



Climate change related credit risk

Case study for U.S. mortgage loans

May 2021, Roland Walles, Rutger Jansen and Marco Folpmers



Quantifying climate change related credit risk in banking

There is an increasing importance for banks to measure climate risk due to climate change. Financial regulators see climate risk as an emerging risk. Banks are expected to incorporate climate risk in their risk management practices. Furthermore, multiple regulators announced stress tests on climate risk. This article describes a case study performed to quantify climate risks in a US mortgage portfolio. The study explores both types of climate risk, physical risk (i.e. flooding) and transition risk (e.g. carbon tax), and their implications for the default risk of a portfolio of mortgages. Furthermore, the physical risk of flooding of the mortgaged home is a statistically significant driver of mortgage defaults in 46 of 50 states.

Climate change impacts today's world as temperature records are broken every year and natural catastrophes become more frequent and intense. A fundamental change to a more sustainable growth path is required to prevent any permanent, devastating consequences of climate change. Financial regulators recognise that such a change may impact the stability of economies.

Financial institutions need to identify, quantify and mitigate the financial risks related to climate change where the financial sector is impacted. In addition, the sector has an active role in combatting climate change and transitioning into a sustainable development trajectory. Financial institutions as well as regulatory authorities are exploring methods for quantifying these climate risks. The BIS publication (see box) already explicitly calls for the development of forward-looking scenario-based analyses of climate-change-related risks.

Climate risk and credit risk

Climate risks can be divided into physical risks and transition risks. *Physical risks* are a direct result of climate change. They include an increased frequency and severity of extreme weather events (e.g. cyclones, floods, and wildfires). Other physical risks are more chronic and long term (e.g. changing weather patterns, and rising sea levels). In this study flood risk is analysed. The study first investigates the default rates of the US mortgage portfolio in relation to floods that have occurred in the past.

On the other hand, *transition risks* relate to the transition into a more sustainable, low carbon economy. These risks may be related to government policy, such as the introduction of a carbon tax. Transition risks can be modelled using scenario analysis, with a future scenario describing a development related to climate change mitigation. Transition risks can result from developments and investments in new

Regulators on Climate related financial risk

Recent publications by supervisory institutions:

- ⦿ The ECB published [guidelines](#) on how it expects institutions to consider climate-related and environmental risks
- ⦿ The EBA's [action plan](#) on sustainable finance announces work on guidelines for ESG risk management
- ⦿ The BIS published [a comprehensive review](#) of approaches to address climate risks within central banks' financial stability mandate
- ⦿ [The EBA's Guidelines](#) on Loan Origination and Monitoring requires ESG criteria to be incorporated in the underwriting processes
- ⦿ EBA launched [a public consultation](#) on draft technical standards on Pillar 3 disclosures of ESG risks

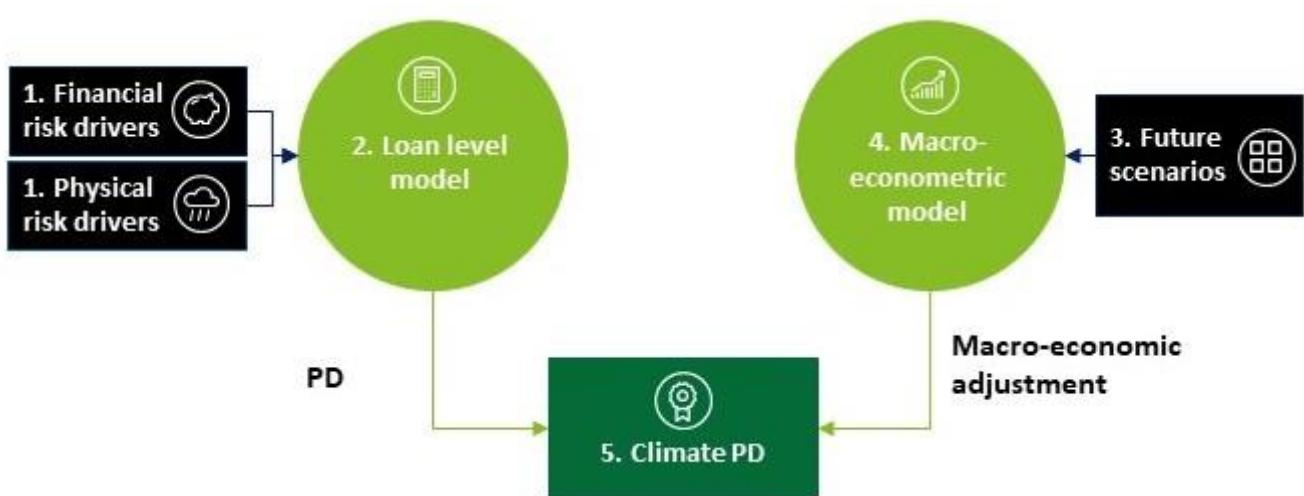


Figure 1 - A schematic overview of the model setup with the physical risk model producing a mortgage loan specific PD. The transition risk model produces a scenario-based prediction of the portfolio default rate.

technologies, changes in consumer behaviour and preferences, as well as costs of raw materials. This can lead traditional factors of production to become economically obsolete. Suppose a significant number of consumers choose to cut down on meat consumption. This change in consumer preferences will lead to a lower demand for products from the meat industry. Meat production is much more labour-intensive than the production of its alternatives. Therefore, the sectoral slowdown in output increases unemployment in the sector because less work is required to meet demand. On average, a rise in unemployment leads to an increase in mortgage loan defaults.

Case study methodology for physical and transition risk

Figure 1 illustrates the set-up of the study and shows how both physical and transition risks are incorporated in the Probability of Default (PD) model for the US mortgage loan portfolio. Physical risk is considered at the loan level. The physical risk considered in this explorative study is flooding. Flood risk is used, together with financial risk drivers, to discriminate in the riskiness of individual loans. The loan level model results in a base PD. In this explorative study the loan level model only depends

on static characteristics of the loan, obligor and collateral at origination. The transition risk is incorporated through scenario analysis. Future transition scenarios are simulated in a macro-econometric model to calculate an adjustment to the base probability of default depending on the scenario. Flood risk drivers are used alongside traditional financial risk drivers in a logit model. This model distinguishes the risk of default of individual mortgage loans. Flood risk depends on the location of a mortgaged home. The risk of financing a home in a flood plain is higher than that of financing a home on a hilltop when all other risk drivers are the same. This set-up disregards that when flooding occurs, multiple loans are affected.

The transition risk is modelled using four transition scenarios. The scenarios were defined by the Dutch central bank in a study of the climate change impact on the Dutch financial sector in the context of an energy transition stress test (Vermeulen et al., 2018). These scenarios are presented in Figure 3.

The four scenarios are the confidence, policy, technology and double shock. A scenario is defined by a time series for the next five years. The technology scenario considers a doubling of the share of renewable energy in the energy mix in the next five years, as well as

write-offs on investments in energy-intensive industries. The policy scenario consists of the introduction of a carbon tax, raising the price of oil and natural gas. The confidence scenario considers a consumer demand decrease of 1% compared to 2019 for the next five years. The last scenario considers a combination of the technology and policy scenarios as a double shock.

This study uses a macro-economic model to estimate the effect of each scenario on the defaults in the mortgage loan portfolio. The macro-economic model consists of a network of econometric relationships. These relationships are captured within statistical models with coefficients estimated based on historical timeseries. The estimated macro-economic model is used as a simulation engine. The simulation is based on a future scenario and the subsequent impact on the development of the economy. This simulation results in a scenario-dependent forecast of key drivers of the portfolio default rate (e.g. the unemployment rate). The annual portfolio default rate is then predicted using a time-series regression model.

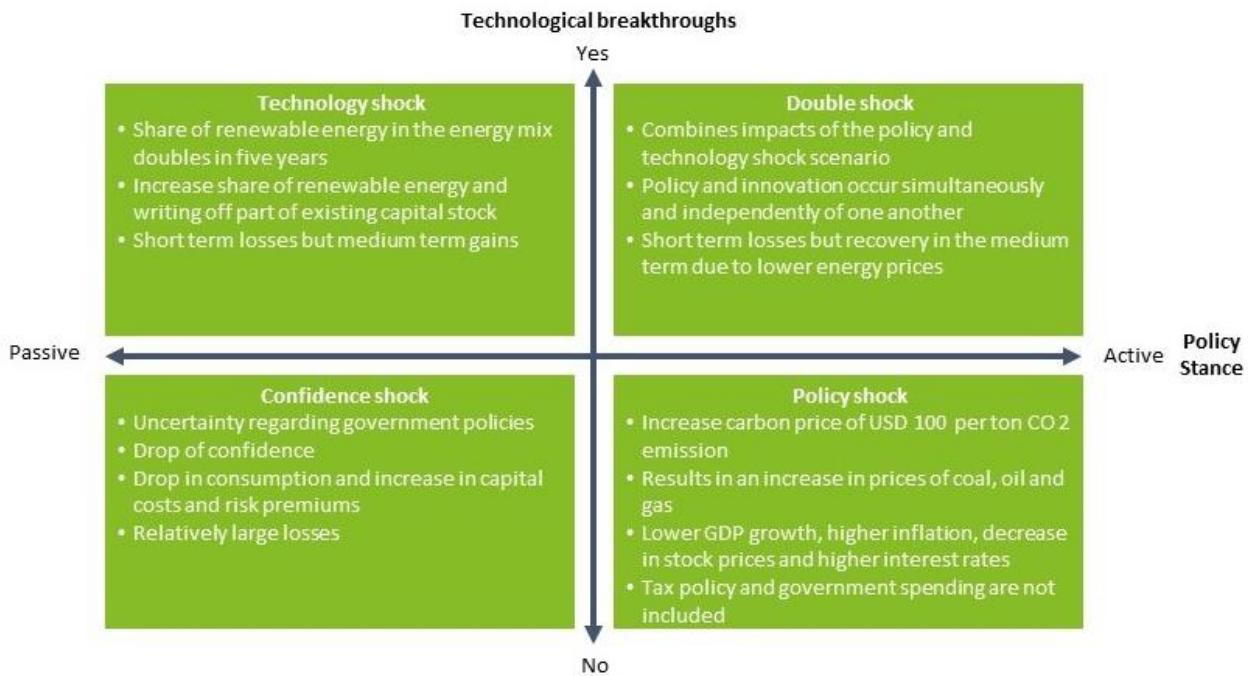


Figure 2 - Description of transition scenarios used.

Source: DNB, An energy transition stress test for the financial system of the Netherlands.

Case study results: Impact flood risk on PD of mortgage loans

There are different drivers of mortgage loan defaults. Conventional default models typically consider financial drivers such as the loan-to-value, the interest rate or the borrower's credit score to determine the risk of default of individual loans. A logit model with financial risk drivers produces an estimate of the PD based on characteristics of the individual mortgage loan.

Physical risks tend to materialise locally. Therefore, specific physical risks such as drought or changing weather patterns may be important drivers for mortgage loan defaults in some states, but less relevant in other states. The approach followed in this study allows the inclusion of physical risk drivers in general in a logit model. Given the local character of physical risks, a specific physical risk can be included in the model for one state but may not be considered in another. For example, a risk driver of wildfires may be important in the model for California, but disregarded in a model for Iowa.

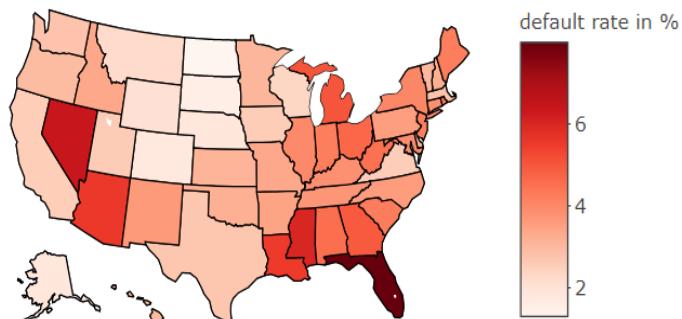


Figure 3 - The default rate between 2000 and 2019 for mortgages in each U.S. state.

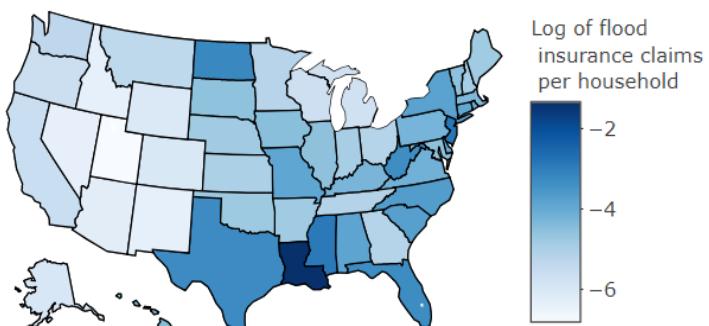


Figure 4 - The natural logarithm of the number of claims in the National Flood Insurance Program per household in the last 50 years as of August 2019.

Figure 3 shows the default rate for mortgage loans in the portfolio for each state between 2000 and 2019. Figure 4 shows the flood risk that each state is exposed to. There is considerable overlap between states that have a high default rate and those that have a high frequency of flood insurance claims. This suggests flood risk drivers can be considered to supplement conventional risk drivers when modeling the PD of the mortgage loan portfolio.

The model coefficients are estimated with historical data that includes a binary variable indicating whether a mortgage loan has defaulted or not during the covered period between 2000 and 2019. The logit model translates this binary value into an estimated PD. A logit model is calibrated for each state. Flood risk is measured with the percentage of National Flood Insurance claims filed per flood zone in the area of the mortgaged property in these logit models. The total number of claims is added as a control variable. A chi-square test for the marginal significance of the flood-related variables shows that flood risk is a driver of the PD in 46 states at the 1% significance level.

Case study results: Impact transition risk on PD of mortgage loans

The macro-economic simulation engine calculates the impact of each scenario on three economic drivers of mortgage loan defaults. These drivers are the unemployment rate, inflation and growth in economic activity. Of these three risk drivers, the unemployment rate is the most important driver of the portfolio default rate. These risk drivers are evaluated for each of the scenarios in Figure 2.

Technology shock

The technology shock scenario leads to a decrease in the unemployment rate. This may indicate that new "green" jobs are created that are associated with renewable energy production. These new jobs lead the technology shock to have the smallest impact on the portfolio default rate.

Policy shock:

In the policy shock scenario, economic output is not impacted. Furthermore, inflation has slightly decreased as a result of indirect effects on industrial prices. Unemployment remains fairly high up to 2023. Therefore the portfolio default rate in this scenario is one of the

highest, because of the high unemployment rate.

Confidence shock

The confidence shock scenario has a large impact on industrial employment resulting in a high unemployment rate as well. However, there is a high degree of uncertainty around this estimate, because the economic system is very sensitive to changes in consumer demand. Inflation remains stable at normal levels. Inflation is indirectly affected by the confidence shock. The large peak of the unemployment rate translates into a peak in the portfolio default rate in this scenario.

Double shock

Lastly, the double shock scenario shows a mix of the results from both the policy and technology shock scenarios. The portfolio default rate for this scenario is in between the technology and policy scenario. This means that the adverse effects of the policy and technology scenarios do not reinforce each other. The effects of the technology shock dominate in the double shock scenario.

Summarising, the scenarios where unemployment is high lead to the

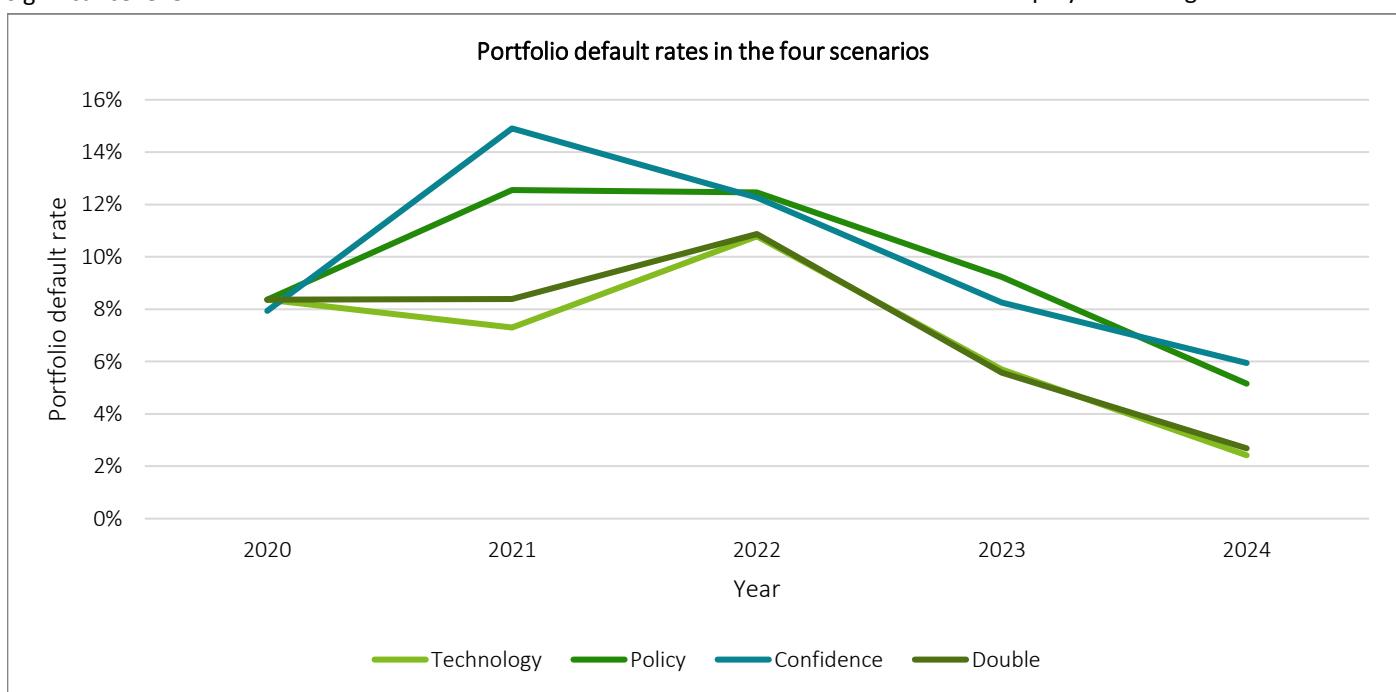


Figure 5 - Point estimates for the portfolio default rate for each of the four scenarios.

highest default rate. The policy shock scenario introduces a carbon tax that is levied on carbon emissions introducing a form of carbon pricing. The introduction of a carbon tax in the policy shock and a drop in consumer expenditure in the confidence shock lead to the highest unemployment rate and therefore also the highest portfolio default rate. In the technology shock scenario the share of renewable energy doubles, and the unemployment rate drops from conventional levels. Therefore, this scenario leads to the lowest default rate of all scenarios.

To estimate the climate PD at the bottom of Figure 1, the physical risk results and the transition risk results must be combined. The logit model with physical risk drivers aims to distinguish in the riskiness of individual loans, independent of time. The transition risk default rate considers the entire portfolio over the next five years in line with the Dutch central bank's scenario horizon. The scenario dependent default rate relative to the historical average default rate can be used as an adjustment factor on the physical risk PD to derive the climate PD.

Considerations and next steps

In the context of a logit model, flood risk drivers are a statistically significant driver of mortgage loan default when used alongside traditional default risk drivers. The logit model in this blog disregards that floods may impact multiple loans at the same time. As a next step this research could benefit from a more complex loan-level model that incorporates the systemic nature of flood risk, more dynamic risk drivers and more physical risk drivers such as heat stress and pole rot.

In addition, scenario analysis can be used to estimate the financial risk associated with existing climate scenarios such as the IPCC's Representative Concentration Pathways (Van Vuuren et al., 2011) or the Shared-Socio-Economic pathways (O'Neill et al., 2014). These scenarios are now solely defined in terms of the climate-change-

related impact and include limited macro-economic indicators. The use of a simulation engine for the economy based on co-integration models allows for the translation of climate-related variables to economic indicators. The simulation engine can supplement scenarios with relevant macro-economic indicators of financial risk, associated with any financial instrument.

For financial institutions it is important to have a method in place that produces forward-looking scenarios in order to quantify climate risk. This study can serve as an example of how climate related risks can be incorporated in PD modelling for a specific portfolio. However, climate risk modelling methodologies are still evolving and there is still a lot to learn and to develop. It remains a challenge for institutions to find the right methods to identify, quantify and monitor climate risks. Now that regulatory requirements are taking shape, institutions should develop methods to quantify climate-related risks for their exposures.

References

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., ... & van Vuuren, D. P. (2014). *A new scenario framework for climate change research: the concept of shared socioeconomic pathways*. Climatic change, 122(3), 387-400.

Vermeulen, R., Schets, E., Lohuis, M., Kolbl, B., Jansen, D. J., & Heeringa, W. (2018). *An energy transition risk stress test for the financial system of the Netherlands* (No. 1607). Netherlands Central Bank, Research Department.

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., ... & Rose, S. K. (2011). *The representative concentration pathways: an overview*. Climatic change, 109(1), 5-31.

Deloitte.

Deloitte refers to one or more of Deloitte Touche Tohmatsu Limited ("DTTL"), its global network of member firms and their related entities. DTTL (also referred to as "Deloitte Global") and each of its member firms are legally separate and independent entities. DTTL does not provide services to clients. Please see www.deloitte.nl/about to learn more.

Deloitte is a leading global provider of audit and assurance, consulting, financial advisory, risk advisory, tax and related services. Our network of member firms in more than 150 countries and territories serves four out of five Fortune Global 500® companies. Learn how Deloitte's approximately 286,000 people make an impact that matters at www.deloitte.nl.

This communication contains general information only, and none of Deloitte Touche Tohmatsu Limited, its member firms or their related entities (collectively, the "Deloitte network") is, by means of this communication, rendering professional advice or services. Before making any decision or taking any action that may affect your finances or your business, you should consult a qualified professional adviser. No entity in the Deloitte network shall be responsible for any loss whatsoever sustained by any person who relies on this communication.