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RESEARCH INSTITUTE FOR HOUSING AMERICA

A Collection of Essays on Climate Risk and the Housing Market

VOLUME 2

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Introduction

Last month, RIHA published the first volume in *A Collection of Essays on Climate Risk and the Housing Market* that included essays by Ceres Accelerator for Sustainable Capital Markets and RiskSpan Inc. Ceres' essay, *Housing Finance and Climate Risk: Taking Action in an Uncertain Future,* discussed the challenges associated with climate-related risks, and the need for engagement and cooperation across sectors and among diverse shareholders to meet these challenges. RiskSpan's *A Practical Approach to Climate Risk Assessment for Mortgage Finance* laid out a pragmatic framework for assessing climate-related risks from the perspective of a mortgage company.

In this second volume of the compendium, we include essays written by Milliman, Inc., and Andrew Davidson & Co., Inc. Milliman's essay, *Climate Change: Challenges for Insurance and Housing Markets,* reviews the emerging impacts of climate change on property insurance and how, in turn, the changes in property insurance will affect housing markets. The essay also discusses how the insurance industry can work with housing stakeholders to mitigate these impacts and increase climate resilience for the United States housing market. AD&Co.'s essay, *Conditioning Mortgage Credit Analysis on Climate Risk: General Approach & Florida Case Study,* provides details on an approach to condition behavioral mortgage and house price models on variability in climate risk as represented economically by variability in rising insurance premiums.

RESEARCH INSTITUTE FOR HOUSING AMERICA **SPECIAL REPORT**

Climate Change: Challenges for Insurance and Housing Markets

Andrew Pai, Leighton Hunley, and Peggy Brinkmann

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MORTGAGE BANKERS ASSOCIATION

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Introduction

Property insurance is often the first line of financial defense for both homeowners and lenders in the event a property is damaged. As a result, property insurance availability and affordability not only impacts homeowners directly but also has downstream impacts to the broader housing market, including lending, real estate, and construction.

For example, western United States wildfires are driving a potential insurance crisis for many California homeowners, and recent studies indicate that decreased insurance availability and affordability may already be affecting the housing market in wildfire-exposed areas.[1] As climate change increases the length and severity of fire seasons, it is possible that this crisis will expand in California and other states. Hurricane experience is another example of how climate change is impacting insurance and housing markets. Hurricane Ian, a category 4 hurricane that struck Florida in September 2022, is estimated to be the costliest Florida hurricane ever.[2] Other perils are likely also being magnified by climate change, as evidenced by the frequency of inflation-adjusted, billion-dollar disasters over the last decade in the United States.

In this essay, we review the emerging impacts of climate change on property insurance. We then consider the potential effects of these changes on housing markets, now and into the future. Finally, we discuss what the insurance industry can do both independently and in collaboration with housing stakeholders to mitigate these impacts and increase climate resilience for the United States housing market.

1. "The Impact of Wildfires on Rent & Home Prices." September 3, 2021. https://www.corelogic.com/intelligence/the-impact-of-wildfires-on-rent-home-prices/

2. "Hurricane Ian could be Florida's costliest storm ever." September 30, 2022. https://www.cnn.com/2022/09/30/business/hurricane-ian-cost/index.html

EMERGING IMPACTS OF CLIMATE CHANGE ON PROPERTY INSURERS

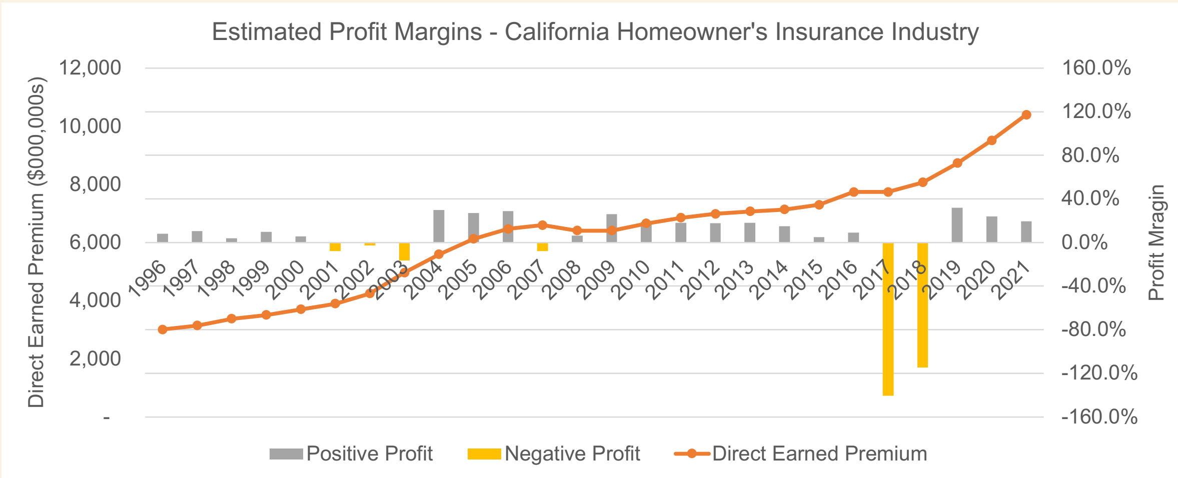
Climate risk drivers can be grouped into one of two categories:

- *Physical risks,* or direct economic and financial losses from natural disasters, which are on the rise due to climate change, and
- *Transition risks,* which arise from the process of adjustment toward a low-carbon economy.[3]

Physical risks associated with climate change directly impact insurance costs in the form of increasing frequency and severity of natural disasters. As physical risks become more complex and unpredictable, insurers and reinsurers alike could suffer significant underwriting losses and be financially challenged if they do not manage those risks properly. And to the extent that the private insurance market is financially unable to serve homeowners, the residual markets, or insurers of last resort, will have to take on the burden. In addition, transition risks could potentially impact insurers indirectly through increased investment risk. While the effects of transition risk on insurers may not be acute, insurers that are heavily invested in carbon-reliant assets should evaluate investment strategies to prepare for potential devaluation of these assets.

The following sections discuss each of these impacts in additional detail.

3. Climate related risk drivers and their transmission channels (bis.org)



Source: Milliman Estimates, based on P&C Combined Industry Annual Statement data from SNL and data from the California Department of Insurance. Excludes impact of reinsurance and investment income.

UNDERWRITING RISK

Insurance is a promise to pay in the event of a loss. Underwriting risk arises from an inaccurate assessment of the risks associated with writing an insurance policy, or uncontrollable factors that result in costs (losses and expenses) that exceed income (premiums). The difference between the premiums and costs is the underwriting profit (or loss). Underwriting losses can be significant in the aftermath of a catastrophic event when insurance companies are hit with a large number of claims with significant amount of payout, and climate change is compounding the risk of these large losses.

In recent years, both California and Louisiana have suffered significant underwriting losses from wildfires and hurricanes, respectively. The recent Hurricane Ian is also expected to cause massive property damage in Florida, currently estimated to be over $60 billion.[4] The California homeowners insurance industry was relatively profitable prior to the 2017 wildfire season. From 1991 to 2016, it is estimated that the industry collected cumulative profit of over $10 billion.[5] However, the 2017 and 2018 wildfire seasons resulted in more than $20 billion in losses for homeowners insurers. In particular, the 2017 wildfire season alone eliminated the cumulative profit the industry earned in the prior 26-year period. The 2018 wildfire season added another $10 billion in losses, making the California homeowners insurance industry unprofitable over a span of just two years. While the industry has stabilized since then with profit returning to pre-2017 levels, the two wildfire seasons still demonstrate the destructive force natural disasters can have on property insurers.

Since Hurricane Katrina, the Louisiana homeowners insurance industry has been profitable in most years, collecting $5 billion in underwriting profit.[6] That changed abruptly when the 2020 hurricane season alone caused nearly $4 billion in losses, with another $7 billion from the 2021 season. The 2020 and 2021 hurricane seasons both generated record-breaking number of storms, ranking first (30 storms) and third (20 storms) among the last 26 years, respectively. These two hurricane seasons caused a significant disturbance to the homeowners insurance market, bankrupting several insurers and leaving hundreds of thousands of policyholders scrambling to find coverage for their homes.

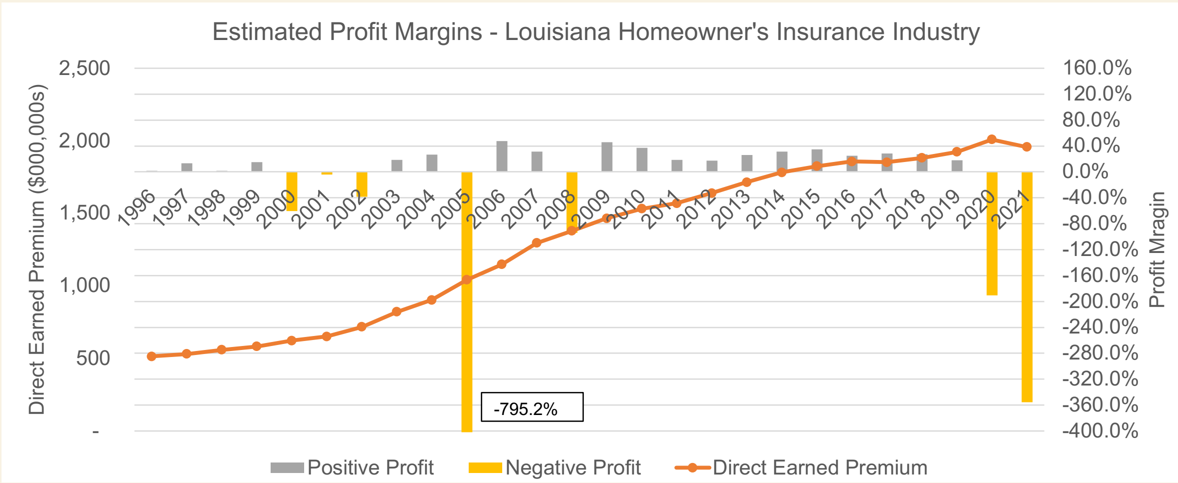
The recent underwriting results in California and Louisiana are prime examples of the catastrophe risks assumed by property insurers and the threat of an event or series of events that could cause insurers to exit a market or become insolvent. Increases in catastrophe exposure due to climate change are highlighting this risk and pushing insurers away from writing business in areas with exposure to climate-related natural disasters, to increase rates, and/or seek greater reinsurance coverage to limit total exposure. For example, eight insurance companies have exited the Louisiana homeowner's insurance market over 2022, either due to bankruptcy or inability to obtain reinsurance coverage.[7]

4. KCC Projects Hurricane Ian Losses Will Top $60 Billion." September 30, 2022. https://www.claimsjournal.com/news/national/2022/09/30/312995.htm

5. Milliman Estimates, based on P&C Combined Industry Annual Statement data from SNL and data from the California Department of Insurance. Excludes impact of reinsurance and investment income.

6. Milliman Estimates, based on P&C Combined Industry Annual Statement data from SNL. Excludes impact of reinsurance and investment income.

7. "Eighth Louisiana homeowners insurer goes under, stranding 10,300 policyholders." August 5, 2022. https://www.nola.com/news/business/article_74eca3b8-1502-11ed-bfc8-8f4127db48fe.html



Source: Milliman Estimates, based on P&C Combined Industry Annual Statement data from SNL. Excludes impact of reinsurance and investment income.

Climate change increases the frequency and severity of extreme weather events and patterns. For example, extended droughts and rains create dried vegetation that fuel wildfires. While there has been no notable increase in the number of fires per year in the United States, the size of the areas burned and the number of structures destroyed have increased. According to the American Academy of Actuaries (AAA), more than 18,000 structures were destroyed by wildfires since 2011, but nearly 80% of them came from wildfires since 2017 despite having fewer number of wildfires during that period.[8] Rising sea level threatens properties with floods, even if they are located in areas that are not historically considered at risk of flood loss. According to a study by National Oceanic and Atmospheric Administration, by 2050 rising sea level would result in major and moderate flood events to occur as frequently as moderate and minor flood events today.[9] All of this puts more pressure on property insurers, as they must be financially prepared to respond to these extreme events and fulfill obligations to their policyholders.

REINSURANCE

Reinsurance, or insurance for insurers, allows insurers to limit their exposure to catastrophic risk by transferring a portion of their liability to a third party. Reinsurance can reduce an insurer's exposure to a large event or disaster, and thus help the primary insurer remain solvent after such events.

One of the many effects of climate change is the increasing cost for property owners to insure their homes, particularly for those who reside in areas that are prone to natural disasters. The source of this increased cost is twofold: 1) primary insurance is more expensive given the increased expected loss for insured properties, and 2) the cost of reinsurance has also increased given the increased frequency and severity of extreme losses. This means it is more expensive for the primary insurance company to transfer the risk, and this cost may ultimately be incorporated in the premium rates charged to property owners.

According to a study by Swiss Re, insured losses from natural disasters have increased by an average of 5-6% annually in recent decades, and 2021 was the fourth highest year for global natural catastrophe losses since 1970. Swiss Re expects these losses to continue to grow at a faster rate than global GDP.[10] Reinsurance broker Aon reported that global insured losses from natural disaster events for the first half of 2022 were 18% above the 21st century average, with a 57% protection gap — meaning that more than half of all economic losses were not covered by insurance.[11]

Reinsurance broker Guy Carpenter reported reinsurance pricing increases of over 30% for some segments in 2022. Guy Carpenter's Global Property Catastrophe Rate-on-Line Index, a measurement of reinsurance premium divided by limit, increased by 10.8% in 2022.

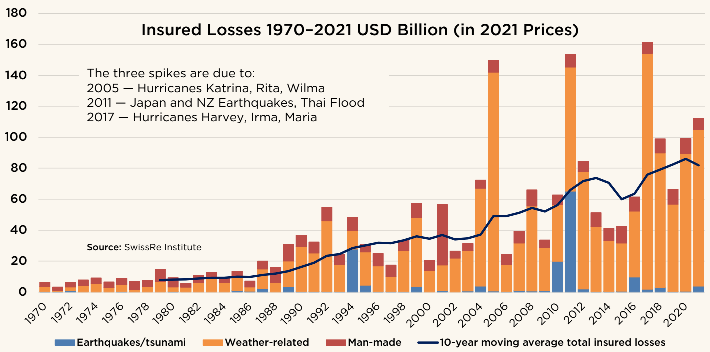
8. American Academy of Actuaries, 2021. "Wildfire: Lessons Learned from the 2017-2018 Events."

9. Sweet, William V. et al. 2022. "Global and Regional Sea Level Risk Scenarios for the United States." National Oceanic and Atmospheric Administration (NOAA).

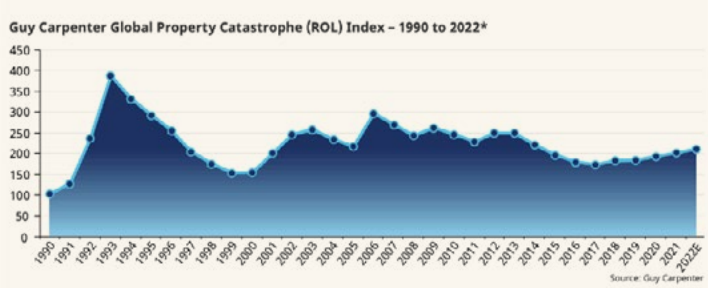
10. "Global insured catastrophe losses rise to USD 112 billion in 2021, the fourth highest on record, Swiss Re Institute estimates." December 14, 2021. https://www.swissre.com/media/press-release/nr-20211214-sigma-full-year-2021-preliminary-natcat-loss-estimates.html

11. "Global insured losses from catastrophes above average at $39bn in H1 2022: Aon." July 20, 2022. https://www.reinsurancene.ws/global-insured-losses-from-catastrophes-above-average-at-39bn-in-h1-2022-aon/

The index is recorded from 1990 to 2022, and spikes can be observed after major catastrophes. Hurricane Andrew in 1992, Hurricane Katrina in 2005, and California wildfires in 2017 all resulted in upward trends. As natural disasters become more frequent from climate change, reinsurance availability and higher cost of reinsurance may continue to increase the cost of property insurance.[12]



In addition, the rising cost of reinsurance may also be passed onto policyholders, further stressing housing affordability. In the event of a reduction in the availability of reinsurance, insurance companies may choose to withdraw from certain markets that have significant catastrophe exposure as they cannot withstand the financial liabilities from natural disasters without adequate reinsurance.



DOWNGRADES

Financial ratings are used to evaluate the financial strength of an insurance company. There are a number of rating agencies that publish financial ratings for insurance companies, such as A.M. Best, Moody's, and Demotech, which leverage publicly available information to assign these ratings.

Maintaining a strong financial rating is important for insurance companies, as it is indicative of the insurer's ability to fulfill their claim obligations. Financial ratings are an important consideration for consumers with federally backed mortgages, as Fannie Mae and Freddie Mac require homeowners to purchase insurance from high-rated insurers.[13] Because of these requirements, if an insurer is downgraded due to financial challenges, this can severely limit the insurer's ability to operate in the marketplace.

With the frequency and severity of catastrophic events on the rise due to climate change, insurers may be required to obtain more capital and/or reinsurance to maintain their financial ratings. Climate change also makes it more challenging and expensive to purchase reinsurance, and inadequate reinsurance coverage can also lead to downgrades, causing disruption to the property insurance market.

Florida is a recent example of the impact of downgrades. The Florida homeowners insurance market was under significant disturbance in 2022 when Demotech announced it was downgrading 17 property insurers.[14] This would have forced a large number of homeowners to find new insurance policies due to federally backed mortgage requirements. Demotech later put many downgrades on hold, but it could not undo the turbulence the news report created in the insurance market. Although Florida's current crisis does not stem from natural catastrophes, it shows how disruptive climate-related downgrades could be in the future.

REGULATORY RESPONSE

One of the responsibilities of insurance regulators is to promote market stability and insurer solvency. In the aftermath of a major catastrophe, there can be significant disturbance to the insurance market, both in forms of availability and affordability of coverage. In such situations, there are often regulatory actions to prevent property owners from losing their policies and protections on their homes.

For example, the California Department of Insurance (CDI) has issued several moratoriums over the years to halt insurance companies from cancelling or nonrenewing

12. "Price increases top 30% on some loss-impacted lines at 1/1: GC." January 5, 2022. https://www.reinsurancene.ws/price-increases-top-30-on-some-loss-impacted-lines-at-1-1-gc/

13. "Florida Establishes Temporary Reinsurance Arrangement for Insurers Facing Potential Financial Stability Rating Downgrades." July 27, 2022. https://www.floir.com/newsroom/archives/item-details/2022/07/27/florida-establishes-temporary-reinsurance-arrangement-for-insurers-facing-potential-financial-stability-rating-downgrades

14. "Demotech notifies 17 property insurance companies of rating downgrades." July 21, 2022. https://www.abcactionnews.com/news/in-depth/demotech-notifies-17-property-insurance-companies-of-rating-downgrades

policies within or in the vicinity of wildfire areas.[15] Other regulatory actions include expanding the coverage of the FAIR Plan (an insurance pool created as a last resort for customers who cannot obtain insurance from the private market) and providing market intelligence to consumers with premium and coverage comparison tools.[16]

While these regulatory actions promote availability of coverage, other regulatory actions discourage actuarially sound rates that would promote insurer solvency. For pricing catastrophe events, California mandates an average view of company historical experience, which may not reflect the current and prospective conditions of the environment. Extreme weather patterns, long droughts, and rising temperatures make today's wildfire risk exposure vastly different from the past. Using a historical view of catastrophe risk exposure, as prescribed by California, can result in a significant gap between the price insurance companies charge and their best estimates of losses. Furthermore, California insurers are not allowed to include provisions in the premiums to cover the cost of reinsurance for wildfire events, which means premiums do not reflect the full cost of the risk.[17]

If insurers are unable to sufficiently match price to risk, they could make business decisions that decrease the availability of coverage, such as limiting areas in which they write policies. This can in turn drive consumers to residual or surplus lines markets, where coverage may not be as comprehensive as the private market.

INSURER OF LAST RESORT

An insurer of last resort is an entity that offers coverage to property owners who are denied coverage by the voluntary insurance market for being too risky. It is often a government-backed entity funded by insurers licensed to write business in the state (who in turn pass the costs along to their policyholders and/or taxpayers), aiming to ensure the availability of insurance coverage to all.

The California FAIR Plan provides insurance coverage for property owners who are denied coverage by the private insurance market. As efforts from insurers to reduce their wildfire exposures has grown, so has the size of the FAIR plan. According to a study by the CDI, the FAIR Plan policies grew over 70% from 2015 to 2020, from 1.7% market share to 2.7% market share.[18] The majority of the growth occurred in wildfire-prone areas as expected, putting the FAIR plan at risk of significant liabilities if another wildfire were to occur.

15. Lara, Ricardo. "Mandatory Moratorium on Cancellations and Non-Renewals of Policies of Residential Property Insurance After the Declaration of a State of Emergency." September 16, 2022. https://www.insurance.ca.gov/0250-insurers/0300-insurers/0200-bulletins/bulletin-notices-commiss-opinion/upload/Bulletin-2022-12-Moratorium-Mill-Fire-Declaration-16-Sept-2022.pdf

16. "Insurance Commissioner Ricardo Lara orders FAIR Plan to offer California homeowners increased coverage options." September 24, 2021. https://www.insurance.ca.gov/0400-news/0100-press-releases/2021/release096-2021.cfm

17. In California, rates are not permitted to consider the cost or benefits of reinsurance except for earthquake and medical malpractice facultative reinsurance (California Code of Regulations Title 10 Section 2655.25)

18. "Fact Sheet: Data on Insurance Non-Renewals and FAIR Plan." December 20, 2021. California Department of Insurance. https://www.insurance.ca.gov/0400-news/0100-press-releases/2021/upload/nr117DataNon-RenewalsandFAIRPlan12202021.pdf

Louisiana's residual market insurer, Citizens Property Insurance Corporation (LCPIC), has similarly grown to over 100,000 policies from private insurance company departures.[19] Florida's residual market entity (Florida Citizens Property Insurance Corporation or FCPIC) is also estimated to hit record level of exposures, with several insurance companies declaring bankruptcy.[20] While Florida's market crisis mainly stems from disproportionate litigation costs, an untimely storm could exacerbate the issue further with the large number of claims it can potentially generate.

As the insurers of last resort grow, their ability to pay off claims following large catastrophic events are being questioned. In the event of a deficit, FCPIC is allowed to assess its policyholders for additional capital. It can also charge an assessment to every policyholder of the private insurance market, if assessing its own policyholders fails to make up for the deficit. An insurer of last resort may increase assessments on primary carriers, causing additional pressure on the carriers that remain in the market. They may be charged prohibitively expensive rates for reinsurance as the concentration of high-risk policies grows. Some plans have been bailed out in the past by state tax revenues.[21] With more property owners struggling to obtain coverage from the private market, insurers of last resort need to be prepared to manage the influx of policies and the financial strain associated with the growth.

FINANCIAL RISK

In addition to underwriting income, investment income is another source of revenue for insurance companies. Property and casualty insurers tend to invest largely in high-quality liquid securities that can be sold quickly to pay claims resulting from a large event.[22] While investment income may be small in comparison to underwriting income, it is nevertheless an important measurement of an insurer's overall performance and should not be overlooked.

Climate change brings both physical and transition risk to an insurer's investment portfolio. Physical risks include economic losses from natural disasters such as wildfires and flood, which can impact the ability of businesses and governments to meet bond obligations and/or impact investment valuations. Transition risks stem from the society shifting towards a low-carbon future, affecting values of carbon-reliant assets and industries such as fossil fuel and coal mines. Insurers that are heavily invested in carbon-reliant assets should reconsider their investment strategy to prepare for potential devaluation of these assets.

Insurers should take action to consider the impact of climate change on investment risk. If insurers cannot obtain a quality rate of return on investments from their surplus and reserves, they may be forced to seek more underwriting profit, further exacerbating both issues on affordability and availability.

The New York Department of Financial Services (DFS) has published guidance for domestic insurers on managing financial risks from climate change.[23] The guidance summarizes the DFS's position on the actions an insurer should take to combat climate change, such as incorporating climate risk into its financial risk management, using scenario analysis to inform business strategies, and considering both current and forward-looking impact of climate change on its business. Using such guidance, insurers can review and adopt strategies to better manage the financial risks associated with climate change.

19. "Louisiana homeowners insured by Florida-based UPC might have to find new coverage." August 16, 2022. https://www.wafb.com/2022/08/17/louisiana-homeowners-insured-by-florida-based-upc-might-have-find-new-coverage/

20. "Citizens could hit record size as private market appetite wanes for Florida: ALIRT." August 25, 2022. https://www.artemis.bm/news/citizens-could-hit-record-size-as-private-market-appetite-wanes-for-florida-alirt/

21. Hartwig, Robert P. and Claire Wilkinson. May 2016. "Residual Market Property Plans: From Markets of Last Resort to Markets of First Choice." Insurance Information Institute. https://www.iii.org/sites/default/files/docs/pdf/residual_markets_wp_051616.pdf

22. "A Firm Foundation: How Insurance Supports the Economy." Insurance Information Institute. https://www.iii.org/publications/a-firm-foundation-how-insurance-supports-the-economy/investing-in-capital-markets/introduction

23. "Guidance for New York Domestic Insurers on Managing the Financial Risks from Climate Change." November 15, 2021. New York Department of Financial Services.

How Insurance Is Impacting Housing Markets

For most property owners, their home is their most valuable asset. It is imperative that this asset is protected with adequate insurance coverage, especially in catastrophe-prone areas, so that homeowners do not suffer a major financial loss after a natural disaster. Insurance provides stability and protection to homeowners; otherwise, the risk is too great for many to invest in homeownership. Furthermore, without adequate and affordable insurance, prospective homebuyers may not be granted a mortgage, as mortgage creditors want to protect their interest in the asset.

A healthy private insurance market is essential to a stable housing market. Changes in insurance availability and affordability in areas impacted by climate change present risks to property values, mortgage lending, and sustainable homeownership. In the following sections, we discuss these examples in more detail.

PROPERTY VALUES

There are many factors that affect the value of a home, such as location, build quality, and school district. Insurance costs can impact home values as well, both positively and negatively. Insurance pricing which does not accurately reflect climate risk distorts home values and could have significant impacts on home values when fully realized.

One example is the financial cost of flooding. According to a study by Milliman and KatRisk, LLC, only 4% of homeowners in the United States have flood insurance today. Most homeowners also believe that if they are not required to purchase flood insurance, their property is not exposed to flood risk. It is estimated by Milliman that unpriced flood costs, including potential flood damage and flood insurance premiums, represent an average potential overvaluation of 2% of property value in the United States.[24]

Property values in wildfire zones may be similarly overvalued where the insurance premiums do not correctly value the wildfire exposure. According to a study by Redfin, property prices grow at a significantly slower rate for homes within wildfire zones than those outside in the three years following major fires.[25] Both studies demonstrate the potential impact to property values from climate risks.

While property values have been relatively resilient so far, the past may not be representative of the future. As public awareness on climate change risk grows, builders may be reluctant to rebuild in these disaster-prone areas, and prospective home buyers may think twice before considering moving in. Property values can therefore be nega-

24. Evans, David D., Leighton A. Hunley, and Brandon Katz. "Unpriced costs of flooding: An emerging risk for homeowners and lenders." January 28, 2022. https://us.milliman.com/en/insight/unpriced-costs-of-flooding-an-emerging-risk-for-homeowners-and-lenders

25. Katz, Lily and Sebastian Sandoval-Olascoaga. "Home Prices Grow at Much Slower Rate in Towns Burned by California's Most Destructive Wildfires." Updated October 12, 2021. https://www.redfin.com/news/california-wildfire-housing-market-impact/#:~:text=Home%20Prices%20Grow%20at%20Much,by%20California's%20Most%20Destructive%20Wildfires&text=In%20-the%20three%20years%20after,just%20outside%20of%20fire%20zones

tively impacted unless state and local leaders develop and implement plans to build communities that are resilient to these disasters.

MORTGAGE LENDING

Mortgage lenders require homeowners to maintain property insurance to protect the lender in the event something happens to the property. Without insurance, the risk of catastrophic loss would make it difficult to obtain financing since lenders and investors would be unwilling to risk funds without some guarantee of safety for their investment.

About two-thirds of mortgage loans are not retained by the originating lender and are sold to intermediaries who "securitize" them to sell to investors.[26] The two largest intermediaries, Fannie Mae and Freddie Mac, require properties with federally backed mortgages to be insured by high-rated insurance companies and require flood insurance in certain areas. The Federal Housing Administration also requires properties located in a Special Flood Hazard Area (SFHA) to maintain flood insurance coverage.

Because of these requirements, insurance availability has a direct impact on the availability of mortgage loans, and the recognition of changes in risk due to climate change is already having impacts in some areas. Insurers in some parts of the country have suspended accepting new business or exited markets entirely due to rising catastrophe risk and shrinking availability of reinsurance, leaving consumers with policies that they can no longer afford or without coverage at all. In Louisiana, due to the market turbulence discussed earlier, tens of thousands of residents have been notified of non-renewal or cancellation of their policies.[27]

Insurance affordability is also an issue for borrowers and lenders. Residents in Louisiana have reported premium increases of 30% or more, with some even seeing their premiums more than double.[28] LCPIC's board recommended a 63% rate increase in 2023 that has been approved by the Louisiana Department of Insurance, potentially further exacerbating the state's affordability crisis.[29] The cost of property insurance impacts the size of the mortgage that is affordable for a new homebuyer and the ability of an existing borrower to continue to make their payments.

To the extent that climate change has not been reflected in mortgage requirements, mortgage lenders and investors (as well as homeowners) are unprotected with respect to uninsured events. For example, properties in areas where flood risk has increased but flood insurance is not currently required leave homeowners, lenders, and intermediaries without protection in the event of a flood. During Hurricane Harvey, for example, an estimated 80% of homeowners in the areas that experienced the most damage did not have flood insurance.[30]

Also, changes in home values are correlated to mortgage defaults. A downward repricing of property values due to the impacts of climate change on affordability and availability of insurance could increase mortgage defaults and loss severities. This would directly affect mortgage security investors, causing further adverse impacts to mortgage markets.

In addition to property insurance, borrowers who do not have a 20% down payment available at time of loan closing are required to obtain mortgage guaranty insurance on conventional mortgages. Mortgage guaranty insurance policies protect lenders against borrower default. The borrower or lender pays the mortgage guaranty insurer a premium and in exchange the insurer will reimburse the

26. "Home mortgage and insurance systems encourage development in climate-risky places, and we all pay the price." March 9, 2022. https://www.brookings.edu/blog/the-avenue/2022/03/09/home-mortgage-and-insurance-systems-encourage-development-in-climate-risky-places-and-we-all-pay-the-price/

27. "42,000 Louisiana homeowners dropped by insurance company Friday; State Insurance Commissioner addresses crisis." July 15, 2022. https://www.fox8live.com/2022/07/16/42000-louisiana-homeowners-dropped-by-insurance-company-friday-state-insurance-commissioner-addresses-crisis/

28. "Louisiana faces an insurance crisis, leaving people afraid they can't afford their homes." September 16, 2022. https://www.nbcnews.com/news/us-news/louisiana-homeowners-insurance-crisis-hurricanes-rcna46746

29. "Louisiana Homeowners Face Dramatic Cost Hike from Citizens, State's Insurer of Last Resort." September 12, 2022. https://www.ldi.la.gov/news/press-releases/10-10-22-ldi-approves-citizens-rate-increase-and-offers-tips-for-policyholders

30. Long, H. (August 29, 2017). "Where Harvey is hitting hardest, 80 percent lack flood insurance." Washington Post. https://www.washingtonpost.com/news/wonk/wp/2017/08/29/where-harvey-is-hitting-hardest-four-out-of-five-homeowners-lack-flood-insurance/

mortgage investor for a portion of the lost principal in the event of borrower default. However, mortgage insurance companies may deny an insurance claim if the principal cause of default giving rise to the claim is physical damage. While mortgage insurance companies may allow extensions of foreclosure timelines and work with lenders through forbearance programs when natural disasters occur, as climate change influences physical damage risk it is important to note that investors will likely not be covered by mortgage insurance with respect to claims related to physical damage risk. This has an acute effect on mortgage borrowers who already are highly leveraged from a financial standpoint during a catastrophic event.

The Federal Housing Administration also provides mortgage insurance for disaster victims through a special program.[31] This insurance program assists those individuals who were victims in a presidentially designated disaster area by helping them to get financing for another mortgage to rebuild or buy another home. Climate change as it relates to an increase in natural disasters and increased physical damage risk for homeowners will directly impact this government program.

WHAT THE INSURANCE INDUSTRY CAN DO

There are several actions the insurance industry can take to help mitigate these potential impacts of climate change on housing:

- **Promote resilience and mitigation.** Insurers can support an industry-wide effort to educate the public on fortifying homes against natural disasters and encourage individual homeowners to improve resilience of their homes against natural disasters. This includes offering economic incentives to homeowners who install mitigation features for their homes, such as installing non-combustible roofs and using fire resistant materials in the siding of their homes. The California Insurance Commissioner recently submitted a wildfire safety regulation that would require insurers to recognize consumers' efforts in wildfire mitigation by offering premium discounts.

- **Improve data.** Insurers can collect more detailed data about the resilience of the properties insured. More accurate data on property mitigation measures are needed for studies to better quantify their efficacy and apply premium credits for mitigation in an appropriate and efficient manner. Insurers can also contribute to the evaluation of new innovations and technologies for mitigation of flood, wildfire, and other climate-related risks.

- **Improve use of catastrophe models for risk assessment.** Catastrophe modeling is in integral part of insurance companies that are exposed to catastrophe risk and is often a key component in insurance ratemaking. While results can vary between different modelers, a diverse selection of models can promote matching of price to risk by reducing reliance on a single model. Lawmakers and regulators in states impacted by natural disasters may consider joining together to develop a common model review process for efficiency and cost saving. A rigorous and standardized model review process could increase regulator and insurer confidence in these models.

- **Product innovation.** Through smart product design, the insurance industry can help bridge the coverage gaps that exist today. For example, to the extent that insurance products are designed using different catastrophe models, consumers can also have a wider range of products to choose from, promoting insurance availability. Other solutions, such as parametric insurance, may also help manage risk and close protection gaps.

- **Collaborate with housing stakeholders.** The housing market and insurance industry are intertwined when it comes to addressing the impacts of climate change. Several mortgage market participants have already taken action to get the conversation started regarding climate change and its impacts on housing. For example, the Federal Housing Finance Agency issued a request for information in early 2021 on climate and natural disaster risk management to the regulated entities, namely, Fannie Mae and Freddie Mac, and received dozens of responses as well as held a speaking session on the topic. The insurance industry will prove to be critical in helping the housing industry understand the gaps in insurance coverage so that control measures can be put in place to help prevent a large-scale mortgage market disturbance.

31. U.S. Department of Housing and Urban Development "Mortgage Insurance for Disaster Victims Section 203(H)." https://www.hud.gov/program_offices/housing/sfh/ins/203h-dft

Conclusion

Both the insurance industry and housing market face significant challenges from climate change. The effects can already be seen in areas with high catastrophe exposure, such as California and Louisiana. Climate change resilience, improved data transparency, incorporation of sophisticated catastrophe models for risk assessment, product innovation, and intermarket collaboration are the key priorities for the insurance and housing industries to ensure stability going forward.

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RESEARCH INSTITUTE FOR HOUSING AMERICA **SPECIAL REPORT**

Conditioning Mortgage Credit Analysis on Climate Risk: General Approach & Florida Case Study

Eknath Belbase & Alex Levin

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Eknath Belbase & Alex Levin,
Andrew Davidson & Co., Inc. (AD&Co.)

MORTGAGE BANKERS ASSOCIATION

RESEARCH INSTITUTE FOR HOUSING AMERICA

Introduction

In recent years, there has been increased interest in measuring exposure to climate risk, both from regulators and investors. At Andrew Davidson & Co., Inc. (AD&Co.), we have also seen interest from market participants engaged in making portfolio and risk decisions who would like to be able to incorporate climate risks into their analyses and decision metrics.

There are two predominant ways to incorporate climate risks — a macro approach and a granular approach. In the next section we discuss the pros and cons of each approach and argue that the granular is preferable. We then describe our granular solution that involves conditioning our existing behavioral and house price models on variability in climate risk as represented economically by variability in rising insurance premiums.

TWO APPROACHES FOR INCORPORATING CLIMATE RISK

We have observed two distinct approaches begin to emerge to incorporate climate risk into portfolio and risk analysis. The first is what we would call the "macro" approach. For example, creating state- or MSA-level stress tests for exposure to wildfire risk or flood risk, and then examining how much of an institution's portfolio is exposed to each.

The advantage of this method is that it is relatively simple to set up and execute and would be a step towards meeting regulatory needs. The limitations of this approach are many: within each state, differences of a few feet in elevation or construction can mean the difference between complete losses on a house or none during a flood. Likewise, there is no way to compare whether it is better to deploy a dollar of risk capital in location A taking more flood risk or in location B taking more exposure to wildfire risk. There is no way to mitigate or limit risk using this method other than avoiding an entire state or MSA. Additionally, pricing and risk-based capital analysis cannot be performed consistently because those are typically loan-level and property-level in their granularity already.

The second approach is what we call the "granular" approach. Granular analysis would require property-level climate risk metrics which are used to condition existing loan-level analytics already used to compute all the required metrics for portfolio and risk decision-making. The disadvantage of this approach is that it is considerably more complex and involved to set up than the macro approach. The advantages of this approach, once set up, include the ability to meet all the requirements from regulators and investors by rolling up granular data but retaining the ability to make loan-level pricing and risk decisions by keeping the data appropriately granular based on the particular climate hazard. As climate models improve, the resolution of this approach will improve as well.

The last observation to make on the two approaches is that if some institutions exclusively take the macro approach and others take the granular approach, we expect the highest risk properties and loans to migrate from the second group to the first group over time. Because the granular approach can satisfy both sets of needs, and we anticipate that many of our clients will want the ability to incorporate climate risks into pricing and risk management, we have chosen this approach.

THE GRANULAR APPROACH

In the remainder of this article, we focus on AD&Co.'s granular analytical approach to measuring how climate risk may impact each of the traditionally measured risk categories: market, interest rate/prepayment, and credit risk. Our goal is to do so in a way that flows through to analytics that institutions rely on: risk-based capital, mortgage insurance premiums, risk-based loan pricing, relative value metrics, portfolio return distributions, etc. Ideally, such a method would also allow attribution of risk exposure to particular sub-types of climate risk.

Core sub-types of climate risk include: coastal and inland flood risk, wildfire risk, cyclonic storm risk (wind, rain, hail), sea-level rise (including subsidence), and water and heat stress. Some of these risks are that of one-time events having higher frequency and severity than in the past; others could be characterized as becoming ongoing nuisances that reduce the utility or enjoyment of a particular area, or increase the ongoing costs required to continue to utilize or enjoy that space. We should point out that due to the nature of reinsurance pricing and its impact on insurance pricing, this conceptual distinction between one-time less

frequent events targeting specific areas may be superficial at an economic level. The incidence of risk can be transmitted as increased ongoing insurance or other costs to a much larger area (where climate models show the overall risk of such events going up) than that impacted by any particular one-time event.

Viewed through this lens, municipal debt, commercial property and debt, and single-family and multifamily property and mortgages are all potentially impacted long-dated asset classes.

We begin by asking some questions:

1. How might individual and commercial insurance premiums (for flood insurance, catastrophe insurance, fire insurance, homeowner, or commercial property insurance) be impacted as a function of different levels of risk exposure?

2. For the highest risk areas, would property tax rates also need to increase in order to increase investment in public infrastructure that mitigates the worst risks or rebuilds damaged infrastructure?

3. How might this combination of increased costs impact future appreciation of both commercial and residential properties?

4. In addition to the observable impact on real estate pricing, might there be additional impacts on the movement of firms and individuals, both in response to priced risks and to perceptions of those risks ahead of any full re-pricing?

Finally, while on the topic of granularity, it is worth noting that different climate risks inhabit somewhat different "zones" of granularity. At the highest level, increased cyclonic storm risks impact multi-state regions and it is difficult to differentiate pure storm risk within these larger regions; similarly, drought/water stress and heat stress also tend to impact geographically larger regions. Next, wildfire risk appears to be increasing in zones of intermediate resolution, and even though individual fires impact fairly concentrated zones, wildfire premium increases are impacting considerably larger zones. At the other end of the spectrum, sea-level rise, coastal, and inland flood risks appear to vary greatly even within MSAs and zip codes, so property-level analysis which takes construction, elevation, and other land feature variation into account is particularly appropriate.

Review of Literature

There is a sizable body of published research on the topic of hazard risks and their subsequent impacts on real estate pricing. We look at some relevant highlights from this literature and note some papers on the related topic of adverse selection. Following the review, we discuss details of our granular approach, which has been inflected by this work.

Bakkensen & Barrage (2017) find direct evidence of belief heterogeneity in flood risks and evidence of self-sorting of homeowners into higher risk areas (e.g., climate skeptics tend to continue to buy in higher risk locations, everyone else moves). The paper also explains why actual flood events have a greater price impact than those predicted by risk models (as perceived via insurance premiums).

Using 460,000 sales between 2007–2016, Bernstein et al. (2019) find the sea level rise (SLR) exposure discount to be 7% and growing over time. It finds that the SLR discount varies, with higher discounts in markets with a higher percentage of sophisticated investors, and lower discounts in primarily owner-occupied markets. The paper also finds no rental market discount.

Blessing et al (2017) find that house price appreciation (HPA) tends to increase after re-building closest to the central area of a fire (due to code updates and more resilient structures being forced to be built by the California code) and that delinquency rates are the lowest for the largest fires (due to more mobilization of state resources and larger insurance payouts), but that these trends are unlikely to be sustainable given the structure of the insurance.

Keenan et al. (2018) utilize Miami-Dade County, Florida (MDC) as a case study to test the hypothesis that the rate of price appreciation of single-family properties in MDC is positively related to and correlated with incremental measures of higher elevation (the ‘Elevation Hypothesis’). As a reflection of an increase in observed nuisance flooding and relative SLR, the second hypothesis is that the rates of price appreciation in the lowest elevation cohorts have not kept up with the rates of appreciation of higher elevation cohorts since approximately 2000 (the ‘Nuisance Hypothesis’). The findings support a validation of both hypotheses and suggest the potential existence of consumer preferences that are based, in part, on perceptions of flood risk and/or observations of flooding.

One common theme through much of the literature is to tie home price data to risk data, which led directly to our choice of insurance premiums (for homeowners, wildfire, and flood) as the most easily observable and salient variable. The key question when we began this project was how exactly homeowners of different levels of expertise or education might go about assessing the exact level of risk; using insurance premiums provides a uniform, relatively objective and available measure that will impact all homeowners who have mortgages regardless of their degree of belief in climate change or changing risks due to climate change.

Ortega & Taspmar (2018) analyze the effects of Hurricane Sandy on the New York City housing market using all housing sales for 2003–2017. Their estimates show gradual emergence of a price penalty among flood zone properties that were not damaged by Sandy, reaching 8% in 2017 and showing no signs of recovery. In contrast, damaged properties suffered a large immediate drop in value following the storm (17–22%), followed by a partial recovery and convergence toward a similar penalty as non-damaged properties. The partial recovery in the prices of damaged properties likely reflects their gradual restoration. However, the persistent price reduction affecting all flood-zone properties is more consistent with a learning mechanism. We would note that it is also consistent with our belief that

insurance costs are a primary economic driver of affordability and hence price dynamics that diffuse risk information beyond properties impacted by any single event.

Ouazad and Kahn (2019) examine whether lenders' sales of mortgages with loan amounts right below the conforming loan limit increase significantly after a natural disaster that caused more than a billion dollars in damages. Results suggest a substantial increase in securitization activity in years following such a billion-dollar disaster. The increase is larger in neighborhoods for which such a disaster is "new news." This suggests that the government-sponsored enterprises (GSEs) may experience significant adverse selection already and supports our belief that any entity which chooses a macro approach will likely face similar adverse selection.

Elements of the Granular Approach

Our granular approach for incorporating climate risks into mortgage analytics consists of the following steps:

- Forecasting insurance premium increases at the appropriate level of granularity. There are several vendors with deep climate expertise who can provide AD&Co. with these inputs (e.g., ICE, Jupiter Intelligence, 427, and RMS). As we continue to improve our granular approach, future versions may also include additional cost impacts, such as a rise in local property taxes due to the need to rebuild or harden public infrastructure.

- Incorporating these insurance premium increase forecasts to condition our suite of behavioral models, including prepayment models (especially turnover) and default models (collectively, the LoanDynamics Model, or LDM).

- Conditioning of our existing house price appreciation (HPA) simulation and valuation grid to take account of the insurance premium increases over the forecast horizon. This component also flows through to the severity upon default component of our behavioral models.

Given the need for potentially property level data, a necessary first step for climate-conditioned mortgage analytics runs would be to exchange the locations with the climate analytics provider and download location-specific data. This would be followed by calls to the AD&Co. Climate Impact Suite. Attribution to the climate dimension could be calculated as the difference between climate-conditioned LDM and base LDM.[1]

In the next two sections, we focus on the use of cost forecasts to climate condition our behavioral models and HPA models respectively. The appendix contains background information on LDM and our HPA model and how they interact.

1. An overview of our LDM, LoanDynamics Model, is described in appendix.

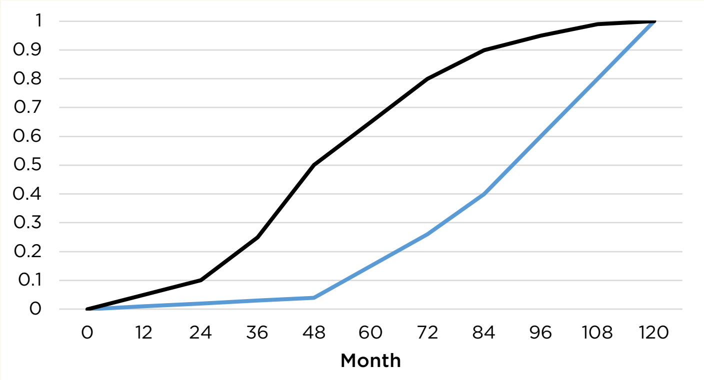
BEHAVIORAL MODELING APPROACH

Climate conditioning our behavioral models includes two components: user-tuning scenarios for the speed at which future losses will be priced into all the components of the mortgage holders' costs (homeowners, flood, wildfire insurance, and property taxes) and conditioning our prepayment and delinquency transitions to vary as a function of these cost increases. Our severity model takes as an input a forward house price path; conditioning house prices for climate will imply that our severity function is also climate conditioned.

The reason for the inclusion of the first component is that climate data providers model losses as a function of different climate scenarios, but the rate at which these rising losses are incorporated into the market price of insurance varies by type of insurance and location. For example, Florida homeowners' insurance rate increases above certain thresholds require elaborate processes involving community comment; policy holders facing large increases also have a state-backed insurer which, for a time, may limit the rate at which observed increases in losses are passed through to observable policy premiums. California wildfire faces a similar dynamic via the FAIR plan, a state-established insurer of last resort collectively backed by the insurance industry. Federal flood insurance has similar "speed bumps" that could delay the recognition of elevated levels of risk in homeowner costs. Such policy-driven factors are less amenable to our modeling approach and scenario analysis around this factor may be preferable.

In Figure 1 we graph some hypothetical user scenarios for potential time periods over which premiums could catch up to actual loss data. The vertical axis represents the current gap between insurance premiums collected and the amount that would be required to be collected to have no underwriting loss. The black line shows a scenario where cost increases (towards a path of actual losses that is itself still rising over time) are allowed relatively quickly, as opposed to the blue line where the process of premium rationalization takes longer. In the second scenario, it is likely that more private insurers would exit the market in question and more of the risk would adversely select into state-backed pools.

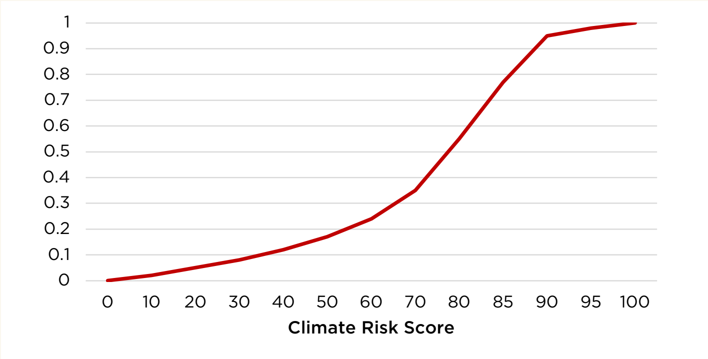
Figure 1: **Scenarios for Insurance Cost Pricing: Insurance Cost (as a % of Repricing)**



The second component links increases in costs to delinquencies and borrower turnover. Our prior would be that in the highest risk areas, as insurance costs rise enough to approach the same order of magnitude as mortgage payments, there would be some increased propensity to move to a lower cost location (assuming the property has a current LTV at the time allowing such a sale, and that the location is still attractive to other borrowers). In the cases where the CLTV or the housing market doesn't allow the sale to occur, the cost impact could also result in an increased delinquency transition.

In Figure 2 we show an idealized curve linking individual climate risk score to the percent of the maximum cost-reset effect on defaults — by this we mean the maximum increase that we would expect in the underlying default rate given the known credit risk factors which are already used by our current default models, but ignoring any impact from affordability issues caused by increased insurance premiums (which are currently not a model factor).

Figure 2: **Default Rates as a Function of Climate Risk Score (% of Maximum Effect)**



In practice, the model would be fed a 30-year forecast of insurance cost increases for each type of insurance (homeowners, flood, wildfire). While data on the impact of increasing climate risks (as reflected in insurance premiums) on turnover and delinquency behavior is currently sparse and limited, we do have a conceptual precedence for measuring the impact of mortgage cost increases on borrower turnover and default behavior from the ARM universe.

Prior to the financial crisis, an increase in interest-only and negative amortization mortgages resulted in significant payment shocks when the interest-only or negative amortization periods ended. The data from this period can be used to form initial expectations for the potential size of any pay shock effect that would occur to what is now a predominantly fixed-rate mortgage universe. In effect, rapid rises in annual insurance premium rates add a yearly floater to the otherwise fixed-rate mortgage payment. When the initial cost of insurance is small in magnitude relative to the fixed-rate mortgage payment, we might expect little to no impact; as the cost of insurance exceeds the size of annual property tax payments (a threshold which has already been crossed in many counties in Florida) and becomes a significant percentage of the monthly mortgage payment, this floater becomes a source of risk in its own right.

Following this line of thought, each homeowner's liabilities consist of the mortgage, the insurance contracts on the home, and the property tax bill. Even if the first is fixed, the latter set are annual floaters that rarely adjust downwards; all floating liabilities might be expected to have some relationship to climate risk, with increases higher than the rate of income growth more likely to have behavioral impact. Over time, this approach to modeling the behavioral impact on turnover and delinquency rates of cost increases will be based on a wide range of data from multiple higher risk locations. For the initial versions of the model, we expect to leverage data from areas where insurance costs have already been rising rapidly, such as coastal Florida, parts of California, and Louisiana.

In the next section, we turn to our house price modeling approach under climate conditioning.

HOUSE PRICE MODELING APPROACH

With regards to home price modeling, there are several factors to consider:

- The effect of increasing property insurance caused by climate change;
- The effect of uninsured or underinsured properties; and
- The effect of population attrition and falling demand of housing in the affected areas.

For the purpose of this paper, we limit our attention to the first two factors, using flood insurance underpricing/underinsurance in the state of Florida.

INPUTS

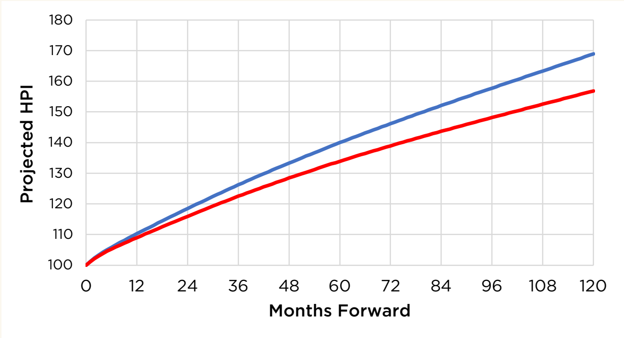
According to Intercontinental Exchange's (ICE) data, the average collected property premium rate for flood insurance is 0.23% — measured relative to replacement value. This level includes all properties, both insured and uninsured. Per ICE's analysis, the objective evaluation of expected annual damages should be around 1.1%; the actual fair premium to be collected is expected to be even higher. For the purpose of our analysis, we assume a 1% flood insurance premium hike measured as additional annual interest on a loan. This will offset various risk-reducing effects (e.g., replacement values being typically lower than loans).

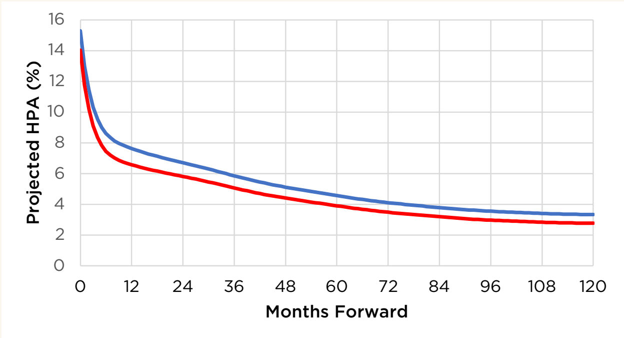
CONVERSION INTO AN HPI OUTLOOK

The economic cost of borrowing is one of the key inputs in AD&Co.'s HPI model. That cost includes mortgage payments, down payment (viewed as another expensive loan), and mortgage insurance (if any). While we didn't explicitly consider the cost of property insurance (or other costs such as real estate taxes and fees), these can be easily added to the model's tuning process.

To illustrate the cost-conversion process, Figure 3 depicts two lines for the Florida home price index (HPI) and the home price appreciation (HPA) rate. The blue lines are from AD&Co.'s HPI3 model. The red lines reflect the downward adjusted outlook coming from the properly increased cost of borrowing (that is equivalent to the increased cost of flood insurance).

Figure 3. Projected HPI and HPA for Florida





ECONOMICS OF LOAN GUARANTEES

Finding a large effect on the base-case economics is not expected, given the positive trend in the housing market. The two projected HPI lines (Figure 3) point to appreciation, even if they differ by 4.5% in 5 years and by 7.7% in 10 years. On the other hand, in a strong downturn, the same relative depression may matter in estimating loan performance.

To solve for the guarantee fee and economic capital, we apply our Capital Charge methodology as described in Davidson and Levin (2014). The method requires two inputs: return on equity (ROE) (taken as 8%) and protection confidence (set to 99%). We then formulate two conditions:

- The expected ROE computed from all cash flow components (premium, losses, release of capital) should be equal to the given target, and
- Given the protection confidence level, the erosion of capital is at or below the worst scenario.

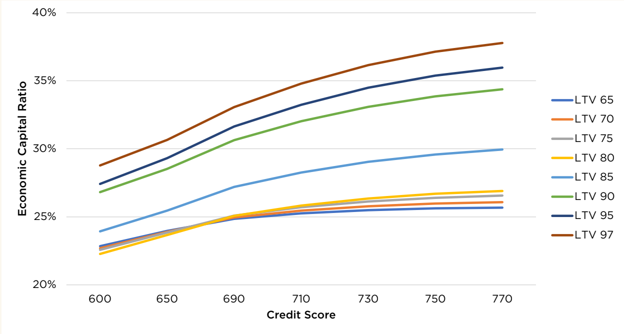
The method is implemented on the AD&Co. standard 20-scenario grid, and available in the LoanKinetics system.[2] The equivalent climate-induced short-term HPA and long-term HPA dials get added to the already existing dials that define the 20 scenarios. Note that the base-cases loss expectation contributes minimally to the guarantee fee, which depends mainly on unexpected losses and is computed concurrently with economic capital.

RESULTS

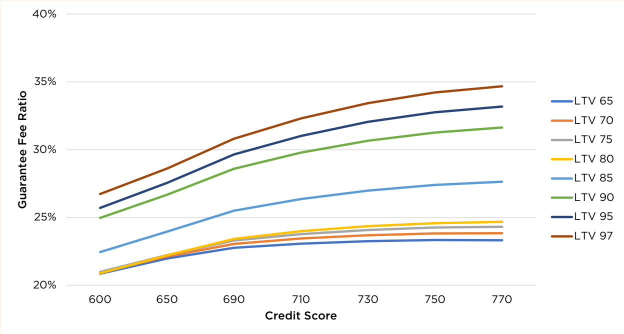
For a range of FICO and original LTV (OLTV) typically utilized for credit analyses of GSE loans, Figure 4 depicts economic capital and annual guarantee fee, both stated relative to the values obtained for the current cost of flood insurance. Note that standard private mortgage insurance (PMI) is assumed for above-80 OLTV loans. The analysis uses market conditions as of 9/30/2022.

Figure 4. Guarantee Fee and Capital Increase from the Spike in Flood Insurance Premium

Economic Capital



Guarantee Fee



The perceived spike in the cost of flood insurance results in a 20% to 35% increase in the cost of GSE guarantees, as well as economic capital. Within this range, the relative increase is somewhat stronger for high-FICO loans and also for high-LTV loans. This dependence on FICO is consistent with the observation that lower-quality borrowers are less sensitive to economic drivers, in general. Given the FICO level, higher-LTV loans tend to be more sensitive to HPA, even if they carry PMI (which provides limited protection).

The dependence of these ratios on the chosen levels of ROE and confidence is very modest and does not warrant a separate review.

RELATIVE EFFECT AS A FUNCTION OF MARKET

Our analysis used market conditions as of September 30, 2022. Interest rates had been much lower prior to 2022 and the HPI outlooks had been stronger posing the following question: How is the theoretical effect we attempt to measure affected by market conditions?

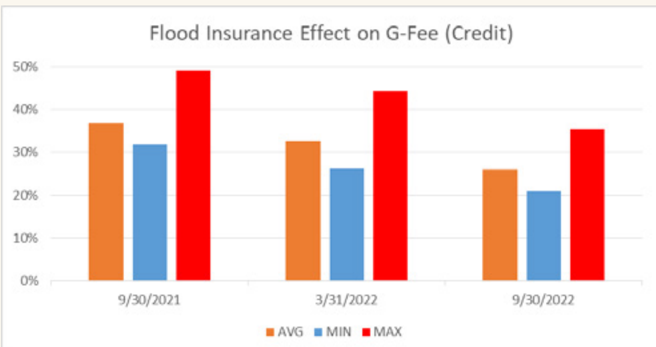
One obvious effect we can identify is the relative decline of the spike in flood insurance cost once it is compared with the increased loan payment. Therefore, we expect that the higher loan rates have recently reduced the effect of climate-related cost increase.

2. Scenario 7 represents a base case whereas scenarios 8 to 19 reflect credit stresses in increasing order. The stresses are achieved by a combination of economic stresses (home prices, interest rates) coupled with adverse model errors.

Another driver is the credit outlook. When it improves, the same spike in cost will mean more, on a relative basis. Figure 5 illustrates these concepts presenting minimal, maximal, and average effects from the OLTV/FICO permutation table, for three points of history.

Figure 5. Effect of Market Conditions

	9/30/21	3/30/22	9/30/22
Primary Rate	3.00%	4.74%	6.79%
1% to Total Cost	13.6%	11.9%	10.3%
HPI Outlook	Very Strong	Positive	Moderate



The role of a 1% increase in flood insurance represented 13.6% of the borrower total cost on 9/30/2021; it fell to 11.9% on 3/31/2022 and to 10.3% on 9/30/2022. The HPI outlook has worsened as well. These market factors would explain the gradual decline in the climate-induced effect over time; it was stronger a year ago. As seen from Figure 5, across the range of FICO, OLTV, and market conditions, the relative increase in g-fee ranges from 20% to 50%.

Conclusions

The incorporation of property-level climate risk forecasts as encapsulated in rising insurance premiums marks a significant step in the evolution of mortgage models, which have gone from generic pool-level models, to loan-level models which have begun to use information of increasing granularity on borrowers and properties.

The forecasting of granular economic drivers, such as increased insurance cost, the ability to distinguish regions with greater and slower property tax cost increases, and, down the road, the ability to identify second order local economic impacts from differences in climate risk are potential future developments. The current article describes work that is a small initial step in this direction.

Among other findings, we assess that the g-fee or the economic capital for loans in Florida would go up 20% to 50% from their present levels — using the diminished, cost-adjusted, HPI outlook alone. This range covers permutations of FICO, OLTV, and starting economic conditions.

Appendix: A Summary of AD&Co.'s Models Used for this Study

INTEREST RATE MODEL

AD&Co.'s library of term structure models includes three one-factor short-rate models (Hull-White, Black-Karasinski, and Squared Gaussian including "shifted" variations) and a two-factor Gaussian model; the Hull-White model is offered by default and used for this study. Any model is instantly calibrated to a swap or Treasury curve and a matrix of at-the-money (ATM) swaptions.

LOAN DYNAMICS MODEL (LDM)

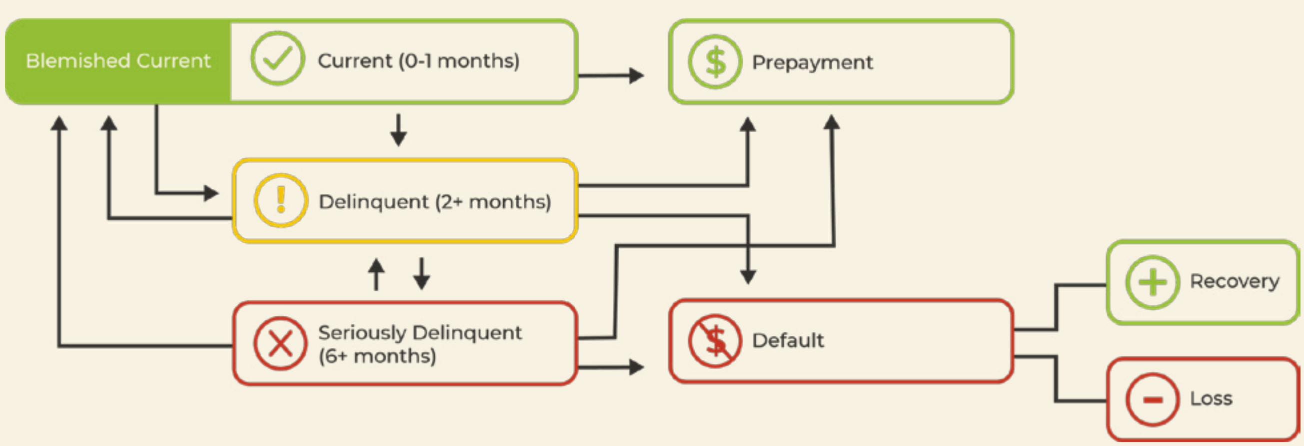
Given loan characteristics and a user-driven scenario for interest rate and house-price indices, the LDM forecasts, on a loan level or portfolio level, time series vectors for CPR, CDR, 60+ and 180+ day delinquency rates, loss severity, and cumulative loss. LDM features an open architecture that gives the user the flexibility to tune the model to better reflect the user's specific expectations regarding the behavior of their loans. LDM extends the traditional "two-state" competing risks model that forecasts only prepayments and defaults to include forecasts for a number of loan transitions as shown in Figure A1. AD&Co. has condensed the number of transitions to those which have sound economic rationale and the greatest impact on investment performance.

The model is unified across credit sector (confirming, jumbo prime, subprime, Alt-A/B, High LTV) and product type (fixed, adjustable, hybrid, IOs, first and second lien) and relies on observed loan characteristics (i.e., data available in the typical servicing system file) to make its projections. As a result, users are not required to make potentially arbitrary judgments about credit sector or product type. Users can apply the model to pools of loans containing a wide mix of underlying collateral. Key drivers are loan characteristics such as LTV, FICO, doc type, state, original loan balance, the paths of future interest rates, HPI, and unemployment. LDM is also capable of handling recent legislative/social events such as loan modifications.

HOME PRICE MODEL

AD&Co.'s Home Price Model is a non-econometric stochastic simulator. It captures a home price volatility pattern and its relationship to interest rates in a way that is consistent with empirical evidence. With the exception of interest rates, it does not relate future home prices to economic factors (which need forecasting themselves). A core model is developed from five indices: the 25-MSA Composite, Los Angeles, Miami, New York, and Phoenix. National HPA, State, and MSA level derived indices are modeled using AD&Co.'s Geographical Localizer.

Figure A1. **LDM Flowchart**



The full model includes four factors: (1) Total borrower cost including loan payment, down-payment, cost of MI, and underpriced credit risk (if any), (2) Income inflation, (3) HPA diffusion (systematic trend), and (4) HPA jump (non-systematic shocks). The ratio of (2) to (1) can be viewed as affordability index, a key driver of HPI equilibrium. The income inflation is linked to the yield curve and an unemployment factor.

Factors (3) and (4) are gauged from the actual HPA and separated by the mean of Kalman filtering. A strong (weak) historical HPA improves (deteriorates) model's forecast. Thus, the actual HPA series is a key input into the model.

The model can also be tuned to utilize the user's own HPI outlook or market median.

UNEMPLOYMENT MODEL

AD&Co.'s Unemployment Model uses home prices and a short rate as its drivers. The model is split into two components: logistic regression for unemployment's "equilibrium," and a differential equation (auto-regression) gradually moving the most recent level towards equilibrium. With slight parameter adjustments, the US model works well geographically.

The unemployment model is also utilized in the Loan Dynamics Model.

20-CREDIT SCENARIO GRID MODEL AND 3-PART VASICEK PROBABILITY MODEL

The Credit Scenario Grid contains a set of 20 engineered stress scenarios ranging from best, to base case, to worst. The Credit Scenario Grid settings are updated as needed by AD&Co. Each scenario in the grid contains interest rate shifts, home-price shocks, and dials for the integrated AD&Co. LoanDynamics Model (prepayment and default). The Credit Scenario Grid settings incorporate adverse model error in the extreme scenarios. The extreme scenarios include both economic shocks and model shocks.

These 20 pessimistic scenarios are used to forecast the performance of each loan in terms of its likelihood to prepay, become delinquent, default, and generate a loss of a certain size. Modifying standard Vasicek theory to take into account scenarios where a loan has neither a 0% likelihood of default nor a 100% likelihood of default, AD&Co. has derived a Cumulative Distribution Function (CDF) for the 20 scenarios. The results of each of the scenarios within the Credit Scenario Grid are weighted based on their marginal likelihood of occurrence. A probability weighted loss across all scenarios within the grid can be used to project the average loss (or reserve) for a loan, whereas the probability weighted loss in the chosen tail of extremely adverse portion of the distribution can be characterized as the Expected Shortfall (capital requirement). Our research shows that this three-part Vasicek approach captures the tail risk inherent in extremely adverse scenarios, which would otherwise only be simulated using a Monte Carlo approach with a vast number of paths.

CAPITAL CHARGE METHOD

In the absence of a benchmark market, the Capital Charge Method allows for computing cost of credit protection and required economic capital. As such, the method is well tailored to working with standard mortgage insurance (MI), hypothetical deep insurance, or a full government guarantee. For details of the method and its derivations, see Davidson and Levin (2014).

The formulas of the method and its inputs and outputs are shown below:

$$P = L(R)+L_{ES}(r)(R - r)IOM(R)$$

$$c = L_{ES}(r) - P$$

$$p=P/IOM(r)$$

Where:

- L is average loss
- L_{ES} is the expected shortfall (average loss in the tail at a given confidence level)
- r is relevant riskless rate
- R is target return on equity (ROE)
- *IOM* is the *IO* Multiple that is commensurate with the premium stream. The rate in parentheses is used for discounting.

The outputs from running the Capital Charge Method are detailed below:

- P — Single up-front premium
- p — Annual premium rate
- c — Economic capital

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