dynamics may be very different in different parts of the euro area for a given period. We also control for annual national growth in house prices to account for heterogeneity in real estate market dynamics not captured by year and country fixed effects or regional GDP and population dynamics.[8] As a final robustness test we remove the countries worst affected by the euro area's sovereign debt crisis - namely Greece, Spain and Portugal - from our sample. These countries also have high physical risk scores and we want to ensure that this is not driving our result. As shown in the final column of Table 1 we continue to find

[5]As we merge these NUTS2-level variables with our transactions data set using postal codes, we are required to drop Ireland from our estimation.

[6]Available here: https://www.bis.org/review/r151009a.pdf

[7]See here: https://www.fsb.org/2015/11/fsb-proposes-creation-of-disclosure-task-force-on-climate-related-risks-2/

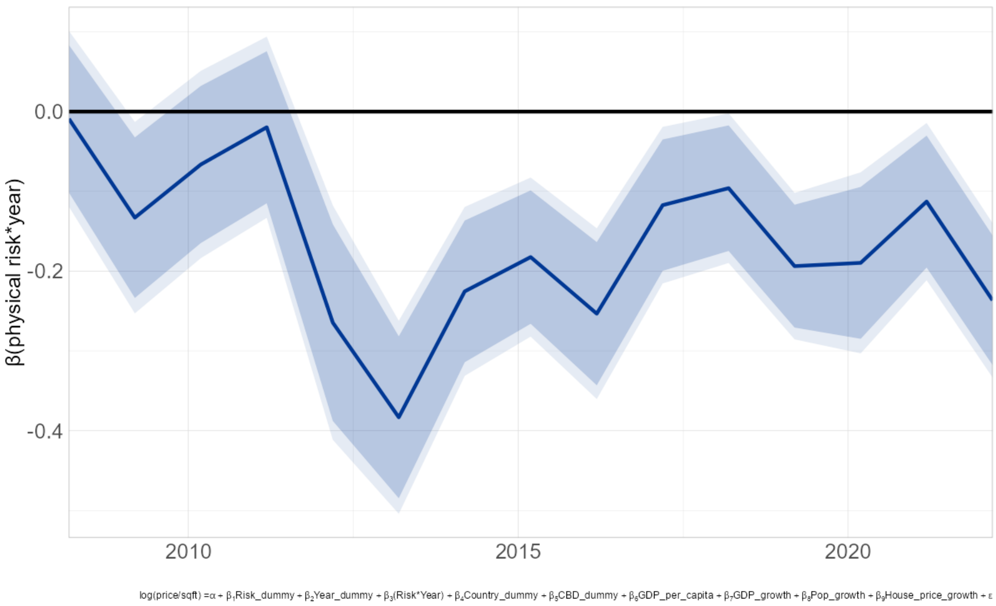
[8]Controlling for commercial real estate market dynamics would require us to drop quite a few countries from our sample as CRE price indices are not available for all countries. Over the period studied commercial and residential real estate markets largely moved in tandem with one another.

a statistically significant and negative result, with a similar coefficient size. In fact statistical significance rises when we drop countries most affected by the sovereign debt crisis.

As we working with 15 full years of granular data we can take this analysis another step further and examine yearly dynamics in climate risk pricing by investors. We interact our physical risk dummy with dummies for each year in our sample (Equation 2). These coefficients will tell us how the discount for high risk buildings has evolved since 2007, the first year of our sample. If the discount applied to high risk buildings increases over the course of our sample we would expect these coefficients to be significant and increasingly negative. For ease of interpretation we show our results by plotting the values of these interaction term coefficients but all results can be found in table form in the paper's Appendix. We continue to control for annual, regional GDP per capita, annual regional GDP and population growth and annual house price growth to account for the role that regional economic dynamics and national real estate market dynamics will play in driving CRE pricing over time. We continue to cluster errors at the postal code level.

$$log(pricesqft_{i,j,t}) = \alpha + \beta_1 year_t + \beta_2 country_j + \beta_3 CBD_i + \beta_4 physicalrisk_{j,t} + \beta_5 physicalrisk_{j,t} * year_t \\ + \beta_6 gdppercapita_{j,t} + \beta_7 gdpgrowth_{j,t} + \beta_8 housepricegrowth_{j,t} + \beta_8 populationgrowth_{j,t} + \epsilon_{i,t} \tag{2}$$

Figure 4: Risk*year interactions show an increase in price penalties over time



Note: Line shows coefficients on *physical risk*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in penalties associated with an office being located in a high risk region between 2007 and the year shown. Full results can be found in the Appendix.

Figure 4 plots the coefficients on our *physical risk*year* interaction terms along with their 90 and 95 per cent confidence intervals. Coefficients are typically not statistically significantly different from zero prior to the year 2012 but from 2012 onward coefficients are always negative and statistically significant. This indicates persistent pricing of climate risks by investors over the latter part of the studied period. Looking at the final year in our sample we find that the discount applied to these buildings has increased by 24pps since 2007, so this increase in pricing is both economically and statistically significant.

The fact that risk pricing appears to have begun even before 2015 explains the relatively low degree of statistic significance in our earlier results. This indicates that in the years leading up to the Paris Agreement - as climate change rose steadily on the international agenda - office markets also began to see price differentiation based on exposure to physical climate risk. Indeed a number of papers show rising media coverage of climate events in the years running up to the Paris Agreement - for example Engle et al. (2020) construct a Negative Climate Change news index which rises consistently from 2013 to 2015. While the wider literature on financial market pricing of climate risks largely points to an effect which begins in 2015, it is maybe unsurprising that markets for phyiscal assets like CRE began pricing risks earlier, given the very clear link between climate events and their values.

We run a number of robustness tests on this result to account for potential confounding factors. The physical risk discount appears to be largest in the year 2013. While our GDP growth control should account for variation in economic dynamics, we still want to ensure that this downward spike in 2013 is not driven by CRE price corrections in those countries worst affected by the sovereign debt crisis. We repeat our analysis again removing Greece, Spain and Portugal from our sample (we were already required to drop Ireland when we merged NUTS GDP and population data on the basis of postal code). Figure 5 shows that results are broadly unchanged.

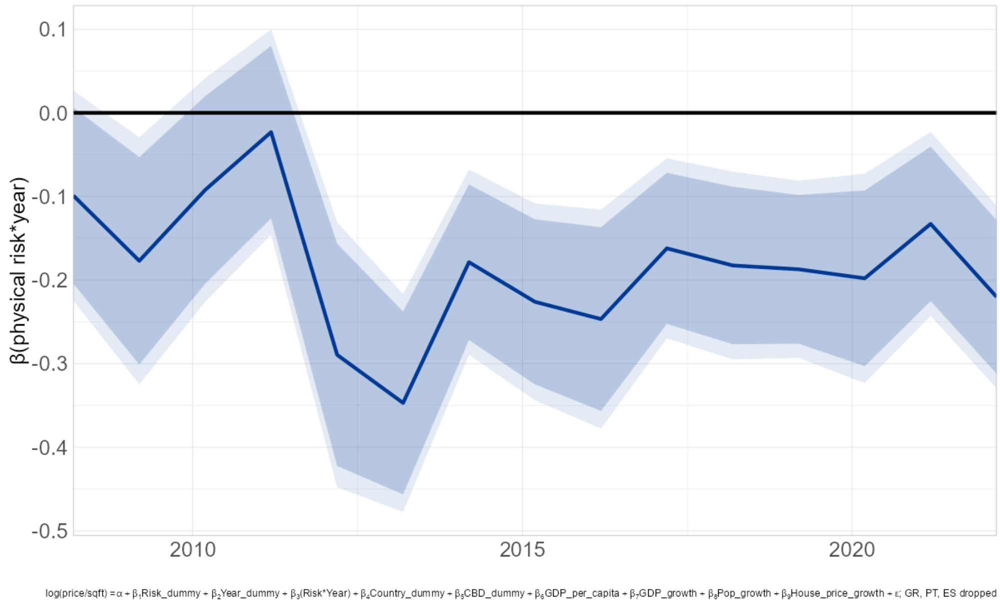
As a second robustness test we also include an interaction between the CBD coefficient and the year of transaction. Market reports indicate that in the years following the outbreak of the pandemic there has been increased demand for "prime" commercial real estate compared to non-prime (Cushman and Wakefield (2023)). This may lead to a change in market pricing of buildings in prime locations -such as central business districts - over time. If central business districts are also typically less exposed to physical risk then this could affect our results. We account for this by adding *CBD*year* interactions to our specification. The left hand side of Figure 13 plots the coefficients for *CBD*year* interactions and confirms that the premium for CBD locations rises sharply at the end of our sample. However, the right hand side shows that coefficients on our *physical risk * year* interactions again remain largely unchanged.

The addition of regional GDP and population data to our regression requires us to drop the final year in our sample as regional GDP data is not yet available for 2023. We re-run our analysis without this control variable and find that the increase in discount we see in 2022 remains stable in 2023. Overall we also see a larger increase in the discount associated with risky buildings in this specification. This emphasises again the importance of controlling for local economic dynamics when accounting for the price impact of physical climate risks on real estate markets.

As a further test we add a control for market risk aversion - VSTOXX - and interact this measure with our physical risk indicator.[9] Here the goal is to test the possibility that variation over the course of our sample in climate risk pricing is driven by market risk aversion. For example, it is possible that investors have a relatively consistent view regarding climate risks but are less willing to take these risks during periods of risk aversion. This interaction is not statistically significant and our *physical risk*year* interaction coefficients also remain broadly unchanged. These results can be found in the paper's appendix.

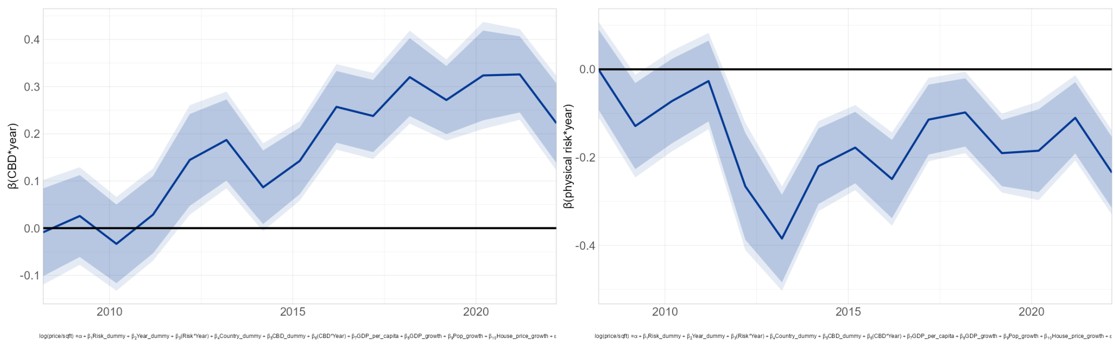
[9]This result also holds when we use VIX instead of VSTOXX.

Figure 5: Risk*year interactions have largely similar dynamics when countries associated with the sovereign debt crisis are excluded



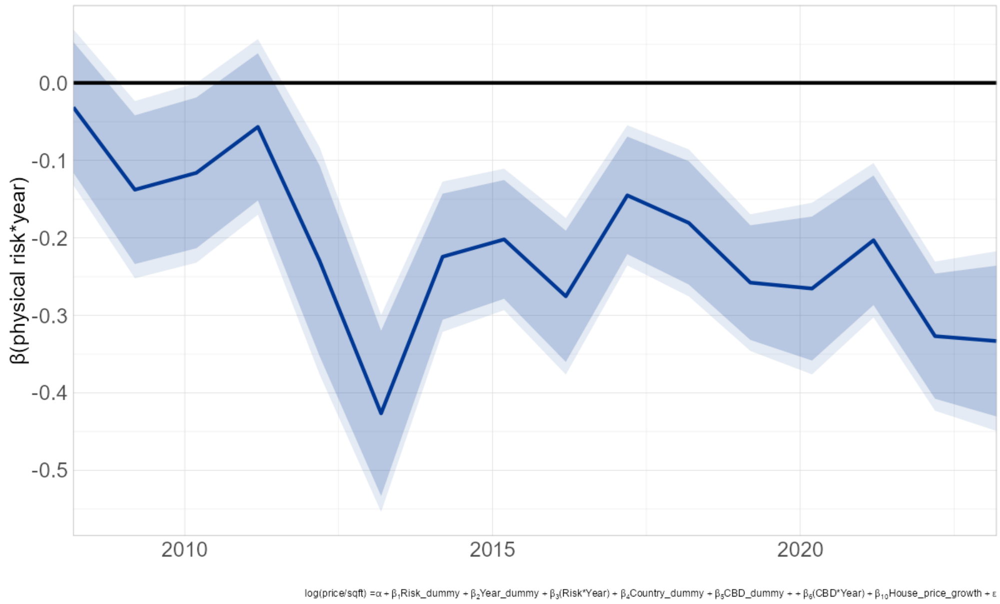
Note: Line shows coefficients on *physical risk*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in penalties associated with an office being located in a high risk region between 2007 and the year shown. Full results can be found in the Appendix.

Figure 6: We see a sharp increase in premia for CBD offices (left) but this does not affect our overall results regarding pricing of climate risk (right)



Note: Line shows coefficients on *physical risk*year* and *CBD*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in penalties associated with an office being located in a high risk region/ premia associated with being in a central business district between 2007 and the year shown. Full results can be found in the Appendix.

Figure 7: Risk*year interactions show a consistent discount in 2023 when regressions are run without the GDP per capita control



Note: Line shows coefficients on *physical risk*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in penalties associated with an office being located in a high risk region between 2007 and the year shown. Full results can be found in the Appendix.

Finally, it is also a possibility that variation in pricing over time is simply driven by greater data availability regarding physical risks as opposed to investors' views regarding climate change. While repricing for these reasons would still benefit market stability and serve to reduce the likelihood of sudden disruptive repricing, comparison of pricing across physical risk types provides some interesting insights. We look at variation in pricing across the different physical risks contained in our sample. In particular, one risk in our sample - earthquakes - is not typically associated with climate change. In contrast, climate change is expected to aggravate the other risks in our sample. If we expect investors to increasingly price physical risk due to increasing fears regarding climate change we may expect to see a more pronounced increase for those risks which are associated with climate change compared to those which aren't. In light of this we repeat our baseline specification but replace our physical risk score with dummies reflecting individual risk types. For most hazards we now have a much smaller sample of observations where our risk dummy equals one. To account for this, instead of interacting it with dummies for each individual year, we now interact the risk dummy with another dummy which equals one for the final two years of our sample.

Table 2 shows results where our physical risk dummy equals one when the average risk in a region is either "High" or "Red Flag" (as has been the case in all of our regressions so far). Here we find a negative and statistically significant interaction term between the hazard and the dummy indicating the final years of our sample for both heat stress and sea level rises. For other risks we find evidence of discount variation when we classify regions on the basis of the maximum risk level in the region (Table 3). For flooding we find evidence of rising discounts for regions where the maximum risk level is "Red Flag". For heat stress and wildfires we find evidence of rising discounts for regions where the maximum risk level is either "High" or "Red Flag". Variation in identification across maximum or average risk measurements may be due to certain risks tending to affect a full region - e.g. heat stress - while others may be more localised - such as flooding and wild fires.

In contrast to those risks which are typically associated with climate change, under no specification do we find evidence of rising discounts for buildings exposed to earthquake risk. We interpret this as support for our hypothesis that rising awareness of climate change risks are driving investors' tendency to apply larger discounts to exposed buildings. Finally, we find no evidence of discounts applied at all for buildings associated with water stress. Again, this finding is intuitive as water shortages are the risk least likely to cause damage to buildings.

5.3 Market activity

Of course dynamics in transacted market prices are only part of the story, as investor concerns will also play out via market liquidity. In particular, where investors are increasingly concerned about physical risk it could become increasingly difficult for owners to sell exposed buildings at any price. While our data do not allow us to measure market liquidity via metrics such as bid-ask spreads, we can examine changes in market activity in the markets for high and low risk buildings. In a scenario where there is falling liquidity in the market for high risk buildings and owners of high risk buildings are increasingly struggling to find buyers, we would expect the share of total market activity occurring in the high risk part of the market to decrease due to longer selling times or failed attempts to sell buildings. Indeed, in their study of liquidity and climate risk in residential real estate markets, Turnbull et al. (2013) use the time taken to sell properties to gauge changes in market liquidity.

In Figure 3 we showed that the share of transacted buildings with high risk scores is stable over the period studied. This suggests that we have not seen a rapid decline in liquidity in the market for higher risk buildings. However, as previously, it is important to account for potential confounding factors before drawing any such conclusions. For example, broader economic factors could drive market activity towards countries which happen to have lower or higher physical risk scores. We run a simple logit regression to account for this. Our dependent variable is a dummy which equals one if a given transacted building has at least one physical risk score of high or red flag and zero if the building does not meet this criteria.[10] We regress this on dummies which equal one if a building is in the CBD, dummies for each euro area country and dummies for each year in our sample. We also control for regional GDP per capita.

$$physicalrisk_{i,j,t} = \alpha + \beta_1 year_t + \beta_2 country_j + \beta_3 CBD_j + \beta_4 gdppercapita_{j,t} + \epsilon_{i,j,t} \quad (3)$$

[10]This is the same construction as the variable we used in our pricing regressions.

Table 2: Examining pricing for the average score of individual hazards in a region shows increased penalties for exposure to heat stress and rising sea levels over the period examined

Model:	Heat (1)	Sea level (2)	Water stress (3)	Floods (4)	Wildfire (5)	Earthquakes (6)
Variables						
CBD	0.48***	0.48***	0.48***	0.48***	0.48***	0.48***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
GDP per capita	2.15***	2.15***	2.15***	2.16***	2.14***	2.14***
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
Heat stress	0.11*					
	(0.06)					
Heat stress × Final years	-0.12***					
	(0.04)					
Sea level rise		0.10**				
		(0.04)				
Sea level rise × Final years		-0.20**				
		(0.08)				
Water stress			0.01			
			(0.06)			
Water stress × Final years			0.03			
			(0.05)			
Floods				-0.03		
				(0.05)		
Floods × Final years				-0.02		
				(0.04)		
Wildfire					-0.15***	
					(0.04)	
Wildfire × Final years					-0.04	
					(0.07)	
Earthquakes						-0.07
						(0.05)
Earthquakes × Final years						0.01
						(0.05)
Fixed-effects						
Year	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	20,835	20,835	20,835	19,987	20,835	20,835
R^2	0.49282	0.49239	0.49229	0.49787	0.49278	0.49243
Within R^2	0.28696	0.28637	0.28622	0.29076	0.28690	0.28641

Clustered (postal_code) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Note: Dependent variable is log of price per square foot. High risk dummies are now based on the average value of that risk in the building's postal code/ city. The risk dummies equal 1 if the relevant hazard in that region has an average score of at least 'High'. CBD is a dummy which equals one when an office is in a physical risk district. Data covers 2007-2022. Final years dummy equals 1 for the final two years of the sample.

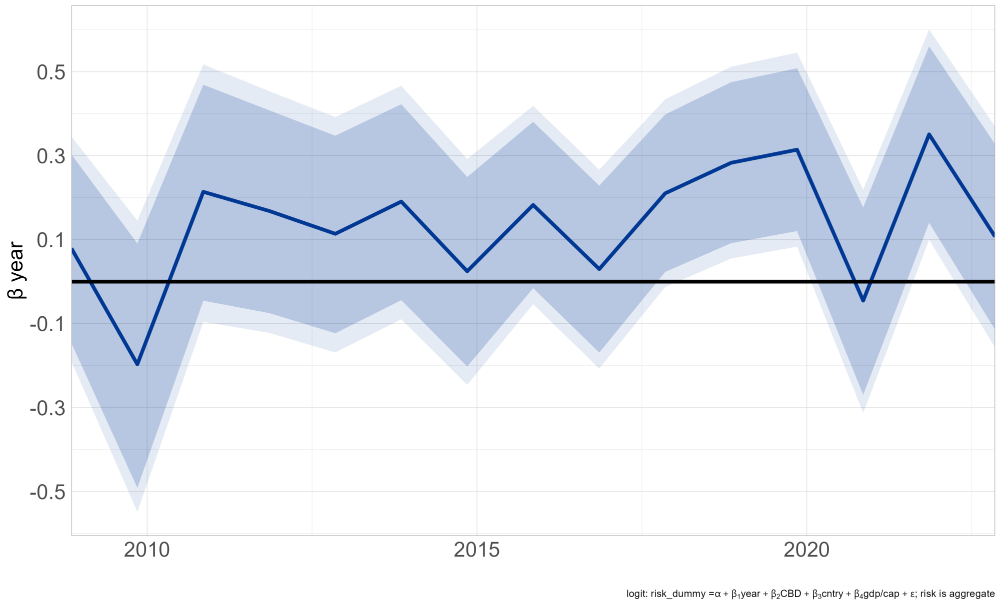
Table 3: Examining pricing for the maximum score of individual hazards in a region shows increased penalties for exposure to floods and wildfires over the period examined

Model:	Heat (1)	Sea level (2)	Water stress (3)	Floods (4)	Wildfire (5)	Earthquakes (6)
Variables						
CBD	0.47***	0.48***	0.46***	0.48***	0.48***	0.48***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)
GDP per capita	2.09***	2.14***	2.02***	2.15***	2.15***	2.15***
	(0.14)	(0.14)	(0.13)	(0.14)	(0.14)	(0.14)
Heat stress	0.20***					
	(0.08)					
Heat stress × Final years	-0.05					
	(0.04)					
Sea level rise		0.08***				
		(0.03)				
Sea level rise × Final years		-0.04				
		(0.04)				
Water stress			0.22***			
			(0.04)			
Water stress × Final years			0.05*			
			(0.03)			
Floods				0.03		
				(0.03)		
Floods × Final years				-0.05*		
				(0.03)		
Wildfire					0.01	
					(0.05)	
Wildfire × Final years					-0.11*	
					(0.06)	
Earthquakes						-0.39***
						(0.13)
Earthquakes × Final years						0.08
						(0.13)
Fixed-effects						
Year	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics						
Observations	20,835	20,835	20,835	19,987	20,835	20,835
R^2	0.49720	0.49295	0.50467	0.49802	0.49236	0.49275
Within R^2	0.29312	0.28714	0.30362	0.29097	0.28631	0.28686

Clustered (postal_code) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Note: Dependent variable is log of price per square foot. High risk dummies are now based on the maximum value of that risk in the building's postal code/ city. The risk dummies equal 1 if the relevant hazard in that region has a maximum score of at least 'High', with the exception of Flooding where we show results for the dummy equalling 1 with a score of Red Flag only. CBD is a dummy which equals one when an office is in a physical risk district. Data covers 2007-2022. Final years dummy equals 1 for the final two years of the sample.

Figure 8: We find no evidence of major changes in the likelihood of a given transacted building being exposed to physical risk over time



Note: Line shows coefficients on *year* dummies terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as difference in likelihood of a given office transaction occurring in a low vs. high risk region between 2007 and the year shown. Full results can be found in the Appendix.

This time our coefficients of interest are those of the year dummies, as they will tell us whether the likelihood of a given transaction being in physical risk area varied over time, accounting for key confounding factors. If it is becoming increasingly difficult to sell a building with a high level of physical risk we would expect the coefficients to decrease in size over time. We find that coefficients are typically insignificant (Figure 8). This suggests that while investors' concerns regarding physical risk may be affecting market pricing, this has occurred in an orderly manner, with limited implications for liquidity in the market for higher risk buildings.

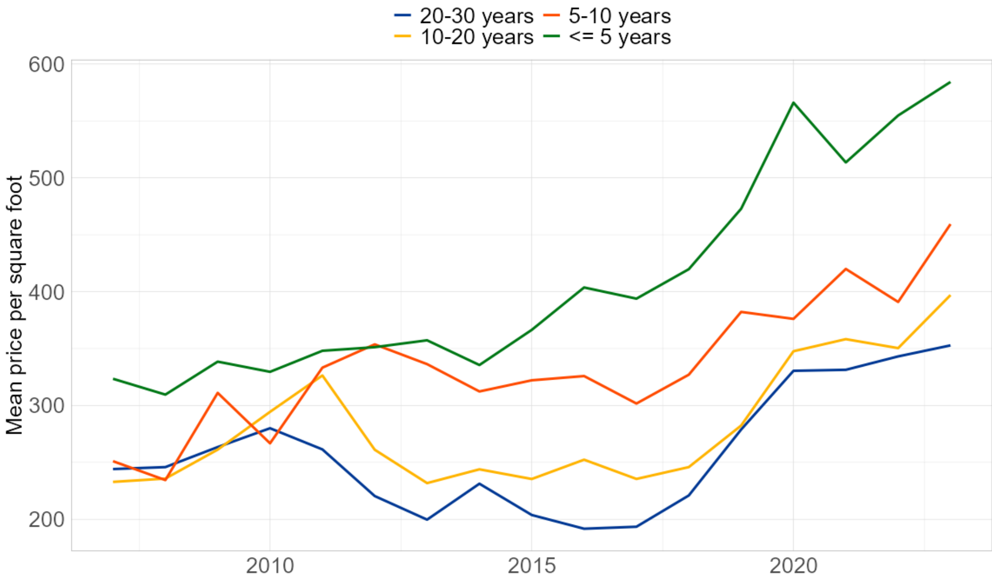
Taking this together with our findings regarding market pricing, this suggests that markets are able to identify buildings exposed to physical climate risk and that since approximately 2012 this has been consistently accounted for these risks in pricing. Stable market activity for high risk buildings also suggests that, while investors are increasingly aware of climate risks, this has not disrupted market functioning, allowing for a gradual transition to incorporating climate risks into office prices.

6 Transition risk

6.1 Descriptive statistics

As before, we examine key descriptive statistics in our data set before moving on to regression analysis. First we track average transacted prices for euro area offices across a range of age brackets. As we would expect Figure 9 shows clear premia for younger buildings across the full time series examined.[11] Moreover, this initial examination does point to variation in the premium over time, with the spread between the under five year and the five to ten year brackets widening significantly in the later years of our sample.

Figure 9: Average transacted prices show a growing spread between buildings younger than 5 years and the rest of the sample over the final years of the studied period

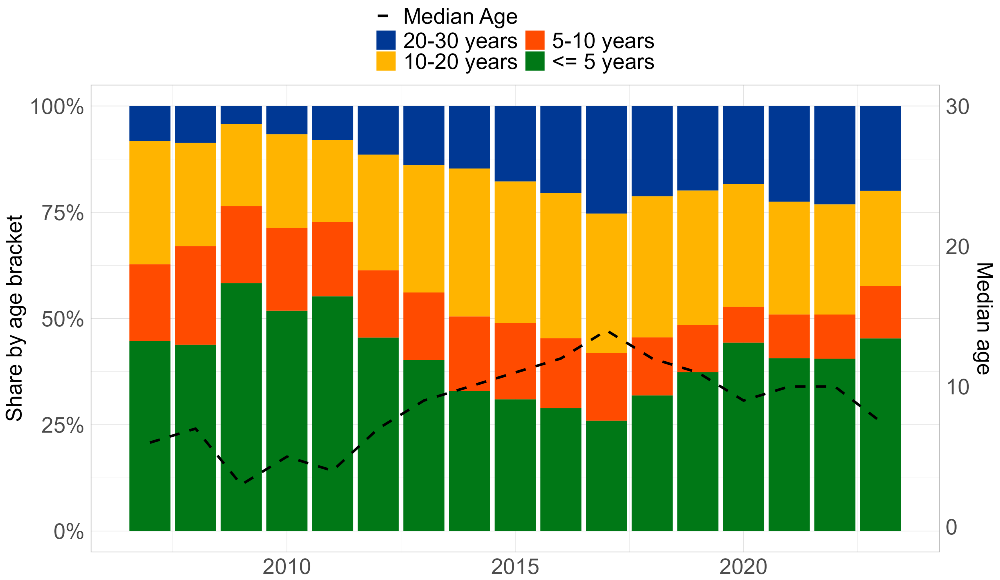


Note: Lines show simple averages of transacted prices split across building age brackets. Buildings with more than 30 years since their last renovation or construction date are removed from the sample as it is highly likely this is the result of missing renovation data.

Next we look at the share of market activity coming from each age bracket. In Figure 10 we see a modest but steady fall in the median age of transacted buildings starting in 2017, about the time that we start to see the spread between the youngest buildings and all other buildings widen in Figure 9. Again this trend is driven by an increased share of buildings in the youngest age bracket. Of course in this case a crucial driver of this dynamic could also be aggregate construction activity, where we would expect rising construction of new buildings to lead to a bigger share of young buildings in total transactions. Indeed we see the highest share of young buildings transacting at the start of our sample, which could be driven by the high aggregate construction in the years prior to the GFC. This share drops steadily in the years following the GFC, possibly driven by the sharp slump in construction activity over these years.

[11]The relatively consistent ordering of these series over time - i.e. the older buildings are cheaper - indicates that we are accurately capturing their quality despite missing renovation data in many cases.

Figure 10: In the final years of our sample we see a declining median age in transacted buildings due to a rise in the share of buildings younger than 5 years in total transaction activity



Note: Stacked bars show the share of market activity by each age bracket and dotted line shows median age (rhs y axis). Buildings with more than 30 years since their last renovation or construction date are removed from the sample as it is highly likely this is the result of missing renovation data.

6.2 Market pricing

While these descriptive charts are a useful first step, again they are subject to a range of potential confounding factors. For example, variation over time in the price of buildings in a given age bracket could also reflect an increased share of market activity occurring in countries where buildings happen to be both more expensive and younger. It could also reflect an increasing share of market activity focusing on the "prime" end of the market, where buildings are newer but are also located in central business districts (CBDs) and are therefore more expensive. Aggregate construction levels may also play a role.

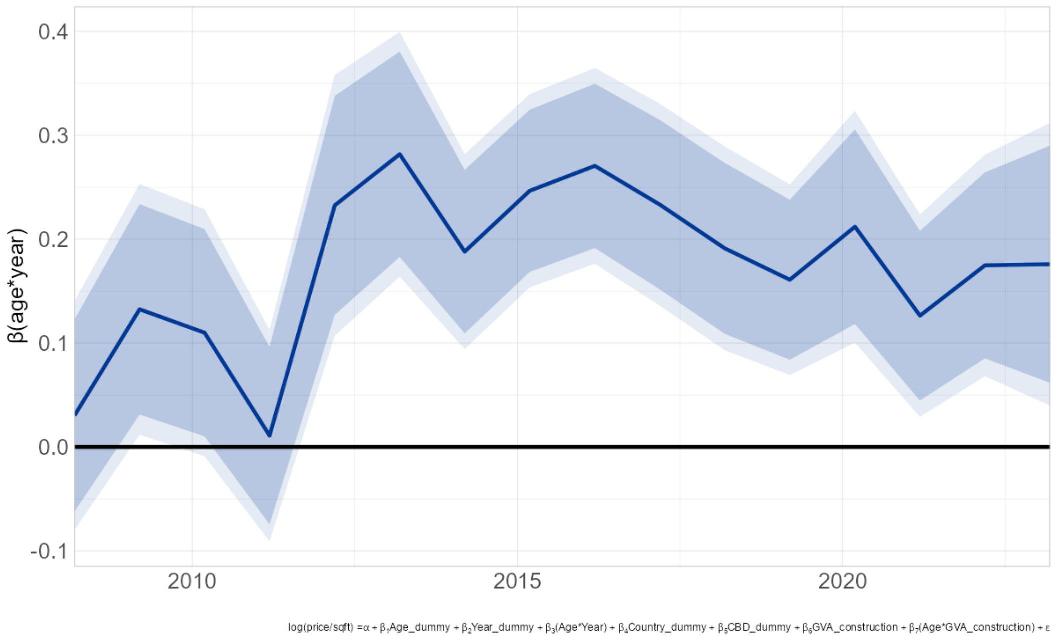
We apply a similar regression method to that used in examining physical risk. In Equation 4 we regress log of price per square foot on a range of fixed effects which should affect a building's price in addition to its age. As before these include include year fixed effects which should capture the overall trend in price growth over time, country fixed effects to capture variation in prices across the euro area and a dummy which equals one if the building is in the central business district. We then enter our *age* dummy. Figure 9 indicates that market pricing may focus in particular on assigning a premium to buildings younger than five years, so we enter age as a dummy which equals one if a building falls into that age bracket and zero otherwise. We continue to exclude all buildings with age greater than 30 from our data set and again it should be noted that our age variable is the number of years since the building's last renovation or - when renovation data is not available - the number of years since its construction.

Unlike in our analysis of physical risks, finding that a premium is associated with younger buildings will not necessarily tell us much about the market's perspective on transition risks. While we do know there is a strong correlation between building age and energy efficiency (ONS, 2022), there are many other - non-climate related - reasons why young buildings are generally cheaper than old buildings. However, we argue that a rising premium over time may reflect increased pricing of transition risk, as investors increasingly apply a premium to energy efficient buildings due to concerns about climate legislation. As before we test this by interacting our age dummy with year dummies. These interaction coefficients are our coefficients of interest: If market participants are increasingly penalising old buildings over time then we would expect the premium for a young building with lower climate transition risk to rise in the final years of our analysis.

$$\begin{aligned} log(pricesqm_{i,t}) &= \alpha + \beta_1 year_t + \beta_2 country_j + \beta_3 age_{i,t} + \beta_3 age_{i,t} * year_t \\ &+ \beta_4 constructiongva_{i,t} + \beta_5 constructiongva_{i,t} * age_t + \beta_6 CBD_i + \epsilon_{i,t} \end{aligned} \tag{4}$$

We also want to account for the role of new construction in driving the spread between the price of new and old buildings. We do this using the average share of economic activity (GVA) in a given year in a given country, coming from the construction sector as this variable is available for our full time series and all countries in our sample. We enter this as a control variable on its own - to account for the effect of rising supply on prices in general - and as an interaction with our age dummy - to account for the effect of rising supply on the spread in prices between new and old buildings.[12]

Figure 11: Age*year interactions show an increase in the premia associated with young buildings since 2007



Note: Line shows coefficients on *age*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in premia associated with an office being less than five years old between 2007 and the year shown. Full results can be found in the Appendix.

[12] Results suggest that this construction control is effective: In years with higher construction the spread between the price of new and old buildings narrows (see results in table form in Annex).

Coefficients for the *age*year* interactions are shown in Figure 11 along with their 90% and 95% confidence intervals. As before results are available in table format in the paper's Annex. Figure 11 shows typically significant positive results from 2012 onward, indicating that the premium associated with younger buildings has increased over the period studied. Indeed the coefficient for the 2023 interaction term indicates that the spread between young and old buildings is 18pps higher in 2023 than it was in 2007.

The similarity in timing is across these results and our physical risk results is particularly striking, with both effects becoming significant from 2012 onwards. We run simple bivariate regressions and find no correlation between our age dummy and our physical risk dummy - suggesting that this is not a case of buildings in high risk areas also being younger. Instead, investors appear to have simultaneously begun applying discounts to buildings which are exposed to physical climate risks and to buildings which are exposed to climate transition risks during the years leading up to the Paris Agreement.

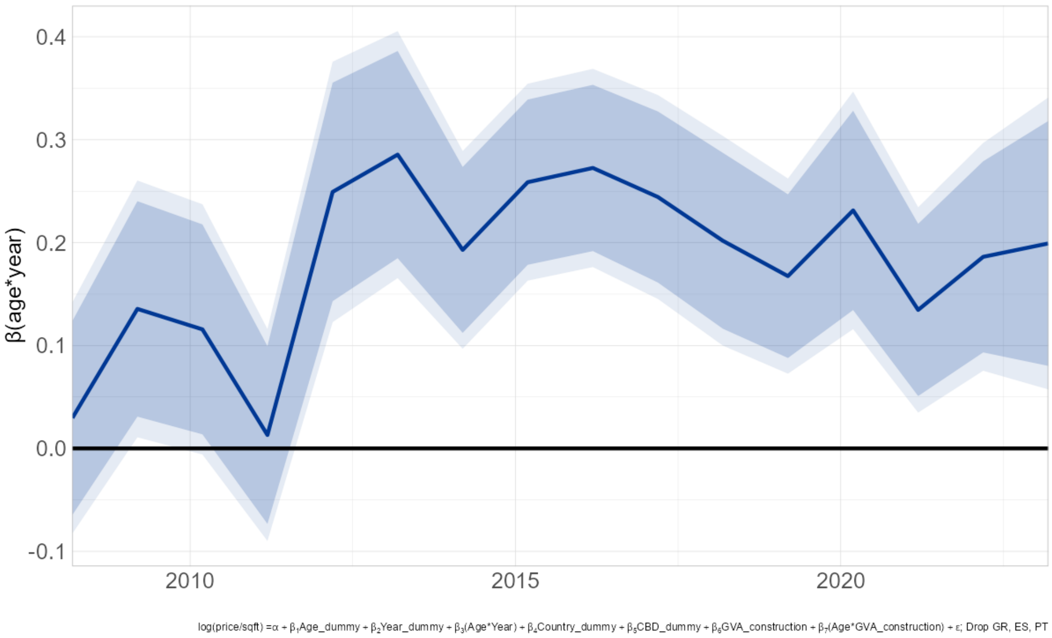
As with physical risk the mean estimate of the premium actually decreases by about 6pps between its peak and the end of the sample we study. We find this particularly surprising given the intensification of climate legislation in recent years and the real estate industry's clear concerns regarding implications for older buildings. First - as before - we check if the 2013 spike is being driven by a rise in market risk aversion in the years following the sovereign debt crisis. This dynamic could lead to a flight to quality and reduce demand for older buildings, particularly in countries most associated with the sovereign debt crisis. We repeat our analysis without countries most affected by the sovereign debt crisis and find that our results are largely unchanged (Figure 12). We also re-run our analysis both controlling for VSTOXX and interacting VSTOXX with our age dummy, this should account for intra-year variation in risk aversion while our year dummies account for changes in average market risk aversion over the course of our sample. Again there are no changes in coefficients for our *age*year* dummies (see table in Appendix).

We also add a time interaction to our CBD dummy to ensure that the rising premium on centrally located buildings (which may also be newer) is not driving our result. Again we find a rapidly rising premium on CBD buildings towards the end of our sample. We do find some effect on our *age*year* coefficients, with this trend appearing to account for some of the increase in age premium seen in 2023.

Finally, we allow for the fact that variation in heating costs may play a major role in driving the premium associated with new and therefore more energy efficient buildings. We add annual growth in national heating costs - taken from the ECB's Statistical Data Warehouse - as a control variable and as an interaction with our age dummy.[13] Again, we find no change in results regarding the remaining premium linked to young buildings over time (Figure 14).

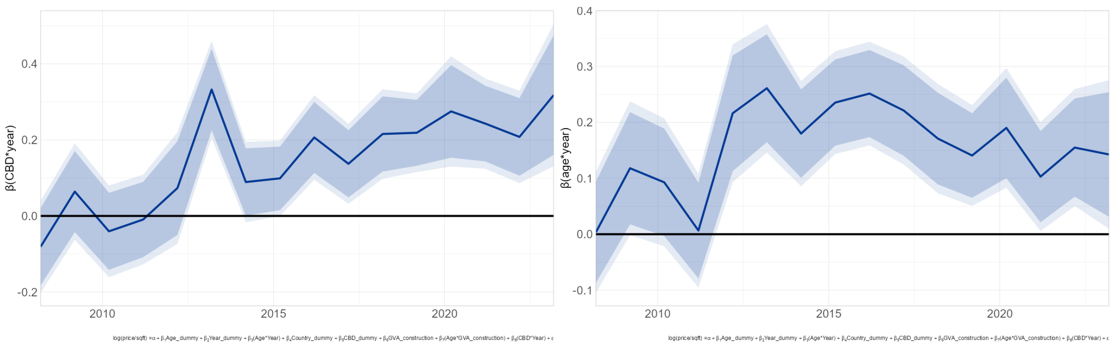
[13]This comes from the Indices of Consumer Prices data set and can be found using series key ICP.A.?.N.045000.4.AVR

Figure 12: This finding is largely unchanged by removing countries most closely associated with the sovereign debt crisis



Note: Line shows coefficients on *age*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in premia associated with an office being less than five years old between 2007 and the year shown. Full results can be found in the Appendix.

Figure 13: We see a sharp increase in premia for CBD offices but this does not affect our overall result

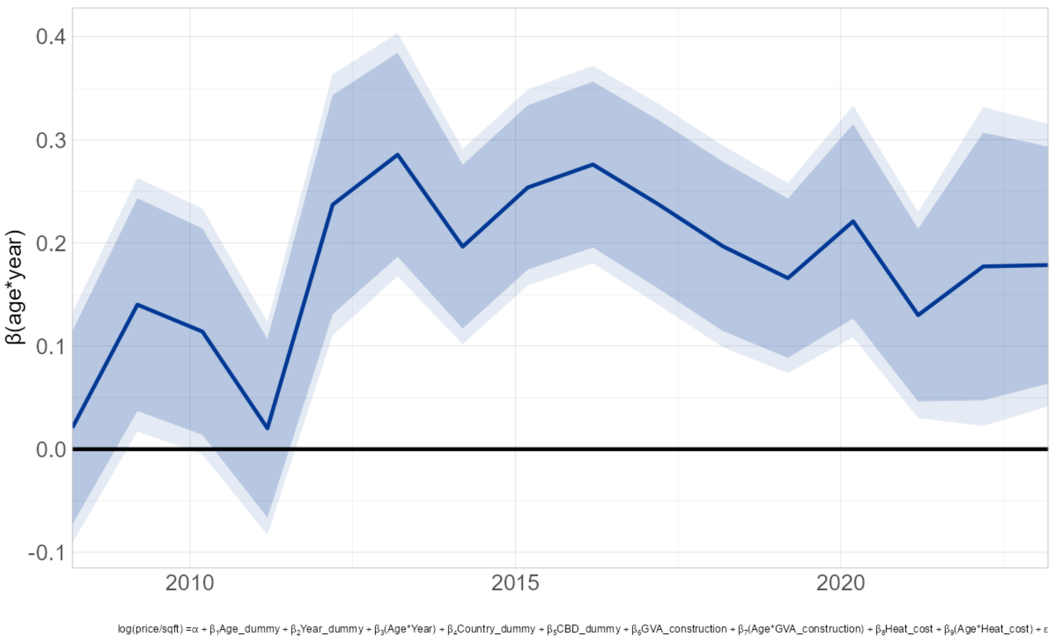


Note: Line shows coefficients on *CBD*year* and *age*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in premia associated with an office being less than five years old/ in a central business district between 2007 and the year shown. Full results can be found in the Appendix.

6.3 Market activity

To examine the implications of transition risk concerns for market liquidity, we repeat our earlier exercise in relation to physical risk. This time the dependent variable for our logit model is a dummy which equals 1 when a given transaction relates to a building with age below five and zero

Figure 14: Including heating costs as a control does not affect our results



Note: Line shows coefficients on *age*year* interaction terms and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the percentage point change in premia associated with an office being less than five years old between 2007 and the year shown. Full results can be found in the Appendix.

when age is above 5.[14] We include fixed effects for country, year and CBD and the share of GVA coming from construction. As before we plot coefficients for *year* as our coefficient of interest. If it is becoming increasingly difficult to sell old buildings - i.e. a higher share of transaction activity is young buildings - we would expect this coefficient to rise for the final years of our sample.

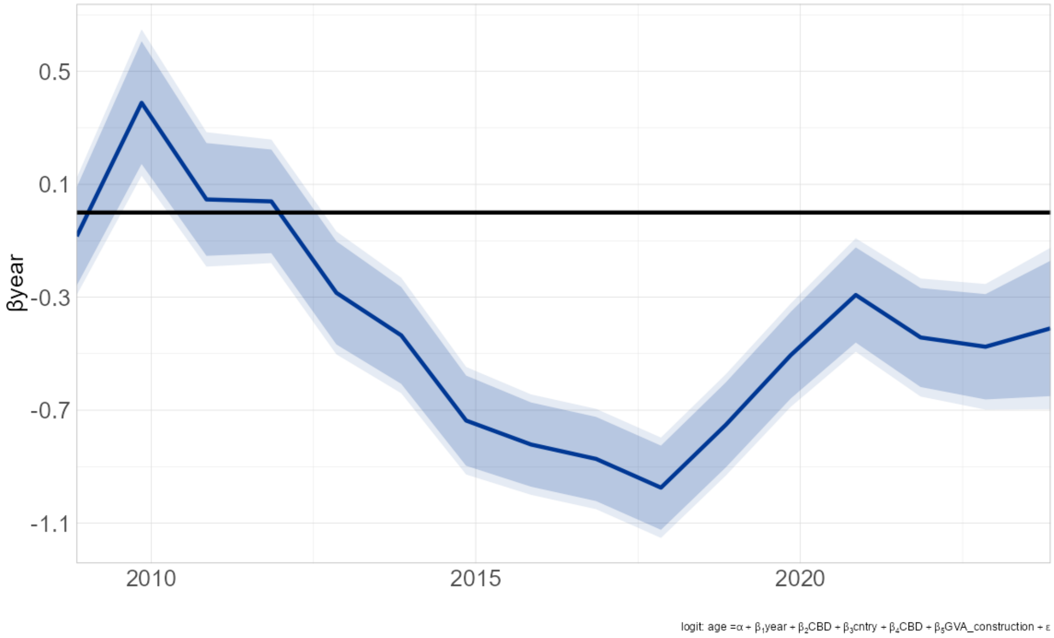
$$age_{i,t} = \alpha + \beta_1 year_t + \beta_2 country_j + \beta_3 CBD_i + \beta_4 constructiongva_i + \epsilon_{i,t} \qquad (5)$$

Unlike our physical risk analysis, we do find a sharp increase in coefficient size from 2018 onwards (Figure 15). This means that market activity has shifted towards younger assets in the final years of our sample, even when we hold other factors equal and account for the supply of new buildings via construction activity. This contrasts with the 2013 period when we saw a rising discount applied to old buildings (rising price premium for young buildings) but also a relatively greater increase in trading activity of old buildings compared to their younger counterparts.

This suggests that the "stranded asset" problem arising from transition risk may already be beginning to take hold in euro area CRE markets. Indeed market activity levels for CRE markets in general have dropped to record low levels since the beginning of the ECB's rate hike cycle (see Ryan et al. (2023)). If this is coupled with a shift towards young buildings in the remaining transaction activity as shown in Figure 15, building owners are likely facing extreme difficulty in selling these assets.

[14] As before this is the same variable we used for *age* in pricing regressions.

Figure 15: The final years of our sample show an increasing likelihood of transacted buildings being young



Note: Line shows coefficients on *year* dummies and shaded areas show 90 and 95 per cent confidence intervals. Coefficients can be interpreted as the change in likelihood of a given transacted office being less than 5 years old between 2007 and the year shown. Full results can be found in the Appendix.

Moreover, the literature on real estate market liquidity and pricing emphasises that large negative shocks to real estate values typically play out via first a sharp drop in market activity and then an adjustment in prices. This occurs because it takes longer for sellers to revise down ask prices than for buyers to revise down their bid prices (Fisher et al., 2003, 2007; van Dijk et al., 2022). Thus this drop in market activity may be delaying the price premium rise we expected to see at the end of our sample.

7 Conclusion

Our paper has provided the first study of climate risk pricing in euro area commercial real estate (CRE) markets. We have shown that exposure to both physical and transition risks is significant. We have found evidence of investors applying a penalty to buildings exposed to physical climate risks and that this penalty has increased over time. By 2022 the discount had increased by 24pps compared to 2007 and this appears to have occurred without disrupting market functioning, as we have not seen any significant changes in the share of market activity related to high risk buildings. Gradual and orderly pricing of these risks may help alleviate the macroeconomic and financial stability effects of these changes, by reducing uncertainty and providing market participants with adequate time to prepare for change.

In contrast, while we do find increased pricing of transition risk since 2007, towards the end of our sample the market response appears to be playing out via liquidity, suggesting that older buildings may already be at risk of becoming "stranded assets".

Our work aims to provide an initial study of what we think is a rich and important topic, assessing exposure to risks and investigating whether there is evidence of risk pricing and if it has changed over time. An important topic for future research is assessing whether or not these risks are adequately or "fully" priced. This will require more precise estimates of risk pricing and of risks themselves. Due to the complexity of such an exercise it remains a topic for another paper. Such an analysis will also require further developments in data used to measure risk exposure and its variation over time. In particular, while we have carried out our transition risk analysis using building age as a proxy for energy efficiency, the absence of widely available data on the stock of buildings with low energy efficiency ratings remains a serious data gap which needs to be filled, given the risks faced by this part of the market.

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9 Annex

Table 4: Physical risk pricing regression results table format

Model:	Baseline (1)	Drop sov. crisis (2)	VSTOXX (3)	CBD*Time (4)	No GDP/pop controls (5)
Variables					
High risk	0.11***	0.14***	0.16***	0.11***	0.11**
	(0.04)	(0.04)	(0.06)	(0.04)	(0.05)
GDP per capita	2.16***	2.17***	2.16***	2.16***	
	(0.15)	(0.15)	(0.15)	(0.15)	
CBD	0.49***	0.49***	0.49***		0.52***
	(0.04)	(0.04)	(0.04)		(0.04)
GDP growth	-0.01***	-0.01***	-0.01**	-0.01***	
	(0.00)	(0.00)	(0.00)	(0.00)	
Pop. growth	-0.03	-0.04*	-0.03	-0.02	
	(0.02)	(0.02)	(0.02)	(0.02)	
House price growth	0.01***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High risk × year2008	-0.01	-0.10	0.02	0.00	-0.03
	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)
High risk × year2009	-0.13**	-0.18**	-0.10	-0.13**	-0.14**
	(0.06)	(0.08)	(0.07)	(0.06)	(0.06)
High risk × year2010	-0.07	-0.09	-0.04	-0.07	-0.12**
	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)
High risk × year2011	-0.02	-0.02	0.01	-0.03	-0.06
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
High risk × year2012	-0.26***	-0.29***	-0.25***	-0.27***	-0.23***
	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)
High risk × year2013	-0.38***	-0.35***	-0.38***	-0.38***	-0.43***
	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)
High risk × year2014	-0.23***	-0.18***	-0.22***	-0.22***	-0.22***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
High risk × year2015	-0.18***	-0.23***	-0.16***	-0.18***	-0.20***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
High risk × year2016	-0.25***	-0.25***	-0.25***	-0.25***	-0.28***
	(0.05)	(0.07)	(0.05)	(0.05)	(0.05)
High risk × year2017	-0.12**	-0.16***	-0.13**	-0.11**	-0.15***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
High risk × year2018	-0.10**	-0.18***	-0.10**	-0.10**	-0.18***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
High risk × year2019	-0.19***	-0.19***	-0.20***	-0.19***	-0.26***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
High risk × year2020	-0.19***	-0.20***	-0.15**	-0.18***	-0.27***
	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
High risk × year2021	-0.11**	-0.13**	-0.11**	-0.11**	-0.20***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
High risk × year2022	-0.24***	-0.22***	-0.21***	-0.23***	-0.33***
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
VSTOXX			0.00*		
			(0.00)		
High risk × VSTOXX			0.00		
			(0.00)		
High risk × year2023					-0.33***
					(0.06)
Fixed-effects					
Year	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes	Yes
CBD x Year				Yes	
Fit statistics					
Observations	20,835	19,538	20,835	20,835	23,457
R^2	0.49669	0.50410	0.49694	0.50276	0.43870
Within R^2	0.29240	0.29506	0.29276	0.15136	0.16814

Clustered (Postal code) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 5: Transition risk pricing results in table format

	Baseline (1)	Drop GR, ES, PT (2)	Age x VSTOXX (3)	CBD x Time (4)	Time x Heat. costs (5)
age ($\leq 5 years$)	0.19***	0.20***	0.14***	0.20***	0.19***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
CBD	0.48***	0.48***	0.48***		0.47***
	(0.04)	(0.04)	(0.04)		(0.04)
Construction GVA (%)	0.02***	0.02***	0.02***	0.02***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
age ($\leq 5 years$)× year2008	0.03	0.03	-0.01	0.00	0.02
	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
age ($\leq 5 years$)× year2009	0.13**	0.14**	0.10	0.12*	0.14**
	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
age ($\leq 5 years$)× year2010	0.11*	0.12*	0.09	0.09	0.11*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
age ($\leq 5 years$)× year2011	0.01	0.01	-0.02	0.01	0.02
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)
age ($\leq 5 years$)× year2012	0.23***	0.25***	0.22***	0.22***	0.24***
	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
age ($\leq 5 years$)× year2013	0.28***	0.29***	0.28***	0.26***	0.29***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
age ($\leq 5 years$)× year2014	0.19***	0.19***	0.18***	0.18***	0.20***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2015	0.25***	0.26***	0.23***	0.24***	0.25***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2016	0.27***	0.27***	0.26***	0.25***	0.28***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2017	0.23***	0.24***	0.24***	0.22***	0.24***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2018	0.19***	0.20***	0.19***	0.17***	0.20***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2019	0.16***	0.17***	0.17***	0.14***	0.17***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2020	0.21***	0.23***	0.17**	0.19***	0.22***
	(0.06)	(0.06)	(0.07)	(0.05)	(0.06)
age ($\leq 5 years$)× year2021	0.13**	0.13***	0.12**	0.10**	0.13**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
age ($\leq 5 years$)× year2022	0.17***	0.19***	0.15***	0.15***	0.18**
	(0.05)	(0.06)	(0.06)	(0.05)	(0.08)
age ($\leq 5 years$)× year2023	0.18**	0.20***	0.18***	0.14**	0.18**
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
age ($\leq 5 years$)× Construction GVA (%)	-0.01***	-0.01***	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
VSTOXX			0.00**		
			(0.00)		
age ($\leq 5 years$)× VSTOXX			0.00		
			(0.00)		
Heating cost growth					0.00
					(0.00)
age ($\leq 5 years$)× Heating cost growth					0.00
					(0.00)
R^2	0.47045	0.47376	0.47077	0.47525	0.47034
Observations	14,721	14,130	14,718	14,670	14,670
Country fixed effects	✓	✓	✓	✓	✓
Year fixed effects	✓	✓	✓	✓	✓
CBD x Year fixed effects				✓	

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 6: Results from market activity logit regressions

	Physical risk (1)	Transition risk (2)
year2008	0.08	-0.08
	(0.08)	(0.27)
year2009	-0.20***	0.39
	(0.05)	(0.28)
year2010	0.21**	0.05
	(0.09)	(0.22)
year2011	0.17***	0.04**
	(0.04)	(0.02)
year2012	0.11***	-0.28
	(0.02)	(0.19)
year2013	0.19*	-0.44***
	(0.11)	(0.05)
year2014	0.02***	-0.74***
	(0.01)	(0.09)
year2015	0.18***	-0.82***
	(0.01)	(0.07)
year2016	0.03	-0.87***
	(0.07)	(0.06)
year2017	0.21***	-0.97***
	(0.00)	(0.14)
year2018	0.28	-0.75***
	(0.19)	(0.19)
year2019	0.31***	-0.51***
	(0.07)	(0.13)
year2020	-0.05***	-0.29***
	(0.00)	(0.08)
year2021	0.35***	-0.44**
	(0.04)	(0.20)
year2022	0.11	-0.48**
	(0.08)	(0.19)
year2023		-0.41
		(0.36)
GDP per capita	-1.88	
	(1.43)	
Constr. activity		0.01
		(0.02)
Observations	21,300	15,143
CBD fixed effects	✓	✓
Country fixed effects	✓	✓

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

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