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CLIMATE RISKS AND BANK ASSET QUALITY DYNAMICS: EMPIRICAL EVIDENCE FOR SERBIA

Klimatski rizici i promene kvaliteta bankarske aktive:
empirijska analiza za Srbiju

Abstract

This paper provides a quantitative assessment of the potential impact of climate-related risks on aggregate credit risk dynamics in the Serbian banking sector. To this end, we develop an empirical non-performing loans (NPL) model that identifies key macroeconomic determinants of NPL dynamics, including GDP growth, inflation, interest rates, and unemployment. These variables capture distinct theoretical channels through which climate-related shocks may affect credit risk, such as income effects, debt-servicing capacity, and financial conditions. Building on this framework, the analysis incorporates climate scenarios developed by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) to examine how climate-related risks may spill over to the future trajectory of NPLs indirectly through their impact on macroeconomic conditions. By comparing baseline projections with climate-adjusted scenarios, the study provides a quantitative evaluation of the potential effects of climate change on banking sector asset quality in Serbia. Overall, the results underscore the importance of integrating climate-related risks into credit risk assessment frameworks and offer policy-relevant insights for banks, regulators, and policymakers in Serbia.

Keywords: *climate risks, non-performing loans, credit risk*

Sažetak

Ovaj rad daje kvantitativnu procenu mogućeg uticaja klimatskih rizika na dinamiku kreditnih rizika u bankarskom sektoru Srbije. U tu svrhu razvijen je model nenaplativih kredita (NPL) koji identifikuje ključne makroekonomske determinante kretanja NPL-ova, uključujući privredni rast, inflaciju, kamatne stope i nezaposlenost. Ove varijable obuhvataju različite teorijske kanale kroz koje klimatski šokovi mogu uticati na kreditni rizik, poput efekata na dohodak, sposobnost servisiranja duga i opšte finansijske uslove. Na osnovu ovog analitičkog okvira, studija uključuje klimatske scenarije koje je razvila Mreža centralnih banaka i supervizora za zeleniji finansijski sistem (NGFS) kako bi se procenilo kako klimatski rizici posredno utiču na buduću putanju NPL-ova preko promene makroekonomskih varijabli. Upoređivanjem baznih projekcija sa klimatski prilagođenim scenarijima, analiza pruža kvantitativnu procenu potencijalnog uticaja klimatskih promena na kvalitet aktive bankarskog sektora u Srbiji. Studija naglašava važnost uključivanja klimatskih rizika u procenu kreditnog rizika kroz evaluaciju njihovog uticaja i time nudi dragocene uvide za banke, supervizore i kreatore politika u Srbiji.

Ključne reči: *rizici klimatskih promena, problematični krediti, kreditni rizik*

Introduction

Climate change has increasingly been recognized as a major source of systemic risk to the global economy and, consequently, to the financial system. Over the past decade, policymakers, regulators, and the academic community have placed growing emphasis on the relevance of climate-related risks. There is a rising consensus that these risks extend beyond environmental or ethical considerations and constitute material financial risks with potentially far-reaching implications for macroeconomic performance, banking sector resilience, and overall financial stability. Climate-related risks can adversely affect borrowers' income streams, asset valuations, and debt-servicing capacity, thereby posing significant challenges to banks' asset quality. As highlighted in the Principles [4] issued by the Basel Committee on Banking Supervision (BCBS), climate change gives rise to both physical and transition risks that may undermine the safety and soundness of individual banks, while also generating broader systemic risks with implications for the stability of the banking system as a whole.

The relevance of analyzing the impact of climate-related risks on the banking sector stems from the central role banks play in financial intermediation, particularly in developing economies where capital markets remain relatively underdeveloped. Climate-induced macroeconomic shocks – manifesting through lower GDP growth, higher inflation, rising unemployment, or increased interest rate volatility – can weaken borrowers' debt-servicing capacity and, in turn, expose banks to elevated credit risk. Consequently, understanding the transmission of climate-related risks through macroeconomic channels to banking sector asset quality is essential for assessing threats to financial stability. This issue is especially pertinent for emerging and developing economies, where financial systems may be more vulnerable to external shocks and where adaptation to climate-related risks has, to date, received less policy attention than in advanced economies.

The global policy framework for addressing climate change has been shaped by the Paris Agreement from 2015 when countries committed to limiting global warming to below 2°C above pre-industrial levels. This agreement

has accelerated the global transition toward low-carbon economies, creating both risks and opportunities for financial institutions. Banks face transition risks arising from changes in environmental regulation, carbon pricing, technological shifts and evolving consumer preferences. At the same time, physical risks related to climate change such as floods, droughts, heatwaves and storms can directly damage economic infrastructure, disrupt production, damage collaterals, and lead to the deteriorating quality of banks' loan portfolio. These developments underline the rising needs for forward-looking risks assessment frameworks that would incorporate climate related uncertainties.

In response to these challenges, international financial regulators have increasingly emphasized the integration of climate-related risks into banking supervision and risk management frameworks. The European Banking Authority (EBA), for instance, explicitly states in its guidelines that climate and environmental risks should be treated as drivers of traditional financial risks, particularly credit risk (see European Banking Authority, 2025, Guidelines on the management of environmental, social and governance (ESG) risks). Beyond the EBA, the relevance of climate-related risks has been widely acknowledged by key international financial institutions, including the International Monetary Fund (IMF) and the Basel Committee on Banking Supervision, which issued high-level principles for the management of climate-related financial risks in 2022.

This broader regulatory and policy agenda is highly relevant for Serbia, an EU candidate country whose financial sector is closely integrated with European markets. Given the strong linkages with the European Union - particularly through banking groups operating under EU regulatory frameworks - climate-related risks may indirectly influence domestic lending conditions and risk assessment practices. This renders the assessment of climate-related impacts on credit risk both timely and policy-relevant. Moreover, Serbia's economy exhibits pronounced exposure to climate-related vulnerabilities, especially in sectors such as agriculture, energy, and infrastructure, which account for a larger share of economic activity than in many EU economies. As a result, the Serbian banking

sector may be particularly sensitive to climate-induced macroeconomic fluctuations, further underscoring the importance of incorporating climate-related risks into financial stability and supervisory assessments.

Despite growing international recognition of climate-related financial risks, many emerging economies, including Serbia, have not yet formally required banks to quantitatively incorporate these risks into their credit risk assessment frameworks. This, however, does not diminish the relevance of such analysis for Serbia. As an EU candidate country, Serbia is expected to progressively align its regulatory and supervisory framework with European standards, which increasingly integrate climate-related risk considerations.

Against this backdrop, this paper examines the potential effects of climate-related risks on the future trajectory of non-performing loans (NPLs) in the Serbian banking sector. The analysis begins with the development of an empirical model based on data from the Serbian banking sector, distinguishing between NPLs in the corporate and household sectors. The model identifies key macroeconomic determinants of NPL dynamics, including GDP growth, inflation, interest rates, and unemployment. These variables capture several transmission channels through which climate-related shocks may affect credit risk, such as borrowers' debt-servicing capacity and broader financial conditions. Building on this framework, the paper incorporates climate scenarios developed by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) to assess how climate-related risks may influence the future path of NPLs indirectly through their impact on macroeconomic variables. By comparing baseline projections with climate-adjusted scenarios, the analysis provides a quantitative assessment of the potential effects of climate change on banking sector asset quality in Serbia.

We find that climate-related risks exert a substantially stronger impact on corporate credit portfolios than on retail portfolios, particularly under scenarios characterized by a delayed or disorderly transition. Under the green policy adherence scenario, the estimated cumulative five-year effect of climate change on corporate non-performing loans amounts to an increase of 1.6 percentage points (pp) in the

NPL ratio. In the case of delayed policy implementation, this effect rises to a cumulative 2.1 pp. While the difference between scenarios is relatively modest in the medium term, it becomes markedly more pronounced over longer horizons. By 2050, the cumulative increase in corporate NPLs reaches 19.1 pp in the case of postponement of climate mitigation efforts by the policy makers in the near future, compared with 11 pp under an immediate and orderly policy response. This economically meaningful divergence in long-run outcomes indicates that postponing climate mitigation efforts substantially amplifies credit risk in the corporate sector. The results are consistent with the view that disorderly transitions are associated with greater macroeconomic disruption and heightened financial stress. The widening gap between scenario trajectories over time underscores the importance of early, credible, and well-coordinated climate policies in mitigating long-term risks to financial stability. By contrast, the estimated effects on retail portfolios are significantly smaller, suggesting a comparatively limited exposure of household credit to climate-related risks.

The paper contributes to the growing literature on climate-related financial risks and offers valuable insights for policymakers, regulators and financial institutions seeking to enhance the resilience of the Serbian banking system in the face of climate change. Unlike most previous studies that analyze aggregate NPL ratios or corporate sector NPL in Serbia, this paper distinguishes between corporate and retail sector NPLs, recognizing that these two segments are exposed to different transmission channels of macroeconomic determinants. By modeling these two segments separately, the study provides a more granular and policy relevant assessment of climate related credit risk. Second, the paper integrates climate risk into the macro-NPL framework by linking projected changes in key macroeconomic variables such as GDP growth, unemployment, inflation and interest rates with future NPL dynamics, providing the first empirical analysis that quantifies the impact of climate related risks for the Serbian banking sector.

The remainder of the paper is structured as follows. The next section presents a review of the relevant literature. The following section outlines the empirical modelling

framework for non-performing loans in both the corporate and household segments. The subsequent section evaluates the effects of climate-related scenarios on the projected NPL dynamics. The second to last section discusses the policy implications derived from the analysis, and the last section offers concluding remarks.

Literature Review

The literature on climate change and its impact on the financial sector has expanded rapidly over the last decade. The early contributions primarily conceptualized climate change as a potential source of financial risk (see for example [1], [19], [24]). More recent studies have increasingly sought to quantify its implications for borrowers, financial institutions, and overall financial stability ([12]), with increasing focus to the role of regulation that could mitigate the risks coming from the identified channels (see [14], [30]).

Literature has evolved along several interconnected lines of inquiry that span micro, bank-level, and macro-financial perspectives. One line of research examines the impact of climate changes on the financial performances of borrowers. These studies examine how exposure to physical risks, such as floods, heatwaves, and droughts, as well as transition risks associated with decarbonization policies, can weaken firms' balance sheets, reduce profitability, and increase default probabilities (see, e.g., [5], [9]). Empirical evidence suggests that firms in carbon-intensive industries face higher financing costs, more volatile earnings, and greater credit rating downgrades, providing a rationale for potential increases in NPL over time in these sectors, as well as in those sectors which are heavily exposed towards them. A second strand of the literature examines climate-induced credit risk from the perspective of financial institutions, particularly banks with significant exposure to carbon intensive sectors, investigating how climate related risks may affect asset quality, loan pricing or portfolio composition ([11], [15]). The bank-level literature underscores the importance of incorporating climate considerations into risk assessment frameworks to mitigate the effects of climate risk.

Finally, a growing body of literature adopts a macro-financial perspective, examining how climate change

interacts with systemic risk and financial stability. Research in this area suggests that climate risks can amplify macroeconomic volatility through multiple channels, including disruptions to productivity, labor markets, and asset prices. Higher temperatures and extreme weather events can reduce agricultural productivity, disrupt supply chains and lower overall economic output. A rich empirical literature documents these effects across different methodological approaches and country contexts (e.g., [27], [21], [20]). At the same time, climate related supply shocks can generate inflationary pressures, especially in food and energy markets ([26], [28], [10]). These studies underscore the importance of understanding the macroeconomic transmission channels of climate change as a foundation for assessing broader financial stability implications. Negative growth shocks, higher unemployment and/or inflationary pressures arising from realization of climate shocks may spill over into increase in default rates, loan performance deterioration, impacting banking sector asset quality. This has opened avenues for analyzing how climate factors may influence financial stability indirectly, by leveraging the well-established framework of credit risk stress testing to capture the transmission of climate shocks through macroeconomic conditions. Extending the macroprudential credit risk stress tests to capture climate-risk-induced credit risk can enhance the effectiveness of the stress-testing toolbox that is already recognized in the literature as an effective tool for crisis management (see [7]). In the last couple of years, the literature developed around climate stress testing as a key analytical tool for assessing financial resilience. Central banks and supervisory authorities, notably the European Central Bank, have conducted climate stress tests to evaluate how different transition pathways and physical risk scenarios could affect banks' balance sheets [16].

In addition to the literature on climate-induced credit risk, this paper is also related to research on the determinants of systemic risk in the banking sectors of emerging economies (see, for example, [13], [22], [2]). Within the extensive literature on non-performing loan (NPL) determinants surveyed by [23], macroeconomic factors are identified as among the most important drivers of NPL dynamics. A broad body of empirical evidence

consistently highlights several key macroeconomic and financial variables as primary determinants of NPLs, including real GDP growth, inflation, unemployment, wages, interest rates, and exchange rates (see, for instance, [6]). These variables capture the fundamental channels through which macroeconomic conditions affect borrowers' repayment capacity and, consequently, the overall quality of banks' loan portfolios. Taken together, existing studies provide robust evidence that NPL dynamics in European and Central and Eastern European (CEE) economies are highly sensitive to macroeconomic conditions, particularly developments in the labor market, economic growth, the price environment, and borrowing costs. Unemployment consistently emerges as one of the most influential determinants, while economic downturns – especially during systemic crises – tend to amplify default risk across both corporate and household sectors.

Building on this literature, this paper develops separate empirical NPL models for the corporate and household sectors in Serbia using publicly available data. By explicitly distinguishing between these segments, the analysis allows for a more granular assessment of sector-specific credit risk dynamics. Based on the estimated models, the paper evaluates climate-induced credit risk in Serbia by adapting the NGFS climate scenarios to the Serbian context. To the best of the authors' knowledge, this study represents the first attempt to quantify the effects of climate-related risks on credit risk in Serbia by providing localized projections and risk assessments. The results

offer a valuable foundation for policymakers and banks to better understand potential climate-related impacts and to design targeted mitigation and adaptation strategies.

Empirical Analysis

Data Description

The main dependent variable in the empirical analysis is the share of non-performing loans in total loans. Quarterly data, separately for the corporate sector and for households is obtained from the National Bank of Serbia (NBS) Financial Stability Report, covering the period from Q1 2010 to Q4 2024. This period allows for the analysis of NPL dynamics across different phases of the economic cycle, including post-crisis recovery, the COVID-19 pandemic, and the subsequent normalization period. Given the well-documented issues related to non-stationarity in macroeconomic and financial time series, all variables entering the model were tested for stationarity and after that were transformed into first differences prior to estimation. This approach mitigates the risk of spurious regression results arising from unit root processes in the underlying data.

Quarterly data for potential macroeconomic drivers of NPL dynamics – real GDP, unemployment, inflation, and nominal wages – are obtained from the Statistical Office of the Republic of Serbia databases. Data on interest rates and the exchange rate were collected from the official websites

Table 1: Data Definitions and Sources

Variable	Definition	Lags included (max)	Source
NPL rate: corporate and household	Share of non-performing loans in total gross loans	4	National Bank of Serbia
GDP growth	Real GDP growth rate seasonally adjusted	12	Statistical Office of the Republic of Serbia
Unemployment rate	share of unemployed persons in total active population	12	Statistical Office of the Republic of Serbia
Inflation rate	CPI inflation (year-on-year)	12	Statistical Office of the Republic of Serbia
Wages	Nominal wages seasonally adjusted	12	Statistical Office of the Republic of Serbia
Euribor	Six-month Euribor rate	12	ECB
Belibor	Six-month Belibor rate	12	National Bank of Serbia
Exchange Rate	Dinar-Euro nominal exchange rate	12	National Bank of Serbia
No ZLB dummy	Takes value 1 for period when ECB policy was not at zero lower bound	Matches lags of Euribor	ECB for quarters at ZLB

Source: Authors' calculations

Note: The table reports the definition of the dependent variable (NPL rate) and explanatory variables used in empirical analysis. Lags included column reports maximum number of lagged quarters used for each variable in empirical analysis.

of the National Bank of Serbia and the ECB (euribor-rates.eu for Euribor rates). Prior to model estimation, each variable was subjected to stationarity testing, and only those variables that were found to be stationary (either in level or the first differences) were included in the final specification. Formal unit root test results for all variables are reported in the online Appendix.

Table 1 summarizes all collected variables and their sources.

With respect to interest rates, it is important to note that the sample period includes an extended phase of historically low – and at times zero – ECB policy rates. To account for potential nonlinear effects of this environment on credit risk, the model incorporates an interaction term between the Euribor rate and a dummy variable indicating periods in which interest rates were above zero. This specification allows the estimation to capture differential effects of interest rate movements under near-zero monetary policy conditions relative to periods characterized by more conventional monetary tightening.

Model Specification

The empirical analysis is based on a linear regression framework that estimates changes in non-performing loan (NPL) ratios as a function of lagged changes in key macroeconomic determinants. The model specification captures both demand- and supply-side channels influencing borrowers' repayment capacity and overall credit conditions. Estimation follows a general-to-specific

modeling approach, allowing for alternative lag structures across the set of potential explanatory variables. In determining the final model specification, only variables with statistically significant coefficients that exhibited the expected theoretical sign and economic plausibility were retained. This selection strategy ensures the economic interpretability and internal consistency of the estimated relationships.

Table 2 presents the results from the final specifications for both corporate and household (retail) NPL models. In line with the existing literature, the final set of explanatory variables differs between the corporate and retail sector models, reflecting the distinct economic mechanisms influencing credit risk in these two segments. In the corporate NPL specification, lagged GDP growth, inflation, and changes in Euribor 6M interest rate (in interaction with dummy for period of non-zero interest rates) are statistically significant determinants of NPL dynamics. This suggests that corporate borrowers are particularly sensitive to overall economic conditions, price developments, and financing costs, which affect their profitability, cash flow, and debt-servicing capacity.

In contrast, the retail NPL model identifies unemployment, inflation, and changes in Euribor 6M interest rate (over the non-zero lower bound period) as statistically significant predictors of household credit risk. The significance of unemployment reflects the importance of labor market conditions for household income stability and repayment ability, while inflation captures the impact of rising living costs on borrowers' financial positions. The statistical significance of the interaction term between six-month

Table 2: Final Specifications of Estimated Models

Variable	Corporate model			Household model		
	Coefficient	Std. Error	pvalue	Coefficient	Std. Error	pvalue
Intercept	-0.009	0.002	0.03**	-0.002	0.000	0.001**
GDP growth (lagged 4 quarters)	-0.103	0.059	0.08*			
Euribor (lagged 8 quarters)	0.001	0.001	0.696	0.015	0.014	0.321
Euribor x No ZLB dummy (lagged 8 quarters)	0.670	0.268	0.016**	0.195	0.079	0.017**
Inflation rate (lagged 2 quarters)	0.079	0.032	0.017**	0.016	0.009	0.095*
Unemployment rate change (lagged 4 quarters)				0.042	0.024	0.083*
Adjusted R-squared		0.31			0.25	

Source: Authors' calculations

Note: The table reports the results from the final regression specification model. All models are estimated with ordinary least squares. All variables are defined in Table 1. *, **, *** denote statistical significance at the 10%, 5% and 1% significance level respectively.

Euribor rate and the period when interest rates were positive and insignificance of the interest rate level variable captures the differential effect of interest rate changes on the NPL dynamics when monetary policy is constrained by historically low or zero interest rates.

Although a substantial body of literature identifies the exchange rate as an important driver of NPLs, particularly in the corporate sector due to foreign currency exposure (see for example [3], [8]), we did not obtain a statistically significant effect of the exchange rate on NPL dynamics in Serbia over the sample period, directly or interacted with interest rates. The data set largely covers a period of managed and relatively stable exchange rate movements, characterized by limited volatility of the exchange rate. Consequently, the lack of pronounced exchange rate fluctuations reduces the likelihood of detecting a strong statistical relationship between exchange rate changes and NPL developments within this sample.

During the general-to-specific estimation process, specifications also included a lagged dependent variable for both the corporate and retail NPL models. Since the lagged NPL variable was not statistically significant in both cases, we proceeded with distributed lag (DL) regression models. However, given the objective of the study to generate long-term projections of NPLs under climate-related scenarios, the specification without the lagged dependent variable would be preferred in any case.

Diagnostics tests indicate that the residuals from both the corporate and retail NPL specifications satisfy standard econometric assumptions. Specifically, the residuals show no evidence of serial correlation or heteroskedasticity, suggesting that the models are well-specified. The chosen model specifications balance statistical rigor with economic interpretability, providing a solid foundation for assessing the potential impact of climate-related macroeconomic shocks on future NPL dynamics in both the corporate and households' segments of the Serbian banking sector.

Application of Climate Scenarios and Assessment of NPL Impacts

To assess the potential impact of climate-related risks on future NPL dynamics in the Serbian banking sector,

the estimated macro NPL models for the corporate and households' sectors were combined with climate-consistent macroeconomic projections based on scenarios developed by the Network for Greening the Financial System (NGFS). Specifically, three scenarios were considered: a Baseline scenario, a Delayed Transition scenario, and a Net Zero scenario. These scenarios are broadly aligned with the NGFS framework and the principles outlined in the NGFS Climate Macroeconomic Modelling Handbook [25], which emphasizes the translation of climate risks into macroeconomic variables relevant for financial stability assessment.

In line with NGFS Climate Macroeconomic Modelling Handbook [25], the baseline scenario represents a counterfactual path in which climate-related risks do not materially alter macroeconomic dynamics beyond existing trends and policies. This scenario serves as a reference point against which climate-adjusted scenarios are evaluated. The Delayed Transition scenario assumes a postponement of climate mitigation efforts, leading to a sharper and more abrupt adjustment at a later stage, characterized by higher transition risks, increased policy uncertainty, and potentially adverse macroeconomic consequences. In contrast, the Net Zero scenario reflects an orderly and gradual transition toward a low-carbon economy, involving early and sustained climate policy action, which mitigates physical risks but may still entail transition-related economic adjustments.

A key methodological challenge in applying NGFS scenarios to Serbia is the absence of country-specific macroeconomic projections for Serbia within the NGFS framework. As NGFS does not provide dedicated climate scenarios for Serbia, it was necessary to approximate the relevant macroeconomic impacts using regional or comparable country groupings.

For inflation, the climate-adjusted trajectory was constructed using the average projected inflation rate for European countries operating under an inflation-targeting regime, for which scenarios are reported in the NGFS database. To better reflect Serbia's specific monetary policy framework, this average was adjusted by the difference between the official inflation target in Serbia and the average inflation target in those countries

over the previous period. This adjustment ensures that the climate-induced deviation from baseline inflation is consistent with Serbia's policy environment.

For GDP growth and unemployment, projections for the “Developing Europe” region were used as a proxy for Serbia, given the structural similarities in economic development, labor market characteristics, and climate vulnerability. This regional approach captures the expected macroeconomic consequences of climate risks in economies with comparable exposure to physical risks and transition challenges. The projected climate-induced deviations in GDP and unemployment relative to baseline were then mapped onto the estimated Serbian NPL models to quantify their impact on credit risk.

In the case of interest rates, our empirical results identify six-month Euribor rate as the statistically significant driver of the NPL dynamics, in line with the still present level of eurization in the domestic economy where Euro indexed loans still constitute the majority of loans in corporate as well as in retail sector. Since NGFS scenarios do not provide explicit projections for six-month Euribor rate, its future dynamics under different climate scenarios were approximated using the projected path of the ECB key policy rate. This assumption is reasonable given the close relationship (correlation) between ECB policy rates and money market rates, particularly over longer horizons.

In line with the NGFS methodological guidance, climate scenarios were operationalized as deviations from the baseline trajectory rather than as absolute levels. That is, for each macroeconomic variable, the climate-adjusted value was calculated as the baseline projection plus the climate-induced deviation implied by the selected NGFS scenario.

The estimated short-term (2026) and mid-term (up to 2030) effects of climate shocks on bank non-performing loan dynamics were derived by directly applying the estimated quarterly climate-induced changes in GDP, inflation, unemployment, and interest rates to the estimated NPL models, taking into account estimated dynamic (lagged) dependencies. This captures the immediate transmission of climate-related macroeconomic fluctuations to credit risk, reflecting how sudden changes in economic conditions

– such as slower growth or rising unemployment – can affect borrowers' repayment capacity in the near term.

The long-term effects were assessed by simulating the cumulative impact of climate-induced macroeconomic deviations over the entire projection horizon up to 2050. In this context, the absence of a lagged dependent variable in the final NPL specification plays a crucial role, as it ensures that long-term projections are driven primarily by the persistent influence of climate-related macroeconomic changes rather than by the inertia of past NPL levels. This allows for a clearer attribution of long-run differences in NPL trajectories to climate risks rather than to model dynamics.

By integrating NGFS-consistent macroeconomic pathways with an empirically estimated macro-NPL model, the analysis offers a forward-looking assessment of how different climate policy trajectories may shape future credit risk dynamics in both the corporate and retail sectors. Despite the limitation of not having Serbia-specific NGFS projections, the use of carefully selected regional proxies and policy consistent adjustments ensures that the results remain informative and relevant for policymakers and financial institutions.

Estimated Effects of Climate Related Risks on the NPL Trajectory in Short, Medium and Long Run

The projected impacts of climate-related risks on non-performing loans indicate a progressively stronger effect over time, with markedly different magnitudes between the corporate and retail segments, reflecting their distinct sensitivity to macroeconomic conditions and exposure to macroeconomic factors. The projected effects coming from climate related risks, calculated as the difference between projected NPL in respective scenario and the one estimated based on the Baseline scenario, are provided in Table 3.

Before presenting the estimation results, it is important to clarify what these results can – and cannot – capture. The estimated results are based on historical Granger causality estimates of the relationship between non-performing loans and macro-financial variables. Consequently, they do not identify the effects of monetary policy shocks or other

structural macroeconomic shocks on NPL dynamics, for more information please see Ramey [29]. Nevertheless, in line with the standard empirical literature on NPLs, the estimates do capture the most relevant predictors of future NPL developments. Furthermore, the simulated scenarios implicitly assume that the underlying parameters remain invariant to future environmental changes and therefore may be subject to Lucas's critique. Despite this limitation, the results provide a useful quantitative assessment of the impact of climate risks on banks' portfolios and may be interpreted as a lower bound on the true effects that could materialize in the future.

Under the Delayed Transition scenario, the analysis suggests that climate-related macroeconomic deterioration is likely to exert a more pronounced upward pressure on NPL ratios over time, particularly in the corporate sector, where credit risk is closely linked to overall economic performance and financing conditions. The Net Zero scenario, while still implying some transition-related adjustments, is expected to generate comparatively smaller long-term increases in NPLs due to lower physical risks and more predictable policy adjustments.

For the households' sector, the projected impact of climate scenarios is largely mediated through labor market developments and inflation dynamics, as reflected in the model specification. As unemployment rises or real purchasing power declines under adverse climate scenarios, household credit risk increases accordingly, while the effects of potential higher borrowing costs are captured by the effects of climate risk on interest rate changes.

In particular, based on the corporate sector model and the NGFS climate scenarios, the estimated increase in the corporate NPL ratio attributable to climate-related shocks is relatively modest in the short term but becomes substantial in the medium to long run. Under the Delayed Transition

scenario, the corporate NPL ratio is projected to rise by 0.4 percentage points in 2026, compared to 0.3 pp under the Net Zero scenario. By 2030, the estimated cumulative effect intensifies to 2.1 pp in the Delayed Transition and 1.6 pp in the Net Zero scenario, reflecting the growing macroeconomic strains associated with climate policy adjustments and structural economic transformation. By 2050, the divergence across scenarios becomes even more pronounced, with an estimated cumulative increase of 19.1 pp in the Delayed Transition scenario and 11.0 pp under the Net Zero scenario. This sharp difference in long-term effect suggests that postponing climate action significantly amplifies credit risk in the corporate sector, consistent with the notion that disorderly transitions entail higher economic disruption, and financial stress.

In contrast, the projected effects on NPLs of retail sector are considerably more muted, which aligns with the estimated lower elasticities of retail NPLs to macroeconomic variables. In 2026, the increase in the retail NPL ratio is projected at 0.2 pp under both scenarios, indicating limited immediate transmission of climate-related risks to household credit quality. By 2030, the cumulative effect rises to 0.8 pp in the Delayed Transition and 0.5 pp in the Net Zero scenario, suggesting that retail borrowers are affected by deteriorating labor market and income conditions, albeit to a lesser extent than firms. By 2050, the projected cumulative increase reaches 3.6 pp under the Delayed Transition and 2.8 pp under the Net Zero scenario, confirming that while climate risks do accumulate over time in the retail segment, their magnitude remains significantly lower and materially smaller than in the corporate sector.

The results underscore that climate-related risks pose a materially greater threat to corporate credit portfolios than to retail loans, particularly under a delayed and disorderly

Table 3: Summary of Projected NPL Ratios Depending on Climate Related Scenarios

Model	Increase in NPL rate in 2026		Increase in NPL rate by 2030		Increase in NPL rate by 2050	
	Delayed Transition	Net Zero	Delayed Transition	Net Zero	Delayed Transition	Net Zero
Corporate sector	0.4 pp	0.3 pp	2.1 pp	1.6 pp	19.1 pp	11.0 pp
Household sector	0.2 pp	0.2 pp	0.8 pp	0.5 pp	3.6 pp	2.8 pp

Source: Authors' calculations.

Note: The table reports the estimated additional cumulative increase in non-performing loans rate in corporate and retail sectors under Delayed Transition and Net Zero climate scenarios versus Baseline scenario in which no accommodation or partial accommodation to climate changes is performed. The results are obtained based on the estimated parameter coefficients and adjusted NGFS scenarios as explained in the main text.

transition. The widening gap between scenarios over time highlights the importance of timely climate action in mitigating long-term financial stability risks, while also demonstrating that incorporating climate scenarios into macro-NPL modeling and stress testing provides valuable insights into future credit risk dynamics.

Concluding Remarks

This study provides an empirical assessment of the potential impact of climate-related risks on credit risk in the Serbian banking sector, a topic that has received limited attention in the Serbian banking sector literature to date. By integrating macroeconomic projections under NGFS climate scenarios with a disaggregated macro-NPL model, the analysis quantifies how climate shocks can influence the dynamics of non-performing loans in both the corporate and retail segments. The results demonstrate that climate-related macroeconomic changes that are manifested through its effects on GDP growth, inflation, unemployment, and interest rates, can have significant implications for the dynamics of non-performing loans in Serbia. This finding underscores the importance of considering climate risks as a material factor in credit risk assessment, even in emerging economies where formal regulatory guidance on climate risk integration is still developing.

By modeling corporate and household NPLs separately, the study captures the heterogeneous transmission mechanisms through which climate-related shocks affect different segments of borrowers. The application of Delayed Transition and Net Zero scenarios highlights how differing climate policy pathways can lead to markedly different credit risk outcomes, providing valuable insights for banks, regulators, and policymakers. This is particularly important for corporate sector.

The results underscore that climate-related risks pose a materially greater threat to corporate credit portfolios than to retail loans, particularly under a delayed and disorderly transition. The widening gap between scenarios over time highlights the importance of timely climate action in mitigating long-term financial stability risks, while also demonstrating that incorporating climate scenarios into

macro-NPL modeling and stress testing provides valuable insights into future credit risk dynamics.

Several avenues for future research emerge. Extending the model to incorporate sectoral-level NPL dynamics, particularly in climate-sensitive sectors such as agriculture, energy, and manufacturing or mortgage and cash loans in retail sector could provide further granularity and policy relevance. In addition, exploring the interaction between climate risk, regulatory interventions, and monetary policy responses could shed light on potential mitigation strategies and the resilience of the banking system under different climate trajectories. Finally, our results capture only existing correlations in the data. Building a causal framework for assessing the effects of climate changes and policy responses warrants a different approach.

Overall, the findings of this study emphasize that climate risks are not only an environmental concern but also a core financial stability issue. Incorporating climate-related shocks into credit risk assessment enhances the ability of banks and regulators to anticipate and manage potential future losses, improve risk-weighted capital allocation, and design proactive risk mitigation strategies. As climate change continues to pose both physical and transition risks, the integration of these factors into credit risk models will be essential for maintaining financial stability and ensuring that the banking sector remains resilient in the face of evolving environmental and economic challenges.

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