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White Paper

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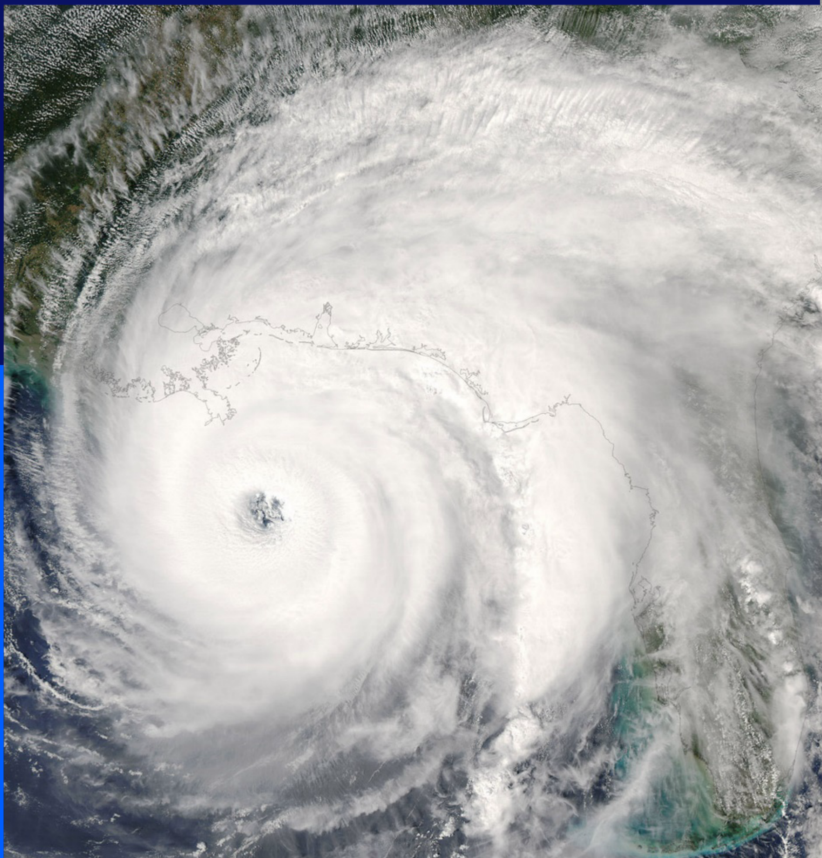
Resilience Under Adversity: Quantifying Physical Risk for U.S. Commercial Real Estate Lending



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PHYSICAL RISK IMPACT FOR CRE

Commercial real estate (CRE) loans represent a larger proportion of bank portfolios and have seen heightened demand in recent years. At the same time, this growth has coincided with a notable rise in physical risks such as wildfires, floods, and other extreme events that can negatively impact the CRE sector. Unlike other asset classes, CRE is uniquely vulnerable to the effects of both economic downturns (through indirect channels such as rising vacancies and lower rent growth) and natural disasters (with the direct impact of physical damage from climate events decreasing values and adding costs to the bottom line). For example, a wildfire can destroy the underlying collateral, resulting in immediate losses for lenders. Similarly, rent growth can stagnate while vacancies rise in markets deemed to be consistently exposed to natural disasters. The United States faces an estimated $6 trillion in cumulative economic losses of GDP from physical risks by 2050. In Southern California alone, the 2017–2019 wildfire seasons resulted in approximately $20 billion in insured losses on assets for the state's property and casualty insurers, emphasizing the scale of potential exposure we could see under a lender lens for those with CRE holdings in high-risk regions.

$6T

Cumulative economic losses in the US from physical risk by 2050

$20b

Property and causality insurer's loss from 2017-2019 wildfires in Southern California

Given the significance of CRE in lending portfolios and the scale of the financial stakes involved, it is critical to quantify these risks, identify their sources, and develop strategies to increase resilience in the sector. In doing so, we contribute to a 'common language of risk' that enables the financial sector to communicate effectively and efficiently on the full range of potential exposures and to innovative solutions for risk transfer, adaptation, and mitigation.

In the analysis that follows we examine a representative loan portfolio and dive into case studies based on cross-sectional data. We find that incorporating physical risk into credit assessments produces notable deterioration in portfolio performance. At a high-level, physical risk damage, in aggregate, leads to an increase in lifetime probability of default by nearly 18% and an increase in expected loss of more than 22% resulting in an additional $270 million in balance lost. We provide a deeper understanding of the composition of CRE loans and the factors that contribute to their risk; highlighting characteristics that distinguish stronger assets from those more vulnerable to natural disasters. We saw a larger increase in risk for geographically homogeneous portfolios in high-risk metros like Tampa and New Orleans. These findings reinforce the need for lenders to integrate climate analytics into portfolio management to strengthen resilience and mitigate long-term financial impacts.

MODELING INPUTS

Climate Damage Assessment

Moody's specializes in quantifying the risks associated with acute and chronic climate-related events on facilities and their operations through a robust modeling framework. Moody's suite of physical risk analytics generates highly granular risk and loss metrics which are calculated based on the sensitivity of properties to these risks taking into account their geographical location and other contextual factors. One key metric is the Annualized Damage Rate (ADR), or the average expected damage as a ratio of annual damage cost due to specific physical risks to the total value of exposed assets. This metric provides a clear view of the anticipated impact of physical risk in any given year for any location, enabling the precise assessment of environmental threats at the property level. In our analysis below, we use the location-level ADR as a 'haircut' applied to the net operating income (NOI) of individual CRE assets under a baseline scenario, thereby reflecting the impact of physical risk on the income generating capacity of such assets. The Moody's physical risk analytics provide insight on potential impact of natural disasters and chronic physical risks associated with a range of perils—such as floods, hurricanes, wildfires, sea level rise, water stress, and heat stress—allowing for a comprehensive quantification of risk across many types of natural disaster.

CRE Credit Risk Framework

We leverage the Moody's Commercial Mortgage Metrics (CMM™) modeling framework to assess physical risk in CRE credit quality across portfolios by comparing baseline and scenario-driven projections. CMM quantifies credit risk for CRE loans by integrating property performance forecasts with commercial mortgage fundamentals. It calculates key risk measures such as Expected Default Frequency (EDF™) and Loss Given Default (LGD) within a consistent framework. These metrics are structurally correlated and consistently estimated by modeling the conditional probability of default and loss given default over various future NOI and market value paths. The platform supports detailed risk analytics, stress testing, and loss provision calculations for CRE portfolios across property types such as multifamily, retail, industrial, office, and hotel. Additionally, the modeling framework accommodates a wide range of loan instrument structures enabling the analysis of single loan and single property deals while also allowing us to examine the impact of physical risks in cross-collateralized loans as well. The models are built on a proprietary database with historical loan default information and the platform leverages market-specific data, including vacancy rates, rent levels, and cap rates, sourced from Moody's CRE. This data enables the analysis of portfolios, properties, and loans under various macroeconomic, interest rate, and real estate scenarios.

Portfolio Selection

For this analysis, we used a diverse set of CRE loans sourced directly from internal historical performance datasets:

→ Moody's CRE Data Alliance: Contains loan-level details from participating financial institutions' holdings. Currently, more than 20 banks and insurance companies participate in the CRE Data Alliance, which includes over 100,000 loans and 160,000 properties, covering 53 states and 362 Metropolitan Statistical Areas (MSA).

→ Moody's CMBS dataset is one of the largest commercially available databases covering the CMBS universe. The database contains comprehensive information and historical performance metrics on the properties that serve as collateral within the CMBS transactions.

We processed recent snapshots of the two loan datasets comprising over $455 billion in total outstanding balance. The combined snapshots include single loan/single property, single loan/multi-property, multi-loan/single property, and multi-loan/multi-property structures. To ensure data quality and relevance, we exclude loans outside the United States, retaining only those with ZIP codes on Moody's approved list. We further filtered the dataset to include only loans with an ADR plus one-standard-deviation exceeding 0.005 for at least one of the following perils: hurricanes, wildfires, or floods. The final portfolio consists of almost 7,000 records across roughly 5,400 unique loan group combinations, forming the basis for the following analysis. Each observation contains key loan characteristics such as loan-to-value (LTV), debt service coverage ratio (DSCR), outstanding balance, and geographic identifiers.

FIGURES 1 and 2 show the breakdown of outstanding balance by property type and property location in our final dataset. Overall, we've selected a diverse collection of sectors to create a portfolio that is representative of what a bank may have, with multifamily representing the largest share: nearly 30% of total outstanding balance. About a quarter of the balance comes from office properties and about a fifth from retail properties. Only about 6.5% of the properties are industrial, making it the smallest segment of the data. These property ratios align with what is commonly seen in a given portfolio.

There is a strong geographic concentration of Southeastern states, specifically those around the Gulf; the dominant state being Florida, making up about 44% of the outstanding balance in our final portfolio. Texas (~19%) and Louisiana (~3%) also make up a large chunk of outstanding balance. This breakdown is unsurprising, given that coastal cities like Tampa, New Orleans, and Houston have an elevated risk for hurricanes and flooding. In addition, California is the third largest MSA in our final dataset, making up about 7% of the total outstanding balance, likely due to the frequent fires that persist in the state.

FIGURE 1 Outstanding balance by property type

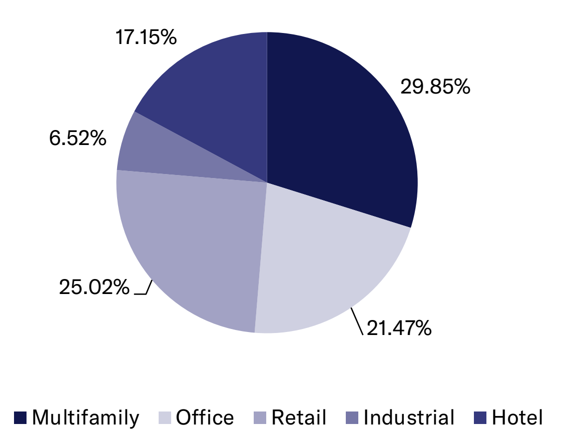
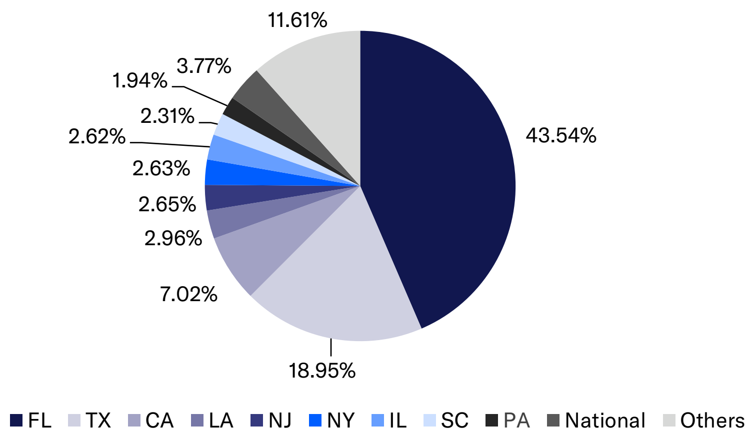


FIGURE 2 Outstanding balance by MSA



The portfolio demonstrates healthy credit characteristics, as seen in FIGURE 3 and FIGURE 4. The median LTV ratio is 53% with very few loans exceeding 70%, suggesting limited exposure to highly leveraged positions. The median debt service coverage ratio is 1.47 with most loans concentrated between 1.2 and 2.0 which is the range considered healthy. Loans with DSCR values below 1.0 would indicate vulnerability and underperformance; however, these loans only make up 2% of our representative portfolio. Additionally, the distribution is right skewed with a large tail of loans exceeding 2.5x, providing them with additional resilience. Overall, both distributions emphasize the portfolio's health under baseline conditions highlighting that potential negative effects in this analysis is likely not due to the credit health of the loan, but rather from direct physical impairments to collateral.

FIGURE 3 Distribution of LTV

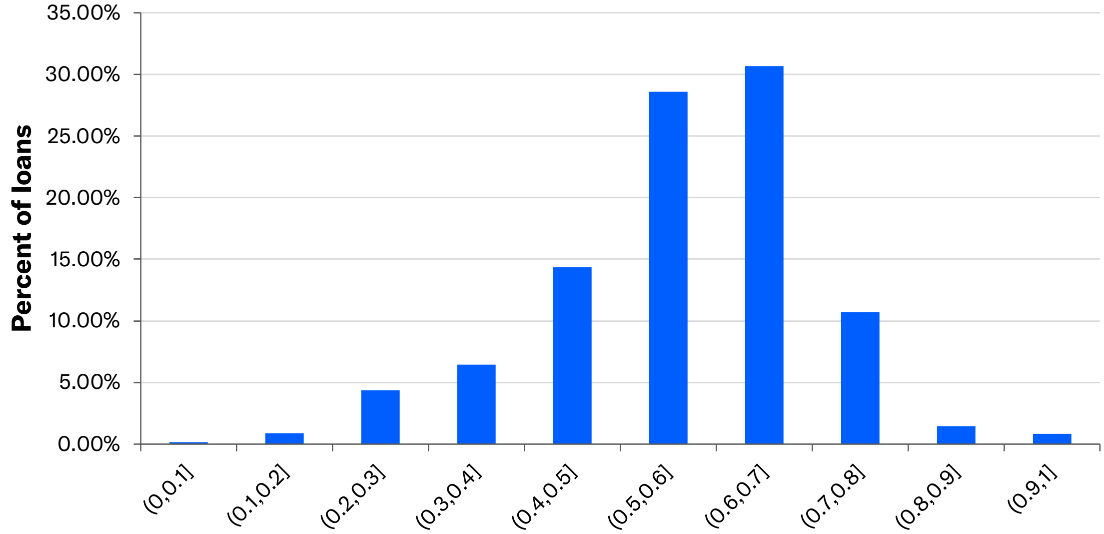
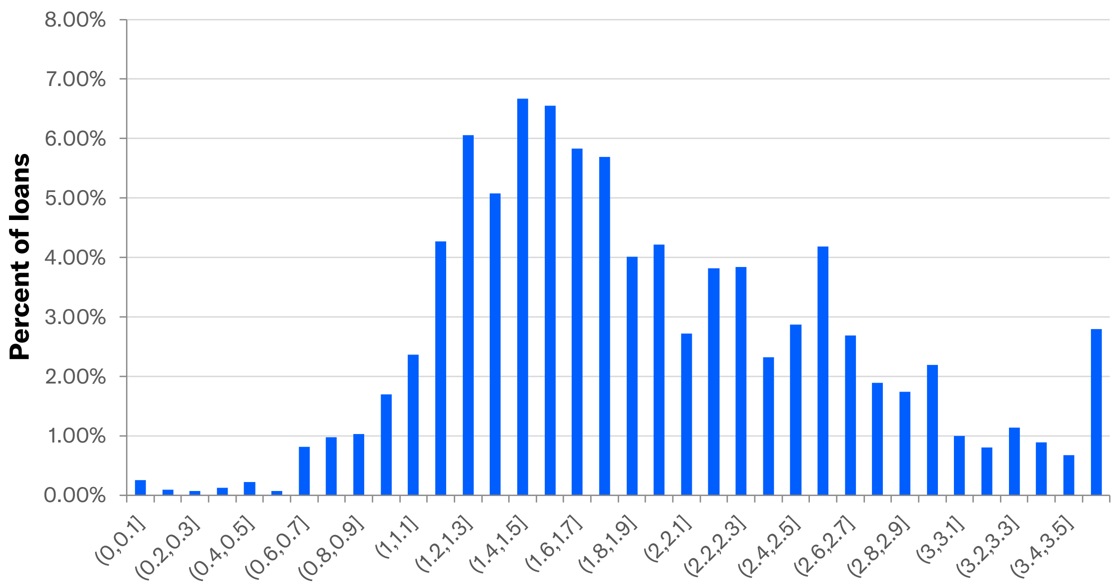


FIGURE 4 Distribution of DSCR



INCORPORATING NATURAL DISASTER IMPACTS

Implied Climate Impact on CRE Performance

To assess the impact of climate related damage on CRE credit risk we first establish a baseline risk level using the portfolio of loans assessed under the assumptions of the Network for Greening the Financial System (NGFS) Current Policies scenario, which assumes that only currently implemented climate policies remain in effect well into the future, with no additional measures to reduce emissions. We run the representative loan portfolio under this scenario through CMM to obtain initial – baseline – credit risk metrics. The credit measures produced in this first stage do not incorporate the effects of direct climate related damage.

In the second phase of the analysis, we account for the effect of direct damage to individual properties by leveraging the ADR damage metrics discussed above. We take the ADR for a given location and assign this damage ratio to properties associated with the specified location. In addition, we add on a one-standard-deviation 'buffer' to capture the additional variability and volatility of average damage estimates. Use of both the ADR and its standard deviation is beneficial as it allows us to identify locations with higher risk volatility and the potential for significant financial losses from rare, high-severity events. A higher ADR and standard deviation signal increases cumulative annual impacts and uncertainty, highlighting areas where risk levels can fluctuate considerably from year to year.

To incorporate them into the CRE credit risk framework, we use the ADR plus standard deviation damage estimates as an impairment factor to the NOI growth rate. We do this for each collateral asset that an individual loan is underwritten on, thus simulating the potential impact of natural disasters in each forecast year. The adjusted NOI growth projections are used in CMM to capture the impact on the income generating capacity of each property, and therefore has implications for the ultimate credit quality and health of the loan. Ultimately, we arrive at final estimates for EDF, LGD, and expected loss (EL) under each scenario for robust quantification of risk.

PORTFOLIO RESULTS

This work builds on Moody's prior analysis of the same portfolio, which examined long term physical impacts through 2050 at a high-level. In this study, we take a deeper look at individual peril scenarios and additional cross-sectional samples to uncover key drivers of risk, provide context for the outcomes, and explore strategies lenders can use to adapt their portfolios for greater resilience. In the aggregate scenario, which accounts for the combined impact of all peril types, we observed a 17.8% increase in probability of default (EDF™) and a 22.1% rise in expected losses under the aggregate physical risk scenario in comparison to the baseline current policies scenario. These shifts translate to an additional $270 million in balance lost and the differences are evident in both FIGURE 5 and TABLE 1 where, under the aggregate scenario there is a clear jump from the baseline. These analyses reinforce that even portfolios with strong fundamentals such as healthy LTVs and strong DSCR can still exhibit climate driven credit deterioration. For lenders, these incremental changes at the portfolio level can compound into substantial financial impacts over time, influencing capital planning and risk management strategies.

FIGURE 5 Lifetime EDF™ and EL for baseline, aggregate, and peril specific scenarios

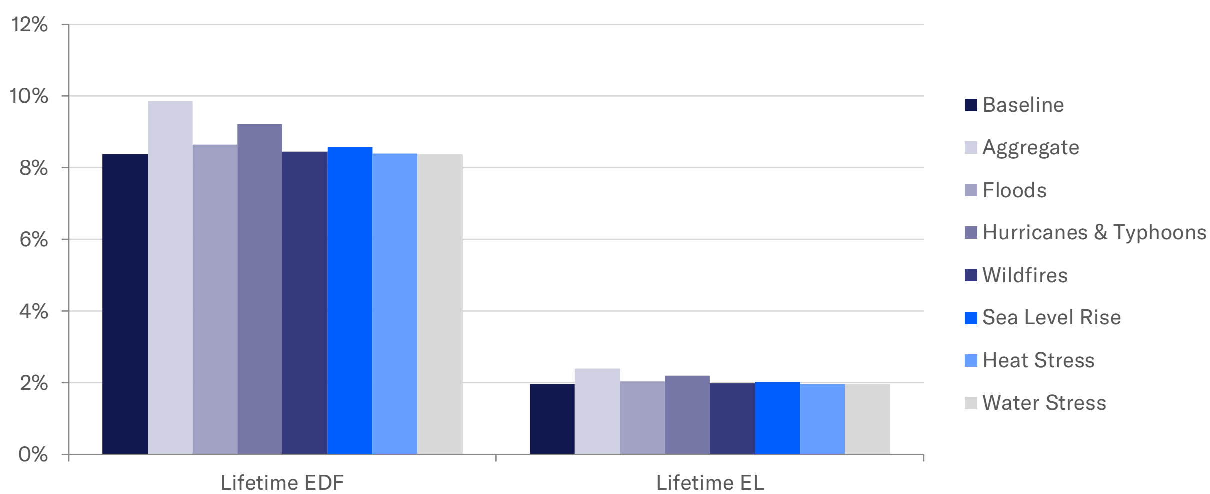


TABLE 1 Table listing EDF, EL, and estimated balance lost values across all scenarios

Scenario	Lifetime EDF	Lifetime EL	Estimate Balance Lost
Baseline	8.37%	1.96%	$1.21B
Aggregate	9.87%	2.39%	$1.48B
Floods	8.65%	2.04%	$1.26B
Hurricanes	9.22%	2.19%	$1.36B
Wildfires	8.44%	1.98%	$1.23B
Sea Level Rise	8.58%	2.02%	$1.25B
Heat Stress	8.39%	1.96%	$1.22B

Parsing out individual perils allows us to better understand the sources of aggregate credit risk impacts across the CRE portfolio, revealing how different hazards contribute unevenly overall and at different geographic granularities (see following section). FIGURE 5 and TABLE 1 also illustrate the implications of individual peril scenarios on lifetime EDF and EL. While individual perils can show substantial localized impacts, it's important to remember that these results reflect the entire portfolio of loans across the United States. Because the portfolio spans a vast and geographically diverse country, extreme events affect only a small portion of overall exposure. This broad distribution significantly dilutes the impact at the national level, even when local losses are severe. With that said, hurricanes and floods exert the greatest individual damage on collateral with clear direct effects for CRE. Heat stress and water stress are more related to indirect damages; however, they still produce meaningful impacts on portfolio performance. Under these two scenarios, damages manifest through impacts on the economy such as reduced productivity or operational disruptions. Historically, these effects have been less pronounced, but emerging trends suggest they could become more material over time. For example, the rapid expansion of generative AI and data center infrastructures is increasing demand for water to cool servers, intensifying water stress in certain regions. This shift could reshape the CRE loan space, with higher demand emerging for water-abundant regions for data center development. Meanwhile, water stressed areas could face declining viability for such uses, potentially collapsing local markets in that sector and influencing long term portfolio strategies.

CROSS-SECTIONAL IMPACT ANALYSIS

While our analysis indicates that physical risks, particularly floods, do have a measurable impact on overall portfolio performance, there remains significant opportunity to deepen our understanding on how these risks shape portfolio resilience. Further research is needed to identify the portfolio structures and underlying practices that most effectively mitigate physical risk, enabling lenders and underwriters to design CRE portfolios that are both robust and adaptable in the face of evolving risks.

Property Types

Across the five key property types in our CRE portfolio, we see the largest increase in risk for retail and multifamily properties. Under the aggregate damage scenario, retail lifetime EL and EDF were 27% and 21% larger, respectively than under the baseline scenario. This difference results in over $53 million more in aggregate losses than under the baseline scenario. Multifamily property EL and EDF grew 23% and 19%, respectively with an estimated increase of $104 million in aggregate losses. FIGURE 6 and FIGURE 7 present the comparison of these two scenarios and their output metrics. While hotel properties tend to be riskier investments due to factors like high vacancy volatility, our analysis shows that the hotel locations associated with loans in our sample portfolio are only moderately affected by physical risk as compared to the other property types with a 21% EDF increase and 15% EL increase. Industrial properties, on the other hand, exhibit both lower levels of risk overall and the smallest difference between physical scenarios; making them both a stable and resilient choice.

FIGURE 6 Lifetime EL across property types between baseline and aggregate scenarios

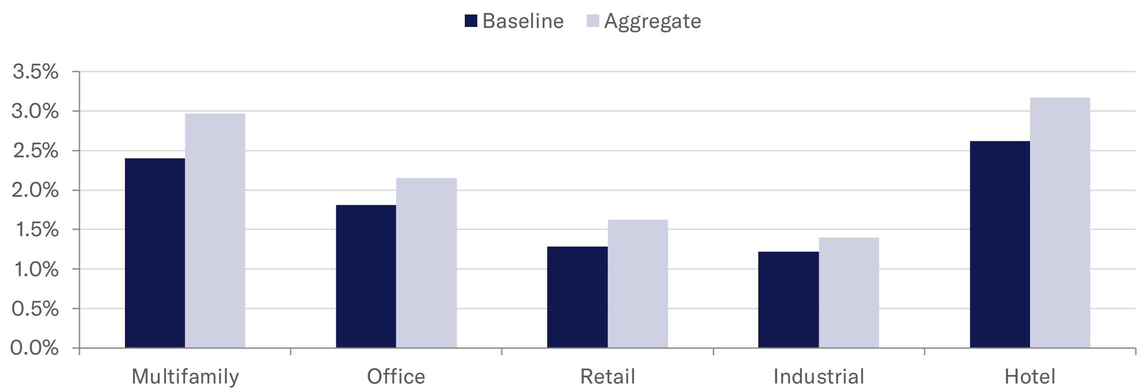
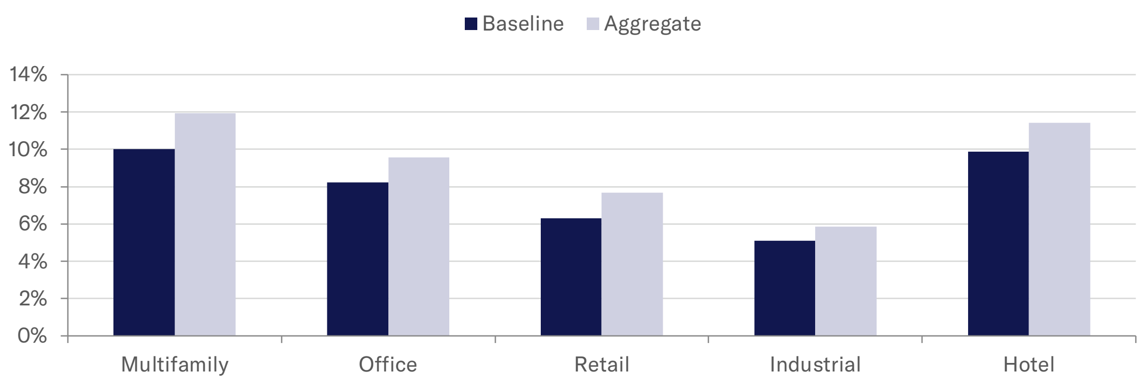


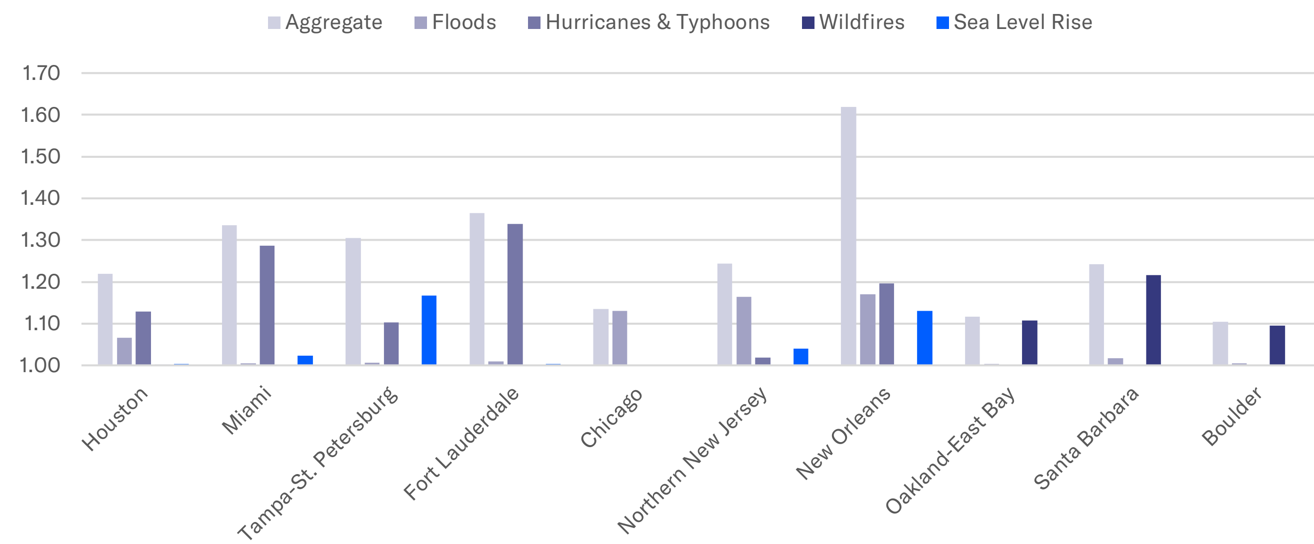
FIGURE 7 Lifetime EDF across property types between baseline and aggregate scenarios



Metro Areas

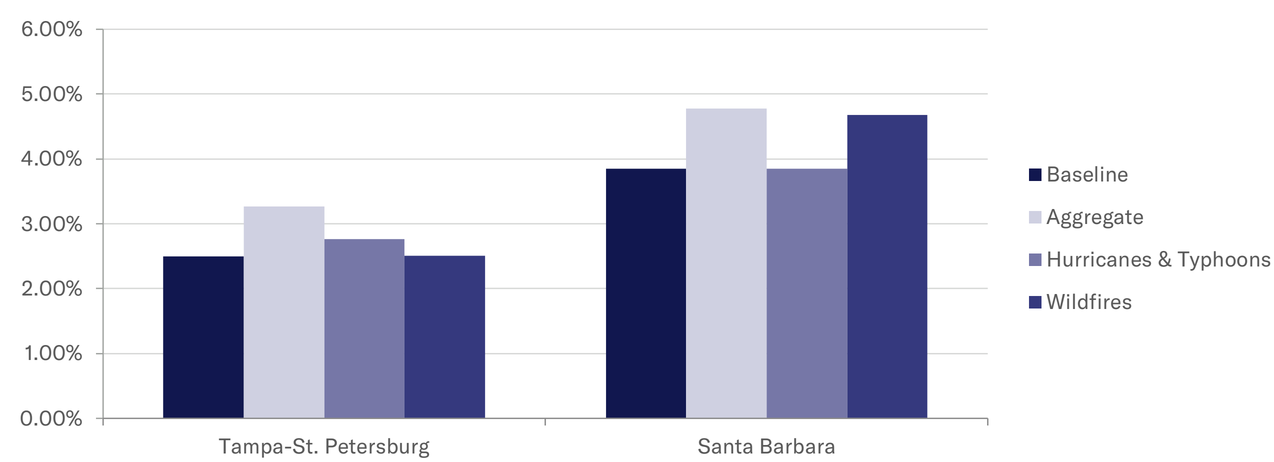
Physical risk does not impact all metros uniformly; certain metros will face specific peril exposures that are not immediately observed in the broader portfolio. For that reason, it is important to unmask the significant variations at the local level as they will have important implications for lenders. FIGURE 8 shows the top ten afflicted metros in our US based portfolio across a range of physical risk scenarios. The values plotted show the difference in EL relative to the Baseline, climate-agnostic scenario to show the additional impact from climate damage expected across these metros. Unsurprisingly, the majority of the cities represented below are either coastal, commonly afflicted by wildfires, or both.

FIGURE 8 Lifetime EL relative to Baseline across major MSAs between relevant scenarios



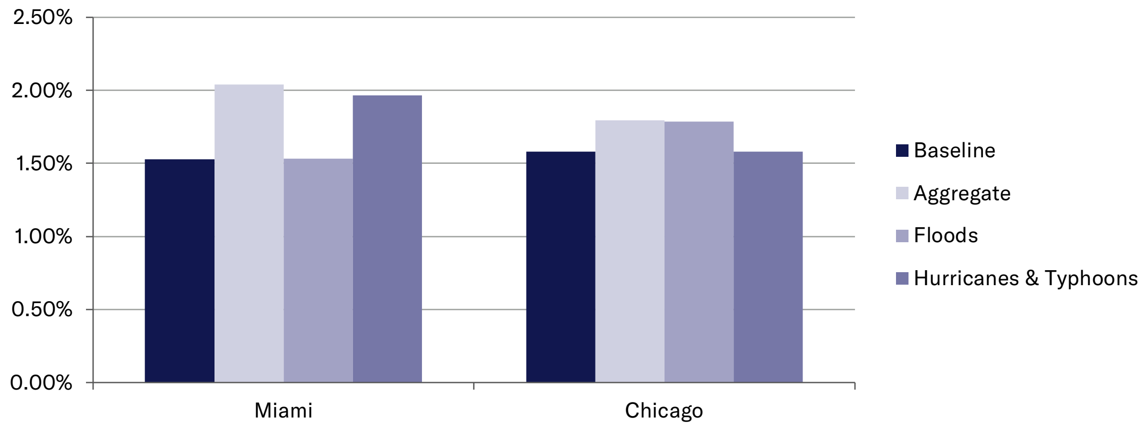
Digging into individual market areas reveals how peril-specific vulnerabilities translate into elevated risk. For example, metros such as Santa Barabara and Oakland-East Bay exhibit sharp increases in lifetime EL under aggregate physical risk scenarios driven primarily by wildfire exposure. As shown in FIGURE 9, a coastal city like Tampa shows a heightened sensitivity to hurricanes and strong headwinds. While a fairly obvious outcome, it underscores the importance of incorporating geographic and peril-specific analytics into portfolio construction.

FIGURE 9 Comparing lifetime EL between Tampa and Santa Barbara



Another cross-section compares two major metros that are both afflicted by severe storms: Miami and Chicago. Much like its neighboring coastal city of Tampa, Miami is heavily impacted by hurricanes and typhoons. Chicago, while also subject to severe storms, demonstrates a different set of resulting risks. Since hurricane related flooding is quantified as damage under the flood peril, risks under the hurricane scenario reflects only wind related damage that is due to cyclonic storms. Consequently, FIGURE 10 shows that the predominant risk in the city of Chicago stems from flooding rather than from wind. This contrast illustrates how similar hazard categories can manifest differently across geographies and emphasizes the need to account for peril interactions rather than relying solely on broader storm classifications.

FIGURE 10 Comparing lifetime EL between Miami and Chicago

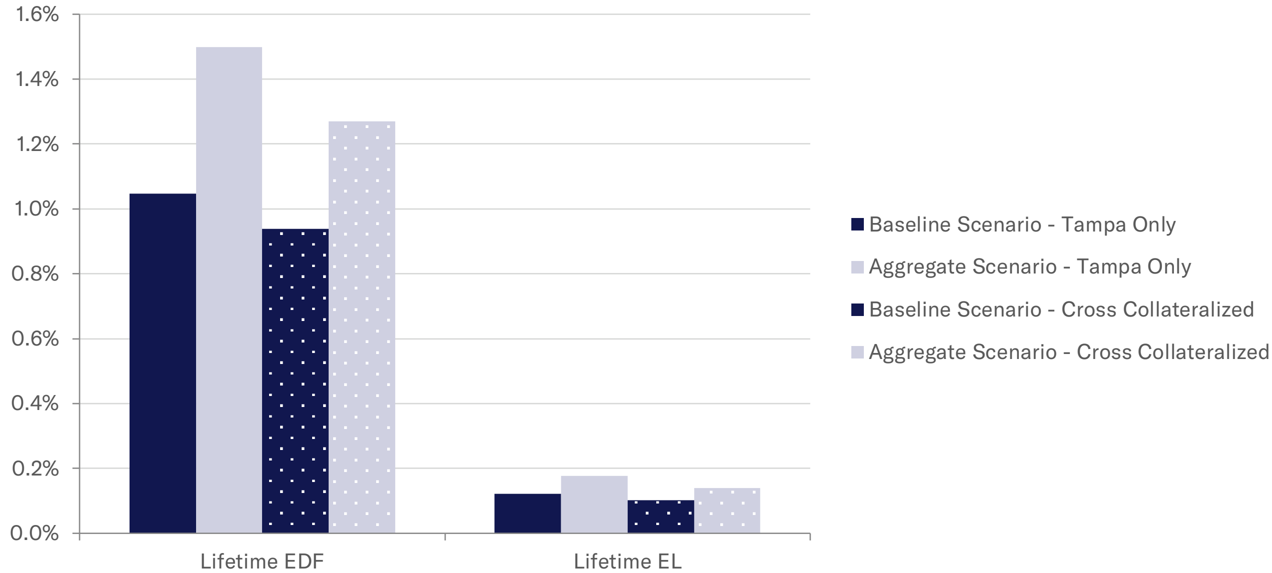


Cross-Collateralized Loans

As a part of our analysis, we also investigate the effect of cross-collateralization on loan results. In other words, how might a loan's performance change if the loan (or collection of loans) is underwritten on multiple properties – particularly if those properties are located in high risk areas – compared to a portfolio in which the loan group is built upon a set of properties that are located in areas that are geographically diverse.

Here, we conduct an experiment in which we identify an actual loan from our representative dataset that consists of four industrial properties located across the country (in Milwaukee, St. Louis, Tampa-St. Petersburg, and Dallas) and ask what the impact on the credit risk of this loan would look like if the loan group only had assets located in the Tampa area. FIGURE 11 compares the EDF and EL for these two loans under both baseline and aggregate scenarios. Under the aggregate scenario, the Tampa-property-only loan exhibits a notable increase in lifetime EDF, with a 43% higher EDF than under the baseline scenario, while the cross-collateralized loan only increased its EDF by 35%. Similarly, the Tampa-property-only loan saw an increase in EL of 45% while the cross-collateralized loan only increased by 36%. The geographically diverse loan – which includes one Tampa property – displays lower overall risk levels, with aggregate EDF and EL remaining well below those observed for the Tampa-property-only loan. These findings highlight the importance of portfolio composition and geographic diversification in mitigating the credit impacts of physical climate risk, even within the same loan instrument.

FIGURE 11 Cross Collateralization Experiment



CONCLUSION

Physical risk is a critical factor for CRE performance and resilience. It manifests both directly, through property damage and increased costs, and indirectly, via economic impacts like reduced rent growth and higher vacancies. While CRE portfolios tend to demonstrate resilience – with their healthy LTV and DSCR distributions – there are clear opportunities to strengthen this resilience by quantifying risks and integrating climate analytics into portfolio management. Specifically, portfolios concentrated in high-risk regions (e.g., Gulf Coast, California) increases exposure to those localized perils, whereas geographic diversification (even in the same loan instrument through cross-collateralization) can limit those exposures.

Adaptation to evolving risks is important, and traditional risk models likely do not fully capture the volatility and severity of climate impacts. For lenders, the ability to demonstrate and communicate robust risk management and transparent mitigation strategies is increasingly critical for securing insurance coverage and favorable terms, especially as premiums rise and coverage tightens in high-risk regions. Rethinking risk management—from static, historical models to dynamic, scenario-based approaches—positions lenders to proactively adapt to evolving threats, maintain access to capital, and safeguard asset value in a rapidly changing climate landscape.

Continued proactive adaptation and robust risk assessment are essential to safeguard CRE holdings against the evolving landscape of climate-related threats. The evolution of physical risk modeling and downstream analytics enables more accurate and forward-looking assessment – allowing lenders and investors to better differentiate between assets. This will continue to drive innovation in underwriting, pricing, and portfolio construction.

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