From Climate Shocks to Financial Stability: A Methodological Framework

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From Climate Shocks to Financial Stability: A Methodological Framework☆

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Resumen

A partir de una versión del modelo macro-fiscal del Banco Mundial (MFMOD) estimado para Uruguay que incorpora daños asociados a sequías se construyen escenarios macroeconómicos ajustados por clima. Estos escenarios constituyen una herramienta para incorporar riesgos climáticos en el análisis macroeconómico y pueden servir como insumo para ejercicios de estabilidad financiera, como pruebas de estrés. Se consideran un evento histórico (sequía de 2022/23) y escenarios probabilísticos de sequía con períodos de retorno de 50, 200 y 500 años.

Los resultados muestran un canal de transmisión consistente hacia los riesgos financieros, a través de menor actividad, depreciación cambiaria, mayor inflación y deterioro del mercado laboral, lo que se traduce en menores ratios de adecuación de capital bancario. Sin embargo, el impacto agregado sobre la solvencia del sistema bancario se mantiene acotado, y el sistema se muestra resiliente tanto ante el evento histórico como ante escenarios más severos.

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Abstract

Using a version of the World Bank's MFMOD macro-fiscal model for Uruguay that incorporates drought-related damages, we generate climate-adjusted macroeconomic scenarios. These scenarios provide a tool to incorporate climate risks into macroeconomic analysis and can serve as an input for financial stability exercises, such as stress testing. We consider a historical single-event shock (the 2022/23 drought) and probabilistic drought scenarios with return periods of 50, 200, and 500 years.

Results show a macroeconomic transmission channel consistent with a supply shock—lower output, exchange-rate depreciation, higher inflation, and weaker labor-market conditions—leading to higher financial risks and a deterioration in capital ratios relative to baseline projections. However, the aggregate impact on banking system solvency remains limited, and the system remains resilient both under the historical event and under more severe tail scenarios. The modest variation across scenarios reflects both the structure of the macro-financial transmission framework and the presence of institutional buffers in the banking system.

JEL: C10, C50, E37, G01, G21, Q54
Keywords: climate shocks; stress testing; financial stability; Uruguay; droughts; floods; climate change

1. Introduction

The assessment of the impact of extreme climate events on the resilience of the financial system has gained increasing attention in recent years, particularly in economies where highly exposed productive sectors—such as agriculture, livestock, or critical infrastructure—play a central role in income generation, employment, and exports. A wide range of approaches has been developed to analyze these risks, spanning structural macro-fiscal models, general equilibrium simulations, and climate econometric techniques applied to economic growth, as well as micro-founded methodologies based on sectoral vulnerability, credit risk analysis, and stress testing frameworks for financial institutions. Recent contributions include financial stress-testing approaches (Acharya et al., 2023), economy-wide climate stress tests (Alogoskoufis et al., 2021), and integrated macro-climate stress-testing frameworks for physical risk (Hallegatte et al., 2022). Within this literature, the development of internally consistent macroeconomic scenarios that incorporate climate shocks has become an increasingly important tool for macro-financial risk assessment.

Each approach captures different dimensions of climate risk. Some emphasize the estimation of general equilibrium effects on economic growth and fiscal accounts; others focus on quantifying physical damages or sector-specific economic losses; while a third strand concentrates on transmission mechanisms to the financial system, such as the deterioration of credit quality, declines in collateral values, or increases in the probability of default of households and firms. This methodological diversity reflects the inherent complexity of linking physical shocks—such as droughts and floods—to specific and measurable financial outcomes. Against this background, the paper contributes by combining internally consistent macroeconomic scenario design with an institutional stress-testing application, thereby providing a coherent and operational framework for assessing financial system resilience within existing analytical infrastructures.

In particular, the magnitude of the impact of climate shocks depends to a large extent on three factors: (i) geographical exposure to droughts, floods, heatwaves, and other extreme events; (ii) public and private mitigation and adaptation capacity; and (iii) the economic importance of the affected sectors, whether through their direct contribution to GDP, their weight in external trade, their role within value chains, or their incidence in domestic consumption.

In this context, Giuliano et al. (2024) develop an estimate of the macroeconomic effects of climate shocks for Uruguay, focusing on both droughts and floods. Droughts are modeled as productivity shocks to the agricultural sector—specifically through a reduction in sector-specific Total Factor Productivity (TFP)—while floods are incorporated through the estimation of infrastructure damages and the associated reallocation of investment toward reconstruction. Both types of

shocks are then transmitted through the macroeconomic framework to assess their effects on related industries, external trade, fiscal revenues, and consumption. These channels are systematically integrated within the World Bank's macro-fiscal model (MFMOD) applied to Uruguay (URY-MFMOD). This approach allows for the capture of second-round effects and the assessment of the resulting macroeconomic dynamics following severe climate events.

The URY-MFMOD climate-shock framework developed by Giuliano et al. (2024) provides a useful basis for constructing macroeconomic scenarios that incorporate the effects of extreme climate events. In particular, these simulations can be used to adjust baseline macroeconomic scenarios—such as those generated by internal models used in the context of the monetary policy process—in order to incorporate the macroeconomic effects of drought shocks. This approach makes it possible to generate climate-adjusted macroeconomic scenarios that remain consistent with the broader macroeconomic framework. Developing tools that adapt existing macroeconomic scenarios to incorporate climate shocks therefore represents a step toward integrating climate risk into macro-financial policy analysis.

Building on the climate-shock simulations developed by Giuliano et al. (2024) using the World Bank's macro-fiscal model (MFMOD) for Uruguay, this paper adapts baseline macroeconomic scenarios commonly used in financial stability analysis to incorporate the macroeconomic effects of drought events. The resulting climate-adjusted scenarios can then serve as inputs for different types of financial stability exercises. The approach is illustrated through a banking stress-testing framework to assess how climate-related macroeconomic shocks could affect banking system resilience.

While this study focuses specifically on drought-related shocks, the proposed framework can be extended to other types of climate events and applied to different jurisdictions. In Uruguay, droughts represent the most critical climate risk for agriculture, as they directly affect crop and livestock production through lower yields, quality losses, and other productivity impacts (FAO, 2017). Agriculture and related industries account for approximately 10% to 13% of GDP and nearly 80% of Uruguay's goods exports. Although their direct contribution to GDP may appear limited, the agricultural sector has strong forward and backward linkages with other activities—such as transport and commerce—generating spillovers across the economy.

In addition, between 2005 and 2024, bank lending to the agricultural sector represented almost one quarter of total corporate loans, reaching more than 40% in one institution and around 19% at the median across banks (Barón et al., 2026). The agricultural sector also exhibits relatively high credit-to-GVA ratios, at around 60-70% in recent years, compared to about 30% for the overall economy. As a result, despite its relatively modest share in GDP, the sector represents a source of direct exposure for the banking system, amplifying the potential transmission of climate

shocks to financial stability. Against this background, the framework is applied to both the 2022/23 drought episode and to probabilistic drought scenarios with different return periods, illustrating how climate-adjusted macroeconomic scenarios can be used to analyze banking system resilience under events of different severity.

While the framework provides an operational and internally consistent approach to integrating climate shocks into macro-financial analysis, it is important to note that it captures primarily the first-round macroeconomic effects of physical risks. In particular, the transmission of shocks occurs through aggregate macroeconomic variables, effectively filtering climate shocks through a macroeconomic layer that may attenuate their intensity, smooth their dynamics, and mask more granular impacts. As a result, the framework is best interpreted as providing a lower-bound assessment of the potential impact of climate-related shocks on financial system resilience.

These results should not be interpreted as evidence that climate-related risks to financial stability are limited, but rather as reflecting the partial transmission channels captured in this framework. The framework does not aim to assess the overall magnitude or materiality of climate-related financial risks, but rather to illustrate how a specific aggregate macro-financial transmission channel can be operationalized.

This paper also relates to recent climate stress-testing exercises for Uruguay based on NGFS scenarios, which adopt a microprudential approach focused on sectoral credit risk exposures. However, these exercises are not specifically tailored to the Uruguayan economy and focus primarily on corporate credit risk. In contrast, the framework developed here incorporates scenarios calibrated to domestic conditions and captures a broader set of financial risks. A detailed comparison between these approaches is provided in Box 2. As such, the framework is best understood as one component of a broader set of climate risk assessment tools used by central banks.

The remainder of the paper is structured as follows. Section 2 presents the methodological background, including the macro-fiscal MFMOD framework and the approach used to construct climate-adjusted macroeconomic scenarios for macro-financial analysis. Section 3 describes how climate-shock simulations are used to adapt baseline macroeconomic scenarios and how these scenarios can be incorporated into the stress-testing framework. Section 4 presents the alternative climate scenarios and their macro-financial implications. Section 5 presents the stress-testing results. Section 6 concludes.

2. Macroeconomic Scenario Framework and Climate Risks

2.1 Macroeconomic Scenario Framework for Financial Stability Analysis

As part of financial stability analysis, central banks commonly rely on macroeconomic scenarios to assess the resilience of the financial system under alternative economic conditions. These scenarios provide a structured framework to evaluate how changes in key macro-financial variables—such as economic activity, inflation, exchange rates, interest rates, and labor market conditions—may affect the financial system.

Incorporating climate-related shocks into macroeconomic scenarios represents an important step toward integrating climate risk into macro-financial analysis. Climate events such as droughts may affect economic activity through multiple channels, including agricultural productivity, energy generation, external balances, and fiscal accounts.

In this context, climate-shock simulations developed using macroeconomic models can be used to adjust baseline macroeconomic projections—such as those generated by internal models used in the context of the monetary policy process—in order to incorporate the macroeconomic effects of extreme climate events. This approach makes it possible to construct climate-adjusted macroeconomic scenarios that remain consistent with the broader macroeconomic framework and can be used for macro-financial risk analysis.

2.2 Climate Shock Simulations in URY-MFMOD

Structural macro-fiscal models provide a coherent framework to assess the economy-wide implications of exogenous shocks. In this context, the core macroeconomic projection model used by the World Bank, MFMOD, is a semi-structural, multi-sector macro-fiscal model that links real activity, prices, external sector and public finances through a system of behavioral equations calibrated to country-specific characteristics. Its structure allows for the explicit incorporation of exogenous climate shocks and the simulation of their dynamic effects over the short- to medium-term horizon.

Giuliano et al. (2024) expand the Uruguay-specific version of the model (URY-MFMOD) to incorporate losses and damages resulting from climate shocks such as droughts and floods. Climate risk is particularly relevant for Uruguay due to the economy's exposure to weather-dependent sectors—most notably agriculture and energy generation. Adverse climate events affect output through several channels, including reductions in agricultural productivity, lower hydroelectric power generation, higher energy imports, and spillovers into related industries.

These real-side effects ultimately transmit to fiscal accounts through lower tax revenues, increased public spending pressures, and greater financing needs.

Within the MFMOD framework, GDP is modeled using three complementary approaches—expenditure, production, and income. The production side is disaggregated into agriculture, industry, and services, and Giuliano et al. (2024) further refine this structure in the URY-MFMOD to better capture sector-specific climate impacts (as also discussed in Tisnés and Medina, 2026). In particular, the agricultural sector is split into livestock (including dairy) and crops, allowing for a more precise representation of how climate shocks affect each subsector.

The MFMOD uses a standard Cobb–Douglas production function to estimate potential GDP, which anchors the real side of the economy. In the short run, output is driven by the expenditure side, with adjustment mechanisms ensuring consistency between demand and supply over the long term.

For drought-related shocks—the focus of this paper—Giuliano et al. (2024) modify the livestock and crops production functions to incorporate sector-specific productivity losses (see Equation 1). These shocks are modeled as reductions in Total Factor Productivity (TFP), parameter di,t of Equation 1, meaning that the same levels of capital and labor generate lower output relative to previous years. These losses are allowed to have an autoregressive component, calibrated to the persistence of shocks (higher for the livestock sector than for the crops sector). This framework allows us to capture both the direct effects of droughts on GDP and inflation, and the indirect consequences for external accounts and fiscal aggregates such as primary balances and public debt dynamics.

Equation 1:

$$Y_{i,t}^{\star} = \left(1 + d_{i,t}\right) A_t \, N_t^{\star\alpha} K_{t-1}^{1-\alpha}$$

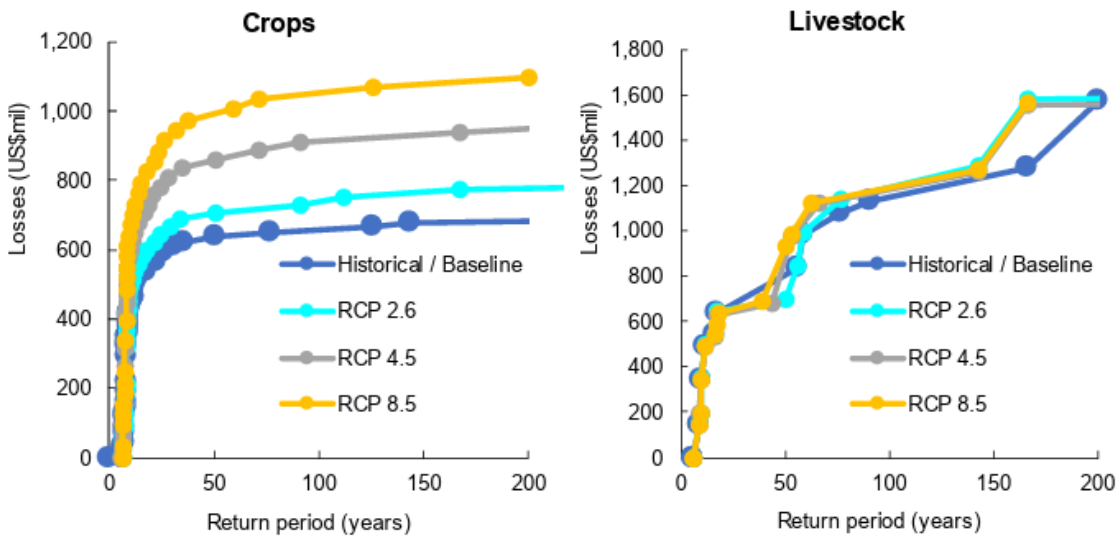
where:

$Y_{i,t}^{\star}$	Potential output of sector *i* (crops or livestock) at time *t*
di,t	Damages or losses due to drought in sector *i* at time *t*
A_t	Total Factor Productivity at time *t*
$N_t^{\star}$	Structural employment at time *t*
K_{t-1}	Capital stock from the previous period
α	Wage share of income

To implement climate risks in the URY-MFMOD, Giuliano et al. (2024) incorporates shocks calibrated to historical events and forward-looking risk assessments. They build on existing studies—such as the IDB (2019) disaster risk assessment and loss estimates produced by MGAP for the 2022/23 drought, which INUMET (2024) estimates as having a return period of 114 years.

The IDB provides loss curves for crops and livestock under different climate scenarios (historical/baseline and various Representative Concentration Pathways, RCPs), which the authors adjust to align with MGAP's estimated damages during the latest drought (Figure 1). These scenarios allow for counterfactual analysis, comparing baseline macro-fiscal trajectories with outcomes under adverse climate conditions. The results highlight the persistence of climate shocks and their potential to amplify macroeconomic volatility and fiscal vulnerabilities, especially when shocks occur in succession or coincide with adverse external conditions.

Figure 1. Loss curves for Uruguay: drought events across return periods and warming scenarios, based on 2023 sector values



Source: Giuliano et al. (2024). Notes: The Figure presents the World Bank estimates of loss curves for crops and livestock based on the loss curves from the disaster risk study from IDB (2019) and data from MEF (2023), and INUMET (2023). Losses are expressed in millions of US$.

By providing a consistent macroeconomic risk scenario under climate stress, MFMOD serves as a starting point for extending the analysis to the financial sector. In particular, its outputs—such as GDP growth, inflation and exchange rate—can be used as inputs for stress testing exercises, enabling a coherent assessment of how climate-induced macro-fiscal shocks translate into financial risk.

2.3 Use of Climate-Adjusted Scenarios for Financial Stability Analysis

As an illustration of how climate-adjusted macroeconomic scenarios can be used in financial stability analysis, this paper considers their application within the banking stress-testing framework used.

Uruguay currently has in place a stress testing framework which is used for the assessment of financial stability as indicated in the macroprudential policy framework published by Banco

Central del Uruguay (BCU, 2024a). This methodology includes, as exogenous variables, forecasts of GDP, unemployment rate, real wages, consumer inflation, nominal exchange rate, international interest rate, country risk, and banks' lending rates to households and firms.

These forecasts are associated with different scenarios: a baseline scenario, an adverse scenario, a stress scenario consistent with the domestic financial crisis of 2002, and additional risk scenarios formulated in the context of financial stability assessments (used for internal purposes). As a result of the simulations, the framework allows the evaluation of banking system resilience under alternative macroeconomic scenarios, allowing for comparisons among the current situation, the baseline projection, adverse risk scenarios, and more severe stress simulations.

In this context, climate-adjusted macroeconomic scenarios can be incorporated as additional risk scenarios, allowing the analysis of how climate-related macroeconomic shocks may affect the resilience of the banking system.

3. Methodological Integration

In this section, we describe how the URY-MFMOD simulations are integrated into the stress-testing framework currently used internally at the Banco Central del Uruguay (BCU) for financial stability assessment.

We first use the URY-MFMOD framework, which incorporates drought-related climate shocks developed by Giuliano et al. (2024), to conduct two types of simulations. These simulations generate a baseline scenario and an alternative scenario that incorporates the climate shock. Details of these exercises are presented in Section 4 (Alternative Scenarios). Our focus is on the differential between the baseline and the climate-shock scenario. URY-MFMOD simulations are produced at an annual frequency.

We then take the most recent baseline scenario produced by the Monetary Policy (MP) Area of the BCU. This scenario is prepared for the Monetary Policy Committee and serves as the reference baseline for financial stability analysis. It is available at a quarterly frequency and has a forecast horizon of two years.

For the purposes of this exercise, we transform the MP baseline scenario to an annual frequency. Although the monetary policy baseline covers a two-year forecast horizon, the simulations presented in this paper focus on the first year of the projection. More generally, the same approach could be applied to rolling forecast horizons if needed. While this simplification facilitates the integration of climate shocks into the stress-testing framework, it abstracts from potential state-

dependent nonlinearities in macro-financial transmission and implicitly assumes temporal stability in the transmission mechanism.

Finally, we apply the differential between the baseline and the climate-shock alternative scenario generated by URY-MFMOD to the MP baseline scenario. In the exercises presented in this paper, the climate shock is introduced in URY-MFMOD in 2023, using observed data available up to 2022. We compute the differential between the alternative and baseline URY-MFMOD scenarios and apply these differentials to the MP baseline projections over the corresponding forecast horizon (two years in the operational framework). In this way, the MP baseline scenario is adjusted to reflect the impact of the climate shock. In the empirical application presented in this paper, we focus on the first year of the projection.

Not all variables used in the stress-testing framework are included in URY-MFMOD. Table 1 presents the mapping between the variables used in the stress-testing scenarios and those available in URY-MFMOD, as well as variables that are treated as exogenous. A full description of MFMOD and its set of endogenous variables is provided in Burns et al. (2019). Variables not included in URY-MFMOD mainly relate to interest rates. In addition, while real wages and unemployment were not included in Giuliano et al. (2024), these variables can be obtained from the model. URY-MFMOD also provides sectoral, fiscal, external, and poverty and vulnerability indicators (see Table A.1 in the Appendix), which—although not directly used in the stress-testing scenarios—are useful for contextualizing the alternative scenarios developed for the stress-testing exercises.

In summary, URY-MFMOD is used to estimate the macroeconomic impact of drought-related climate shocks, and the resulting differential relative to the baseline scenario is applied to the baseline projections used in the stress-testing framework.

Table 1. Mapping between stress-testing scenario variables and MFMOD

Stress-testing scenario variable	Source for alternative scenario	URY-MFMOD variable code
Gross Domestic Product	MFMOD	URYNYGDPMKTPKN
Unemployment	MFMOD	URYLMUNRTOTL_
Real wage	MFMOD	URYNYWRTTOTLXN & URYNECONPRVTXN
Exchange rate	MFMOD	URYPANUSATLS
Consumer Price Index	MFMOD	URYNECONPRVTXN
Households interest rate, local currency	International interest rate and exchange rate	---
Firms interest rate, local currency	Assumed equal to baseline	---
Firms interest rate, US dollars	Assumed equal to baseline	---
Country risk	Assumed equal to baseline	---
International interest rate	Exogenous	---

Source: Own elaboration. *Notes*: The table reports the correspondence between stress-testing scenario variables and MFMOD outputs. For each variable, it specifies whether the alternative scenario is derived from MFMOD simulations or based on an explicit assumption and lists the corresponding MFMOD variable code when available.

As shown in Table 1, core macroeconomic variables such as GDP, unemployment, real wages, the exchange rate, and consumer prices are directly taken from URY-MFMOD simulations. In the case of real wages, the indicator is constructed using the relevant URY-MFMOD wage and price variables. International interest rates are treated as exogenous and are assumed not to be affected by a drought occurring in Uruguay. This assumption reflects the small-open-economy nature of Uruguay and the localized and transitory character of the climate shock. Country risk is assumed to follow the same trajectory as in the baseline scenario. Although it could, in principle, react to a severe drought, recent experience suggests otherwise. During the last major drought episode, no significant changes in country risk were observed (see Figure A.1. in the Appendix). Given the transitory nature of the climate event and the absence of persistent changes in sovereign credit fundamentals, we assume that country risk remains unaffected.

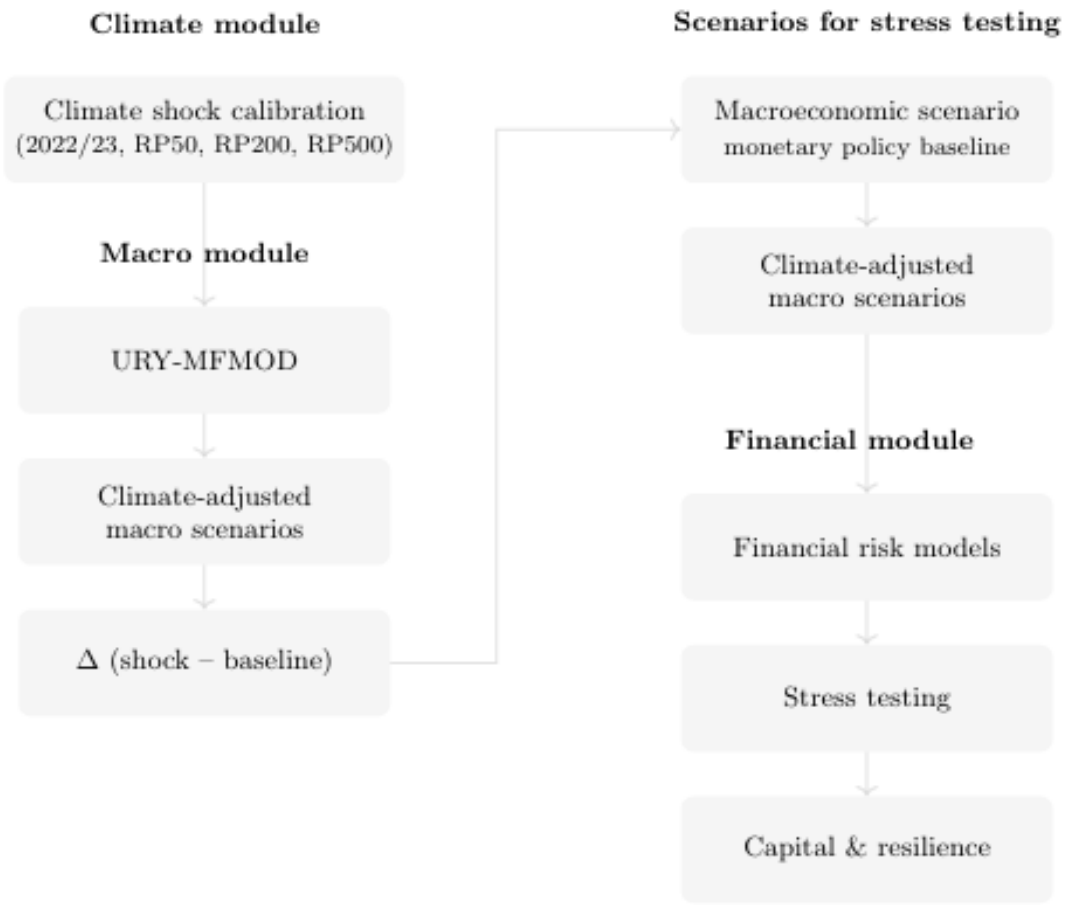
Interest rates are not modeled within URY-MFMOD and therefore need to be specified through additional assumptions. Projections for corporate interest rates in pesos and U.S. dollars follow the same approach used by the MP in the construction of the baseline macroeconomic scenario (Barón et al., 2022). The corporate interest rate in pesos is assumed to depend on its own lag and on the monetary policy rate. Given the transitory nature of the shock, inflation expectations and

the monetary policy rate are assumed to remain unchanged, implying no differences across scenarios. The corporate interest rate in U.S. dollars is assumed to depend on international interest rates and country risk. Since neither variable change in the alternative scenario, this rate is assumed to remain unchanged across scenarios. Finally, for household interest rates in pesos, baseline projections are not available. In this case, both in the baseline and alternative scenarios this rate is adjusted according to changes in the exchange rate and international interest rates.

Finally, we apply the simulated scenarios to the financial module. Using data from the Uruguayan credit registry, we estimate the impact of each scenario on banks' capital adequacy ratios under the assumption of static balance sheets.

In summary, URY-MFMOD is used to estimate the macroeconomic impact of drought-related climate shocks, and the resulting differential relative to the baseline scenario is applied to the baseline projections used in the stress-testing framework. Figure A presents a schematic overview of this end-to-end integration.

Figure A — End-to-end architecture of the exercise



Notes: The calibration uses direct agricultural damages from the 2022/23 event and IDB loss curves for 50/200/500-year return periods. The URY-MFMOD differentials are applied to the baseline macroeconomic scenario after harmonizing frequencies. Interest rates and sovereign risk are held constant across scenarios.

In the following section, we describe the two simulation exercises used to construct scenarios with climate shocks.

4. Alternative Scenarios

In this section, we present the two simulation exercises used to construct alternative scenarios incorporating drought-related climate shocks.

In the first exercise, we build an alternative scenario in which macroeconomic variables are affected by a climate shock that replicates the impact of a single drought event of the magnitude observed in 2022/23, following the approach in Giuliano et al. (2024). We refer to this scenario

as *Single drought event (2022/23)*. According to INUMET (2024), the estimated empirical return period of this event is 114 years. Estimates from Cortelezzi et al. (2023) indicate that direct damages to the agricultural sector—including crops and livestock—amounted to approximately USD 1.8 billion, equivalent to around 3% of GDP and 40% of agricultural GDP.

In the second exercise, we generate three alternative scenarios using the loss curves from the IDB (2019) disaster risk analysis, introduced in Section 2.1. These loss curves report direct losses for crops and livestock associated with drought episodes of different return periods (see Figure 1). IDB (2019) provides loss curves both for historical (baseline) climate conditions and for alternative climate scenarios reflecting climate change. Losses are expressed as a function of the return period of drought events, measured in years, with higher return periods corresponding to more severe events.

We use these loss estimates to calibrate the damage parameter in the production functions for crops and livestock in URY-MFMOD (see Equation 1, parameter di,t). Specifically, we consider drought events with return periods of 50, 200, and 500 years. We rely on the historical (baseline) climate loss curves, as we assume that the climate shock materializes in the short term—specifically, in the first year of the MP baseline scenario. Under this assumption, using alternative climate change scenarios (i.e., different RCP pathways) could be less appropriate since the objective of this exercise is to assess short-term physical risk materialization rather than long-term transition or chronic climate change dynamics.

For each calibration, we run URY-MFMOD and obtain a baseline scenario and a corresponding alternative scenario incorporating the climate shock. We then compute the differential between the two scenarios and apply it to the MP baseline scenario, as described in Section 3.

As a result, the second simulation exercise yields three alternative scenarios that differ in the severity of the drought shock, which we label Drought RP50, Drought RP200, and Drought RP500. These scenarios, together with the Single drought event (2022/23) scenario from the first exercise, are used as inputs to the stress-testing framework. These return periods are selected to represent progressively more severe drought shocks—from a moderate stress scenario to low-probability tail-risk events—allowing for a non-linear assessment of macro-financial vulnerability across different levels of physical risk intensity.

In the stress-testing exercises, the impact on banks is assessed over the year in which the climate shock materializes, in this paper that corresponds to 2026. Accordingly, all banking stress test results reported in the following sections refer to the first year of each alternative scenario, when the macroeconomic effects of the drought are most pronounced. This timing reflects the scenario

construction described in Section 3, where historical climate shock differentials are mapped into the MP baseline scenario.

Before turning to the stress-testing results, we briefly summarize the main macroeconomic features of the alternative scenarios. Figure 2 presents the differential between the alternative and baseline scenarios generated by the URY-MFMOD simulations, focusing on the macroeconomic variables directly produced by the model. Figure 3 presents the difference between the baseline and alternative scenarios for the household interest rate in pesos. All other variables are assumed to follow identical paths in both scenarios.

The results presented in Figure 2 show a coherent supply-driven macroeconomic adjustment across all drought scenarios. Consistent with the modeling strategy described in Section 2, the shock is introduced as a negative productivity disturbance in the agricultural sector. As the severity of the shock increases, its aggregate effects become progressively more pronounced. GDP declines between 1.8% and 2.9% relative to the baseline, reflecting the direct contraction of agricultural output and the propagation of this sectoral shock to related activities and external demand. Output losses increase sharply at moderate return periods but display diminishing marginal effects at higher return periods. This pattern reflects both the limited weight of agriculture in aggregate GDP and the absence of endogenous macro-financial amplification mechanisms in the current framework, which constrain the transmission of increasingly severe sectoral shocks to the broader economy.

The deterioration in export revenues weakens the external balance, leading to exchange rate depreciation of between 3.5% and 6.1%. This depreciation increases the domestic currency cost of imports and, through exchange rate pass-through, feeds into consumer prices. Inflationary pressures are further reinforced by the negative supply shock in food production. Agricultural and livestock prices increase due to lower productivity and, in the case of crops, their linkage to international prices denominated in foreign currency. Overall, consumer prices rise between 1.1% and 2% relative to the baseline.

Labor market conditions adjust in line with the contraction in activity. Unemployment increases as firms respond to lower output, while real wages decline due to both weaker production and the erosion of purchasing power associated with higher inflation. These macroeconomic dynamics constitute the main transmission channels to credit risk within the stress-testing framework, as they directly affect borrowers' income and debt-servicing capacity, potentially through offsetting macroeconomic channels.

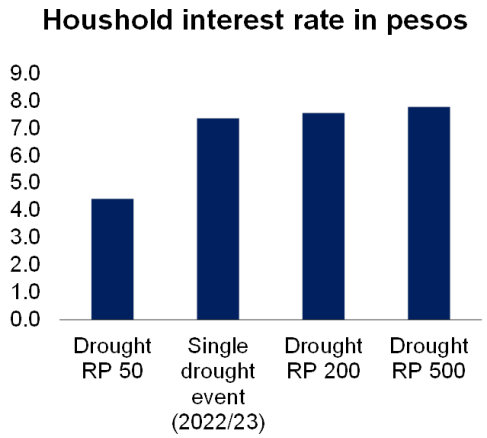
Figure 2. Macroeconomic impact of drought shocks: deviation from baseline (URY-MFMOD simulations)

Source: Own elaboration based on URY-MFMOD and Giuliano et al. (2024). *Notes:* The figure reports percentage deviations from the baseline scenario. For all variables except unemployment, deviations are computed as the percentage change of the alternative scenario relative to the baseline. For unemployment, the deviation is defined as the difference (in percentage points) between the alternative and baseline scenarios.

Figure 2 illustrates a coherent supply-driven macroeconomic adjustment mechanism: a negative productivity shock in the agricultural sector propagates through output, external balances, prices, and labor market conditions. The magnitude of these effects increases with the severity of the drought event, although the macroeconomic responses under the RP200 and RP500 scenarios are broadly comparable to those observed for the 2022/23 event at the aggregate level.

Figure 3 shows that household interest rates in domestic currency increase across all drought scenarios relative to the baseline. Within the approach taken, this adjustment is rule-based rather than fully endogenous: household lending rates in pesos are assumed to depend on exchange rate dynamics and international interest rates. Given that international rates are held constant across scenarios, the observed increase in borrowing costs is entirely attributable to exchange rate depreciation under the alternative climate scenarios. As drought severity intensifies, larger depreciations mechanically translate into higher lending rates, reinforcing the transmission of the macroeconomic shock to household debt-servicing capacity.

Figure 3. Household interest rate in pesos: baseline vs. alternative scenario



Source: Own elaboration. Notes: The figure reports the difference (in percentage points) between the alternative and baseline scenarios for the household interest rate in pesos. All other interest rate variables are identical across scenarios.

The magnitude of this adjustment rises with the severity of the drought shock, as larger exchange rate depreciations generate correspondingly higher lending rates through the rule embedded in the framework. Although this adjustment is mechanically determined under the current specification, the resulting increase in borrowing costs still amplifies the impact of adverse macroeconomic conditions on households' repayment capacity, strengthening the quantitative transmission from macroeconomic stress to credit risk.

Taken together, Figures 2 and 3 indicate that drought shocks produce a broad-based macro-financial tightening, characterized by lower output, higher inflation, exchange rate depreciation, deterioration of labor market conditions, and higher borrowing costs. These dynamics directly affect borrowers' repayment capacity and the overall credit environment faced by banks. They therefore constitute the main transmission channels through which climate shocks are expected to influence banking sector solvency in the stress-testing exercises.

5. Results of Climate Stress-Testing

This section presents the main results of the stress-testing exercise under the alternative climate scenarios described above. The analysis focuses on the transmission of drought-induced macroeconomic shocks to credit risk and banking system solvency within a stress-testing framework. Results are reported at the aggregate level of the banking system, consistent with institutional disclosure constraints and with the objective of assessing system-wide resilience rather than bank-specific vulnerabilities.

A central finding of the stress-testing exercises is that climate scenarios generate limited deviations from the baseline scenario. In the simulation described above, capital adequacy ratios decline by up to 0.1 percentage points relative to the baseline, at the aggregate level. These results reflect the transmission of drought-related macroeconomic shocks into a deterioration in credit quality and a corresponding decline in capital adequacy, which is largely offset by other factors described below. As a result, the magnitude of these effects remains modest and does not significantly alter the overall solvency trajectory of the banking system.

Under a scenario replicating the 2022/23 drought episode, the impact on aggregate solvency ratios is similarly modest, suggesting that the banking system remained resilient even under historically observed extreme conditions. A retrospective analysis shows that capital adequacy ratios remained broadly stable during that period, as documented in successive financial system reports by the Banco Central del Uruguay (2021–2024). This resilience can be partly attributed to policy measures implemented by the government and the central bank to support affected sectors, as well as to the activation of insurance mechanisms that helped mitigate losses (Barón et al., 2026), thereby dampening the transmission of the shock to the banking system.

Probabilistic drought scenarios associated with longer return periods lead to higher credit losses, thereby exerting downward pressure on capital adequacy ratios. However, even under more severe shocks, projected capital ratios remain close to baseline levels, with only marginal reductions. These findings suggest that climate-induced macroeconomic shocks propagate through standard macro-financial transmission channels—primarily via lower economic activity, weaker income dynamics, and higher default probabilities—but their aggregate quantitative impact remains limited. An additional consideration relates to the structure of sectoral exposures. While agriculture has a relatively limited direct contribution to aggregate output, the banking system exhibits a comparatively high degree of exposure to the sector. This highlights a potential disconnect between macroeconomic relevance and financial risk exposure, which may not be fully captured when shocks are transmitted primarily through aggregate macroeconomic variables.

In the simulations, exchange rate depreciation also generates offsetting effects. In particular, the banking system maintains a positive net foreign-currency asset position relative to capital, which generates valuation gains under exchange-rate depreciation, partially offsetting the deterioration in credit quality. While this effect provides an important buffer in the simulations, it also depends on the stability of observed exchange rate dynamics and could be further assessed through sensitivity analysis under alternative correlation structures.

An additional factor contributing to the limited impact on capital ratios is the presence of dynamic (statistical) loan-loss provisioning mechanisms within Uruguay's prudential framework. Under this system, banks accumulate provisions during periods of strong credit performance, which can subsequently be used to absorb increases in credit losses during adverse macro-financial conditions. As documented in Frache et al. (2017), this countercyclical provisioning regime acts as a buffer that helps absorb such losses and mitigate their impact on bank profitability and capital during downturns. This mechanism represents a key driver of the limited impact on capital ratios and could be further explored through sensitivity analysis, for instance by assessing the resilience of provisioning buffers under more severe or prolonged stress scenarios.

Beyond these institutional and structural factors, the limited impact of the simulated shocks also reflects features of the modeling framework. Within the current setup, drought-induced productivity losses affect banking system solvency mainly through aggregate macroeconomic conditions, which respond only moderately to sector-specific disturbances. Additionally, other channels—such as interbank contagion or common exposures across financial institutions—could amplify the transmission of shocks within the financial system. These mechanisms, which are not explicitly modeled in the current framework, have been shown in the literature to play a relevant role in the propagation of climate-related financial risks (Roncoroni et al, 2021).

These results are largely driven by structural features of the modeling framework that constrain the propagation of physical shocks to the financial system. First, climate damages are modeled as productivity losses in agriculture-related activities, whose direct contribution to aggregate output remains relatively limited, leading to diminishing marginal macroeconomic effects. Second, key financial variables—including sovereign risk and most lending rates—are assumed to remain constant across scenarios, dampening the transmission to financial conditions. Third, the stress-testing application depends on aggregate macroeconomic indicators rather than borrower- or sector-level exposures, smoothing heterogeneity in physical risk. Finally, the analysis is conducted at the system-wide level and does not capture bank-level portfolio composition. The interpretation of these results requires careful consideration of the underlying modeling assumptions (see Box 1).

Box 1. Interpreting Limited Quantitative Impacts of Climate Stress Scenarios

The relatively small quantitative differences observed across climate scenarios should be interpreted with caution. These results reflect key features of the modeling framework, including the absence of strong non-linearities and that the climate shock is filtered through macro variables, as well as the presence of institutional buffers within the financial system. Additionally, in the illustration presented in this paper, stress testing is performed at the corporate level, without distinguishing differential impacts across economic sectors.

As a result, increasingly severe physical shocks do not necessarily translate into proportionally larger macro-financial impacts within the current framework. This may lead to relatively similar outcomes across scenarios with markedly different return periods, which may appear counterintuitive.

Importantly, these findings do not imply that climate-related risks are limited. Under alternative modeling assumptions—such as the inclusion of non-linear macroeconomic responses, sectoral level assessment or financial contagion channels—more severe climate events could generate larger macro-financial impacts. Overall, the results can be interpreted as a lower bound of the assessment of financial vulnerability associated with physical climate risks.

Taken together, climate stress scenarios generate marginal deviations around the baseline path rather than distinct financial stress regimes. These results therefore reflect both the limited macro-financial sensitivity embedded in the current modeling architecture and the presence of institutional buffers within the banking system, rather than suggesting that climate risk is economically negligible. The interpretation of these results benefits from comparison with alternative climate stress-testing approaches applied to Uruguay, particularly those based on NGFS scenarios. Box 2 discusses the main methodological differences and their implications.

Box 2. Comparing Climate Stress Testing Approaches for Uruguay

This paper complements recent climate stress testing exercises for Uruguay based on the Network for Greening the Financial System (NGFS) short-term scenarios (Barón et al., 2026), which assess banks' exposure to physical risk through sectoral shocks to probabilities of default (PDs). While both approaches aim to evaluate climate-related financial risks, they differ in key methodological aspects, leading to distinct yet consistent results. The NGFS-based exercise applies PD adjustments associated with different scenarios of a tail physical risk event—combining heatwaves, droughts, and wildfires—at the level of sectoral credit exposures. These scenarios are generated by an integrated suite of models (GEM-E3, EIRIN and CLIMACRED)

(NGFS, 2025), ensuring internal consistency in the underlying macro-financial environment. However, given the lack of country-specific scenarios for Uruguay, the analysis relies on regional (South America) scenarios, which may not fully capture country-level characteristics. The approach highlights credit concentration and tail risk, revealing substantial heterogeneity across banks and identifying institutions for which expected incremental losses may represent a significant share of regulatory capital. It focuses on the direct materialization of credit risk and is well suited for vulnerability analysis.

On the other hand, this paper embeds climate shocks in a structural macro-fiscal model tailored to the Uruguayan economy (URY-MFMOD) and transmits them to bank stress tests through aggregate macroeconomic variables, which in turn inform PD adjustments at the corporate and household levels. In this setting, climate risk affects banks through its impact on output, employment, inflation, and the exchange rate. Therefore, in comparison to the paper based on NGFS scenarios, the results are based on country-specific scenarios for Uruguay and reflect PD adjustments at a more aggregate level of credit exposures.

Another key difference relates to scenario design. The NGFS short-term scenarios feature the simultaneous occurrence of multiple severe hazards within a single year, implying a more adverse configuration than in the MFMOD framework, which in this exercise considers only drought-related shocks. In addition, as commented in Box 1, the MFMOD framework may smooth the propagation of shocks, particularly under more extreme conditions.

In addition, Barón et al. (2026) focus exclusively on credit risk at the firm level, without incorporating other balance sheet risks. As a result, effects such as valuation gains from exchange rate depreciation are not captured, nor are prudential loss-absorbing mechanisms such as dynamic provisioning. These features are included in the present framework and contribute to the more limited impact on capital ratios.

These differences explain why estimated impacts here are modest at the aggregate level, while the NGFS-based exercise identifies material losses for some institutions. The results are complementary: climate shocks may be manageable system-wide—particularly in the presence of buffers and strong foreign currency positions—yet remain significant for banks with concentrated exposures to climate-sensitive sectors. A comprehensive assessment therefore benefits from combining both perspectives.

6. Conclusion

This paper develops an operational framework to incorporate climate-induced physical shocks into macroeconomic scenarios used for macro-financial analysis. By integrating climate-shock simulations derived from a structural macro-fiscal model with baseline macroeconomic scenarios generated through internal institutional processes, the framework provides a practical and institutionally implementable approach to constructing climate-adjusted macroeconomic scenarios consistent with the broader macroeconomic framework used for financial stability analysis.

Applied to drought scenarios of varying severity, the results indicate a consistent macroeconomic transmission mechanism operating through lower economic activity, exchange rate depreciation, higher inflation, and weaker labor market conditions. These dynamics illustrate how climate shocks can affect macro-financial conditions and, through this channel, influence banking system resilience.

As an illustration of their potential use in financial stability analysis, the climate-adjusted scenarios are incorporated into the banking stress-testing framework. At the aggregate level, the banking system appears broadly resilient, within the scope of this aggregate macro-financial framework, to historically observed extreme events and remains broadly stable even under low-probability tail scenarios. Differences across scenarios are limited in magnitude, reflecting both the structure of the macro-financial transmission mechanism considered in this exercise and the presence of institutional buffers within the banking system, rather than similarity in the underlying physical shocks. In particular, the limited quantitative impact reflects both features of the modeling framework and structural characteristics of the financial system, including the role of loss-absorbing mechanisms and balance sheet structures that partially offset the effects of adverse shocks.

These findings underscore an important implication for climate stress testing: the quantitative impact of physical risk scenarios depends not only on the severity of the underlying hazard, but also on the structure of the macro-financial transmission framework used to translate physical damages into financial outcomes.

From a policy analysis perspective, the framework provides a practical tool for integrating climate risk into macroeconomic scenarios already used in financial stability analysis, while remaining complementary to existing assessments. As discussed in Box 2, microprudential exercises based on NGFS scenarios highlight potentially larger losses for specific institutions, reflecting exposure concentration and borrower-level heterogeneity. Taken together, these approaches offer a more comprehensive assessment of climate-related financial risks.

Future work could expand the framework by incorporating multi-year climate scenarios, including consecutive droughts, drought–flood sequences, or combinations of climate and macroeconomic shocks, to better assess financial system resilience. Other possible extensions include interactions between physical and transition risks, endogenous policy responses, financial contagion, relaxing assumptions on key financial variables—such as interest rates and sovereign risk—as well as conducting a more granular assessment.

Overall, while subject to these limitations, the framework provides a tractable and institutionally consistent starting point for integrating climate scenarios into macro-financial policy analysis, while highlighting key areas where further methodological development is needed.

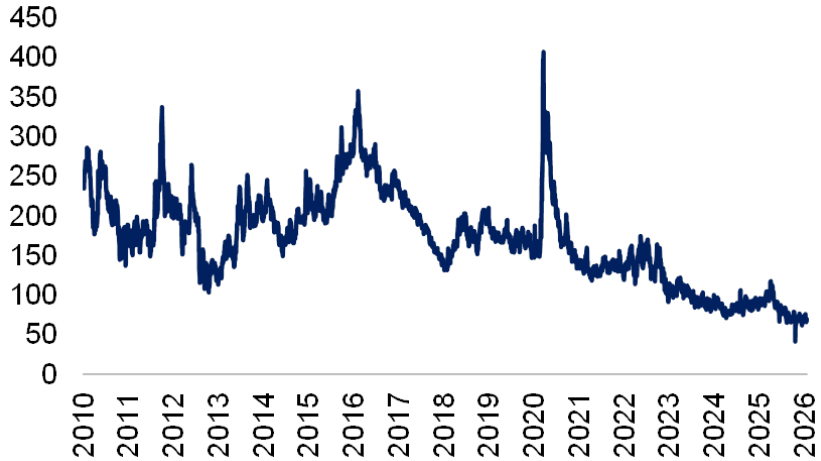
7. Appendix:

Table A.1. Macroeconomic variables generated by URY-MFMOD for the assessment of climate shocks (Giuliano et al., 2024)

Real Sector	**External Sector**
Real GDP	Nominal effective exchange rate
Real domestic demand	Real effective exchange rate
Real exports	Current account balance (% of GDP)
Industry output	
Livestock output	**Fiscal Sector**
Crop output	Fiscal balance (% of GDP)
Unemployment	Total revenues (% of GDP)
Salaries	Total expenditures (% of GDP)
Prices	Social service transfers (% of GDP)
Consumption prices	Debt-to-GDP ratio
Industry prices	
Import prices	
Livestock prices	
Agricultural prices	
Factor prices	

Source: Own elaboration. *Notes*: The table reports the macroeconomic variables from URY-MFMOD used to assess the impact of drought-related climate shocks, following Giuliano et al. (2024). All variables are generated endogenously by the model and are used to construct the baseline and alternative scenarios considered in the analysis.

Figure A.1. Uruguayan country risk



Source: J.P. Morgan (EMBI Global Index), data retrieved from Central Bank of the Dominican Republic.

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