Climate risk and credit risk of housing loans portfolios: Evidence from USA

Lucia Gibilaro
LUMSA Univerisity
e-mail l.gibilaro@lumsa.it

Gianluca Mattarocci
(corresponding author)
Tor Vergata University of Rome
e-mail gianluca.mattarocci@uniroma2.it

Abstract

Climate change increased the frequency of extreme and unpredictable weather events that may affect negatively not only companies but also homeowners. Individuals may suffer of significant losses due to this type of event and frequently their risk profile may be increase. Financial institutions may be significantly exposed to losses related to hurricanes, fires, floods, or draught because the main guarantee for home loans could lose value after the event.
The paper aims to investigate if lending policies are affected by the climate risk exposure and if there is a significant difference in expected loss for a portfolio exposed on areas affected by the extreme weather events. The empirical analysis considers a representative sample of housing loans offered in the United States and evaluates the impact on the lending policies and risk over the time period 2018-2022. Results show that lending policies adopted by financial institutions are not ex-ante affected by the climate risk exposure but ex- post the probability of default and the Loss Given Default changes due to an extreme weather event.

Keywords: climate risk, catastrophe risk, probability of default, loss given default

EFM codes: 510, 780, 520

1. Introduction

Losses from weather disaster in the past decades has been decidedly noticeable, if not unprecedented, determining incommensurable damages globally to human capital and physical assets, due to the manifestation of extreme events and climate change (Oxera, 2024). The risk of extreme events and climate change depends on the conjecture of natural hazards, that can cause e potentially damaging phenomenon on a given time horizon, and socio-economic vulnerability (UN Department of Humanitarian Affairs, 1992). The prediction of such risk is mainly concerned with short term time horizon, assuming known hazards and present vulnerability, while climate change has a long term nature manifesting over the course of decades or century (O'Mahony, 2021). In particular, the degree of vulnerability depends on human infrastructures and socio-economic conditions and copying mechanisms are often classified as protection, dealing with the built environment, and risk mitigation, based on socio-economic responses (Downing et al., 2002).

Among the multifaced consequences of vulnerability to the manifestation of extreme events and climate change effects, there is the impact on the capability of banks to extend loans and the ability of debtors to repay (Batten, Sowerbutts and Tanaka, 2016). Literature shows that financial institutions react to the climate risk by changing their lending policies and credit standards in order to reduce their exposure to losses but there is not a clear evidence on the impact of the expected loss drivers due to a climate risk exposure.

The paper investigates the impact of weather disaster on the credit risk exposure by considering the insolvency risk and the recovery risk and evaluate the change in the risk exposure of the banks' portfolio once the extreme event happens. Results show that banks are not changing significantly the lending policies in areas that are more or less affected by this type

2. Literature review

The capacity of banks' lending to debtors affected by extreme events can be threatened by the losses deriving from the increase in the frequency of defaults and the reduction of the collaterals value if they are not able to raise new equity, even though empirical evidence show that the consequences are mitigated in countries with a rigorous financial regulation and supervision (Klomp, 2014). Additionally, the increased demand for precautionary liquidity by affected customers can determine the reduction in cash reserves and deposits impacting the bank intermediation (de Bandt et al., 2024), even though unaffected depositors may respond to actual or perceived uncertainty by increasing cash holdings (Deissaint and Matray, 2017). As a consequence, the scope of the diversification of banking activity can contribute to the flexibility in the lending after the manifestation on an extreme event as the loan volume distributed by the branch units of smaller banks are found to deteriorate (Bayangos, Cachuela, and Del Prado, 2021).Looking at diversified banks, it is to underline the spillover effects that extreme events can determine on the offer of credit in unaffected areas due to portfolio reshuffling to support debtors in affected areas (Cortés and Strahan, 2017), that only partially is offset by shadow banks (Ivanov et al., 2022).

The ability of affected debtors to repay debts after the manifestation of an extreme event can be strongly compromised due to the damages suffered by human capital and physical assets, particularly when the debtor is financially fragile (Ratcliffe at al., 2020), even though the overall macroeconomic impact can be less impressive compared with the damages suffered due to the replacement production and disaster-rescue activities (Horwic, 2000) and new investments that can boost the economy (Hallegate, Hourcade, Dumas, 2007). The persistence and the length of the effects of the extreme event are crucial in transforming temporary delinquency in credit risk: such evolution can be avoided due to mitigation, like insurance, government aid (Gallagher and Hartley, 2017). Looking at the natural disaster type, the availability of such mitigation instruments can also lead to inefficient condition for term loan financiers after the manifestation of a wildfire, as low indebted affected debtors can use funds to prepay, as available fund from the insurance would be insufficient to rebuild (Biswas, Hossain, Zink, 2023) raising the risk transformation for the creditor from counterparty risk to interest rate risk. Different results are observed for risky loans: extreme events determine effects on nonperforming loans lasting till 5 years and amplifying the risk of the loan (Chan, Zhou and Chang, 2024). With the manifestation of flooding events, it is observed a moderate increase in the probability of default, that becomes irrelevant under recourse to mitigation measures, required in some areas and protecting both the debtor from loan delinquency and the creditor from severe losses (Kousky, Palim and Pan, 2020) and high income of affected households, that are found to populate high risk flooding areas (Garbarino and Guin, 2021). When considering small economic activities, the increase of the risk of affected debtors by flooding events is relevant, also considering the modest coverage insurance due to the low willingness to pay to avoid flood risks (Skevas, Massey and Hunt, 2023). Focusing on the indirect effects of extreme events like heats and droughts, the empirical investigations are more limited. Households retain that the ability to repay insured loans can be affected when associated with other extreme events like wildfires or storms, while limited concern is expressed for drought (Kurowski and Sokal, 2023): as a consequence, alternative approaches like stress testing of loan repayment based on macroeconomic analyses can be implemented (Breaden, 2023). The repayment of the loans extended to households affected by the expected increase of the sea level would rely on governmental financial aid as insurers are expected to reduce the supply of insurance by retreating from the existing contracts (Storey et. al., 2024).

In light of the observation of the impact of the manifestation of extreme events and climate change, banks can adapt lending policies (Berg and Schrader, 2012) that are highly vulnerable to disasters (Boucher, Carter and Guirkinger, 2008), both in lending to firms (Huang et al., 2022) and households (Skoufias, 2003) as institutional investors consider physical risk affecting their portfolio in a two years time horizon (Krueger, Sautner and Starks, 2020)

Looking at pricing, the impact of physical risk on loan spreads is found to determine, on average, a quarter of percentage point increase for one unit increase in the exposure to the underlying types of climate risk (de Bandt et al., 2024): firms in locations with higher exposure to climate change pay higher spreads on their bank loans (Javadi and Al Masum, 2022) consistently with evidence observed for loans collateralized by real estate properties exposed to a greater risk of sea level rise (Nguyen et al., 2022). Considering the risk of draught, borrowers affected by extreme conditions are found to face tighter conditions, in particular in the food industry, even though low financial risk is acting like mitigator of risk (Do et al., 2020) while insurance is not considered a viable solution to avoid the increase of loan spreads in the mining industry (Pinto-Guterriez, 2023). Physical risk is found also impacting the pricing of loans of debtors at risk, but unaffected by natural disasters: in the aftermath of the event, the magnitude of the increase of the loan spread can be equivalent to a one notch rating downgrade, in particular for bank dependent borrowers, that can be attributed only partially to higher credit risk, but it is due to salience amplified by investors attention (Correa et., 2023)

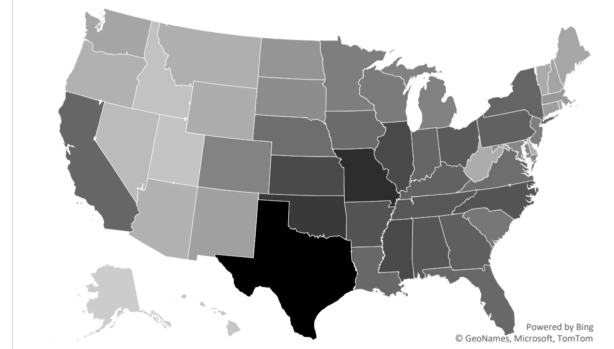
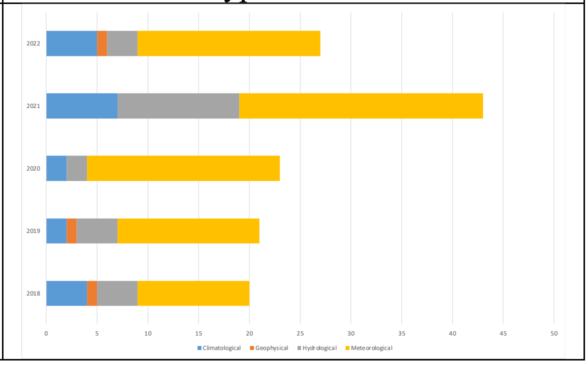
Regarding lending standards, available empirical evidence shows that largest US banks reduced lending to areas suffering from floods and wildfires, even though the contraction of lending is significant only for high levered debtors (Meisenzahl, 2023). Considering extreme events affecting the local economy and local banks, lending standards tightens in disaster-hit counties since they expect long lasting effects impacting the local economy, even though such adaptation of lending standards does not affect subprime loans and counties for which the belief of increase of climate change is low (Duanmu et al., 2021). Local banks can allevieting the impact of damages due to natural disaster increasing the amount of the credit offered to address liquidity needs of affected debtor (Schubert,2024) even though they can be exposed to the same risk of the territory they serve (Pagliari, 2023).

3. Empirical analysis

3.1 Sample

The climate risk analysis considers all the events registered from 2018 to 2022 in the United States by considering all the different types of events that may be related to climate change (Graph 1).

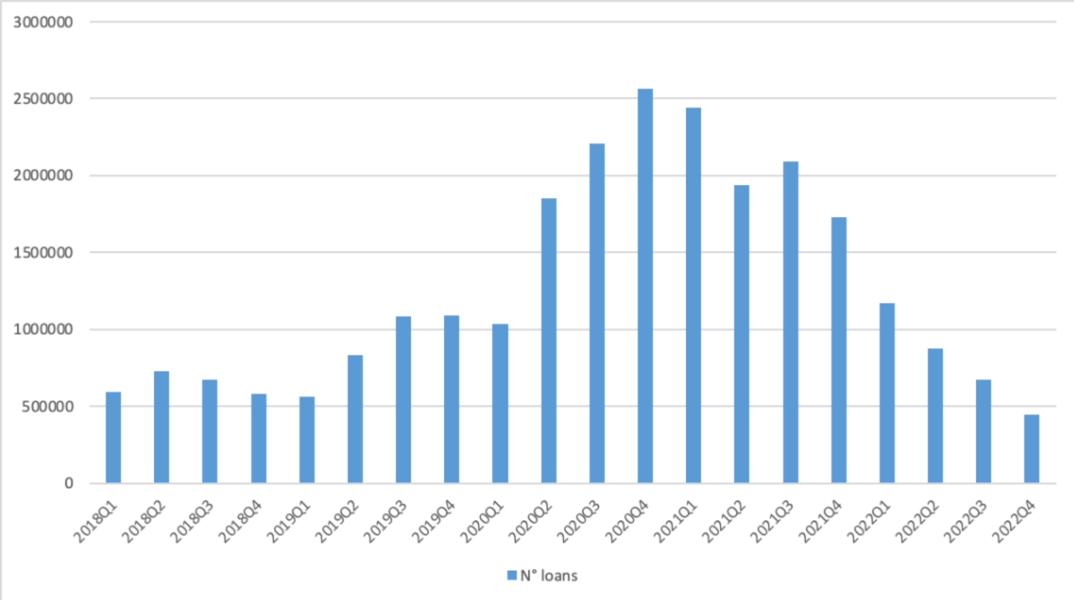
Graph 1. Climate risk dataset

Country analysis	Type of event
	

Source: EM-DAT data processed by the authors

Countries more affected by climate events are Alabama, Arkansas, California, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, Tennessee, and Texas, which were affected by at least 30 events over the time period selected. Events are mainly related to meteorological events (64.2%), Hydrological (18.7%), and climatological (14.9%).
The data about mortgages considers all the loans included in the single-family loan-level dataset provided by Freddie Mac for the period 2018-2022.

Figure 2. Loans dataset



Source: Freddie Mac data processed by the authors

The sample considers 25,164,429 new loans generated in the time horizon 2018-2022, and for each of the quarters, we have at the minimum 222,225 (4th quarter of 2022) and at the maximum 1,282,769 loans (4th quarter of 2020) new mortgages. For each loan data about the contract features are available and every quarter is possible to monitor

3.2 Methodology

The analysis of the recovery risk will consider the probability of default by using the definition of the 90 days past due adopted in the Basel III agreements and without applying any materiality threshold. In formula:

$$PD_i = \begin{cases} 1 \; if \; past \; due \geq 90 \; days \\ 0 \; otherwise \end{cases} \tag{1}$$

The analysis will compare Countries more and less exposed to climate risk in order to measure significant differences in the probability of default by considering all the loans and only the loans that did not went into default only due to the extreme climate event.

The analysis of the risk of recovery considers for the defaulted entities two proxies of the loss given default computed as follows:

$$LGD_i = \frac{Net \; sales \; proceeds_i}{Deferred \; UPB_i} \tag{2}$$

The analysis will compare Countries more and less exposed to climate risk in order to measure significant differences in the probability of default by considering all the loans and only the loans that did not went into default only due to the extreme climate event.

The last analysis will consider for each country affected by extreme weather events the time necessary to re-align the credit risk exposure (measured by PD and LGD) to the comparable values with respect to other countries.

3.3 Results

The comparison of borrowers' features living areas that are more and less affected by climate risk events allow to identify some interesting differences.

Table 1. Climate risk exposure and lending contract features

	Climate risk	2018	2019	2020	2021	2022
Score	High	748.83	754.02	759.27	751.92	744.98
	Low	749.72	754.61	761.28	752.52	747.17
LTV	High	75.83%	75.69%	73.39%	68.23%	73.13%
	Low	76.85%	75.59%	67.93%	70.59%	73.25%
Interest Rate	High	4.74%	4.15%	3.11%	2.96%	4.73%
	Low	4.75%	4.16%	3.08%	2.96%	4.75%
DTI	High	46.10%	35.92%	32.57%	34.50%	36.91%
	Low	44.73%	35.58%	33.62%	33.48%	36.67%
Term (n° months)	High	334.61	330.31	311.87	322.00	336.48
	Low	334.46	334.56	320.96	315.07	338.03
Number of borrowers	High	1.46	1.47	1.48	1.47	1.45
	Low	1.49	1.49	1.52	1.48	1.46

Source: Freddie Mac and EM-DAT data processed by the authors

Areas that are more affected by climate risk have on average worse customers in terms of their credit score and even if is small the gap it does not change significantly over time.
The amount financed measure by the combined load to value does not show difference on the basis of the climate risk exposure of the area and on average lenders finance from the 60% to 80% of the housing value.
Interest rates are not significantly different between areas that have a different degree of exposure to climate risk events also because the focus is only on residential mortgage loans for which banks are more interested to cross selling opportunities than on profitability of the financial service offered.
The mortgage sustainability is normally measured by the debt-to-income ratio, and values higher that 36% are normally considered critical for the borrower. The sustainability of the debt is lower in the areas that are more affected by climate risk because the DTI is significantly higher and frequently is near or even higher than the critical threshold[1].

[1] The database does not consider loans with DTI higher than 45% at the origination stage because they are not eligible for sale to Freddie Mac.

The term of the mortgage is normally from 25 to 30 years and the contract terms do not change on the basis of the exposure to climate risk. Loan applications are frequently done by more than one borrower in all the areas and the frequency of mortgage with 2 or 3 borrowers is higher in areas less exposed to climate risk than the rest of the country.
The analysis of the change in climate risk exposure shows the same results highlighted by the previous analysis and there is no clear link between contract features and increase or decrease of the frequency of climate events (Table 2).

Table 2. Climate risk exposure change and lending contract features

	Climate risk	2018	2019	2020	2021	2022
Score	Growing	748.69	753.83	759.81	752.91	745.09
	Decreasing	749.97	754.50	761.33	753.09	745.62
LTV	Growing	74.09%	74.21%	71.45%	68.59%	75.21%
	Decreasing	77.51%	75.82%	68.33%	69.78%	72.55%
Interest Rate	Growing	4.74%	4.14%	3.11%	2.94%	4.84%
	Decreasing	4.74%	4.16%	3.08%	3.00%	4.71%
DTI	Growing	47.57%	36.06%	32.99%	34.26%	36.05%
	Decreasing	44.67%	36.05%	33.49%	34.40%	37.11%
Term (n° months)	Growing	338.32	331.77	317.98	318.82	334.05
	Decreasing	332.24	333.06	317.57	321.38	337.26
Number of borrowers	Growing	1.49	1.49	1.50	1.48	1.42
	Decreasing	1.46	1.47	1.50	1.46	1.46

Source: Freddie Mac and EM-DAT data processed by the authors

4. Conclusion

Climate change is expected to represent a key issue for the future and supervisory authorities are currently taking care about how to manage properly this type of risk for the financial institutions (FSB, 2025). Risk management has to monitor the climate risk and include these features in the pricing formulas in order to avoid the risk of losses and in order to reduce a risk of contagion in the financial system (GARP, 2019).
Empirical evidence provided show that even if the risk exists there are no differences in the main contract features for areas more or less exposed to risk. In the short financial institutions do not react to the climate risk by modifying the pricing or the other conditions for the loan. The analysis of the risk after a catastrophic event show that, as expected, both the average probability of default and the loss given default increases and it requires some years in order to adjust back to values that are more in line with the average market conditions.
Further investigations are necessary for understanding how to adapt regulation for measuring the climate risk and avoid losses for the banks' portfolio. Moreover an analysis of the loan portfolio dynamics may help in identifying the public intervention solutions that may be more effective in supporting households affected by this type of extreme events. The increasing frequency of climate related extreme events has been already considered by the supervisory authorities but more detailed criteria are needed for measuring credit scores that includes also climate exposure and risk adjusted values of the guarantees.

References

Bayangos, V., Cachuela, R. and Del Prado, F. (2021), "Impact of extreme weather episodes on the Philippine banking sector—Evidence using branch-level supervisory data", *Latin American Journal of Central Banking*, vo.2, n.1, p.1–18.

Batten S., Sowerbutts R. and Tanaka M. (2016), "Let's talk about the weather: the impact of climate change on central banks", *Staff Working Paper*, n. 603

Berg G., Schrader J. (2012), "Access to credit, natural disasters, and relationship lending", *Journal of Financial Intermediation*, vol. 21, n. 4, p. 549-568

Biswas S., Hossain M., Zink D. (2023), "California Wildfires, Property Damage, and Mortgage Repayment", *Federal Reserve Bank Philadelphia*, working paper, n.23-05

Boucher, S., Carter, M. and Guirkinger, C. (2008), "Risk rationing and wealth effects in credit markets: Theory and implications for agricultural development", *American Journal of Agricultural Economics*, vol.90, n.2, p. 409–423.

Breeden L. (2023), "Impacts of Drought on Loan Repayment". *Journal of Risk and Financial Management*, vol.16, n.2, p.85

Chen X., Zhao X., Chun-Ping Chang C. (2023), The shocks of natural disasters on NPLs: Global evidence, *Economic Systems*, vol. 47, n.1, 101050

de Bandt O., Kuntz L., Pankratz N., Pegoraro F., Solheim H., Sutton G., Takeyama A., Xia F. (2024), *The effects of climate change-related risks on banks: A literature review, Journal of Economic Surveys,* 1-42

Correa, R., He A., Herpfer C. , and Lel U. (2022), "The rising tide lifts some interest rates: climate change, natural disasters, and loan pricing," *International Finance Discussion Papers* 1345. Washington: Board of Governors of the Federal Reserve System

Cortés K., Strahan P. (2017), "Tracing out capital flows: How financially integrated banks respond to natural disasters", *Journal of Financial Economics*, vol. 125, n.1, p.182-199

Dessaint, O., and Matray, A. (2017), "Do managers overreact to salient risks? Evidence from hurricane strikes", *Journal of Financial Economics*, vol. 126, n.1, p. 97–121.

Do, V., Nguyen, T. H., Truong, C., and Vu, T. (2021), "Is drought risk priced in private debt contracts?", *International Review of Finance*, vol.21, n.2,p. 724–737.

Downing, T.E., Greener, R.A. and Eyre, N. (1994) Global Emissions and Impacts, Report to the International Energy Agency, *Environmental Change Unit*, Oxford

Downing T., Gawith M., Olsthoorn A., Tol R. and Vellinga P. (2002), Introduction, in Downing T., Olsthoorn A., Tol R. , *Climate, Change and Risk*, Routledge, London

Duanmu, J., Li, Y., Lin, M., and Tahsin, S. (2021), "Natural Disaster Risk and Residential Mortgage Lending Standards", *Journal of Real Estate Research*, vol. 44, n.1, p.106–130.

FSB (2025), The Relevance of Transition Plans for Financial Stability, available at https://www.fsb.org/ (accessed January 10th, 2025).

Gallagher, J. and Hartley, D. (2017), "Household Finance After a Natural Disaster: The Case of Hurricane Katrina", *American Economic Journal: Economic Policy*, vol. 9, n.3 p. 199–228,

Gallagher, J., Hartley, D. and Rohlin, S. (2023), "Weathering an Unexpected Financial Shock: The Role of Federal Disaster Assistance on Household Finance and Business Survival". *Journal of the Association of Environmental and Resource Economists,* vol. 10, n.2 p. 525–567

Garbarino, N. and Guin, B. (2021),"High water, no marks? Biased lending after extreme weather", *Journal of Financial Stability*, 54, 100874

GARP (2019), Climate risk management at financial firms. Challenges and opportunities. Available at https://www.garp.org/ (accessed January 10th, 2025).

Hallegatte S., Hourcade J., Dumas P. (2007), "Why economic dynamics matter in assessing climate change damages: Illustration on extreme events", *Ecological Economics*, vol 62, n. 2, p. 330-340

Horwich, G. (2000), "Economic Lessons of the Kobe Earthquake." *Economic Development and Cultural Change,* vol. 48, n. 3, p. 521–42.

Huang H., Kerstein J. Wang C., Feng W. (2022), "Firm climate risk, risk management, and bank loan financing", *Strategic Management Journal*, vol.43, n.3, p.- 2849-2880

Ivanov I., Macchiavelli M., Santos J.(2022), "Bank lending networks and the propagation of natural disasters", *Financial Management*, vol.51, p.903–927.

Javadi S. and Al Masum A. (2021), "The Impact of Climate Change on the Cost of Bank Loans", *Journal of Corporate Finance*, vol. 69, 102019.

Klomp J. (2014), 'Financial fragility and natural disasters: An empirical analysis', *Journal of Financial Stability*, vol. 13(C), p. 180-192.

Kousky, C., Palim, M., Pan, Y. (2020), "Flood damage and mortgage credit risk: A case study of hurricane Harvey", *Journal of Housing Research*, vol.29, n.1, p. 86–120.

Krueger, P., Sautner, Z. and Starks, L. (2020), The importance of climate risks for institutional investors. *Review of Financial Studies*, vol.33, p. 1067–1111.

Kurowski, Ł., & Sokal, K. (2023). "Polish household default risk and physical risk of climate change", *Financial Internet Quarterly*, vol.19, n. 3, p.87–99.

Meisenzahl, R. (2023). "How climate change shapes bank lending: Evidence from portfolio reallocation", *Working paper,* n. 12, Federal Reserve Bank of Chicago.

Nguyen, D., Ongena S., Qi S., and Sila V. (2022), “Climate Change Risk and the Cost of Mortgage Credit”, *Review of Finance*, vol 26, 1509–1549.

O'Mahony T.(2021), Cost-Benefit Analysis and the environment: The time horizon is of the essence, *Environmental Impact Assessment Review*, Vol. 89, p.106587

Ouazad A. and Kahn M. (2022), “Mortgage Finance and Climate Change: Securitization Dynamics in the Aftermath of Natural Disasters”, *The Review of Financial Studies*, vol. 35, n. 8, p. 3617–3665

Oxera (2024), “The economic cost of extreme weather events”, *ICC report*, November , https://iccwbo.org/, 12/12/2024

Pagliari, M. S. (2023), “LSIs’ exposures to climate change related risks: An approach to assess physical risks”, *International Journal of Central Banking*, vol. 19, n1, p.1–54.

Pinto-Gutierrez C. (2023), *“*Drought risk and the cost of debt in the mining industry*”, Resources Policy,* vol.83, p.1–10

Ratcliffe, C., Congdon, W., Teles, D., Stanczyk, A., & Martín, C. (2020), “From Bad to Worse: Natural Disasters and Financial Health”, *Journal of Housing Research*, vo.29, sup1, p.S25–S53

Schubert, V, (2024), “Recovery Lending After Natural Disasters”, SSRN, Available at SSRN: https://ssrn.com/abstract=4703598 or http://dx.doi.org/10.2139/ssrn.4703598

Skevas T., Massey R., Hunt S. (2023), “Farm impacts of the 2019 Missouri River floods and economic valuation of flood risk reduction”, *Journal of Environmental Management*, vol.344 118483

Skoufias E. (2003), “Economic Crises and Natural Disasters: Coping Strategies and Policy Implications”, *World Development*, vol. 31, n. 7, p. 1087-1102

Storey K., Qwen S., Zammit C. and Noy I. (2024), “Insurance retreat in residential properties from future sea level rise in Aotearoa New Zealand”, *Climate Change*, vol. 177, n. 44