BORRADORES DE
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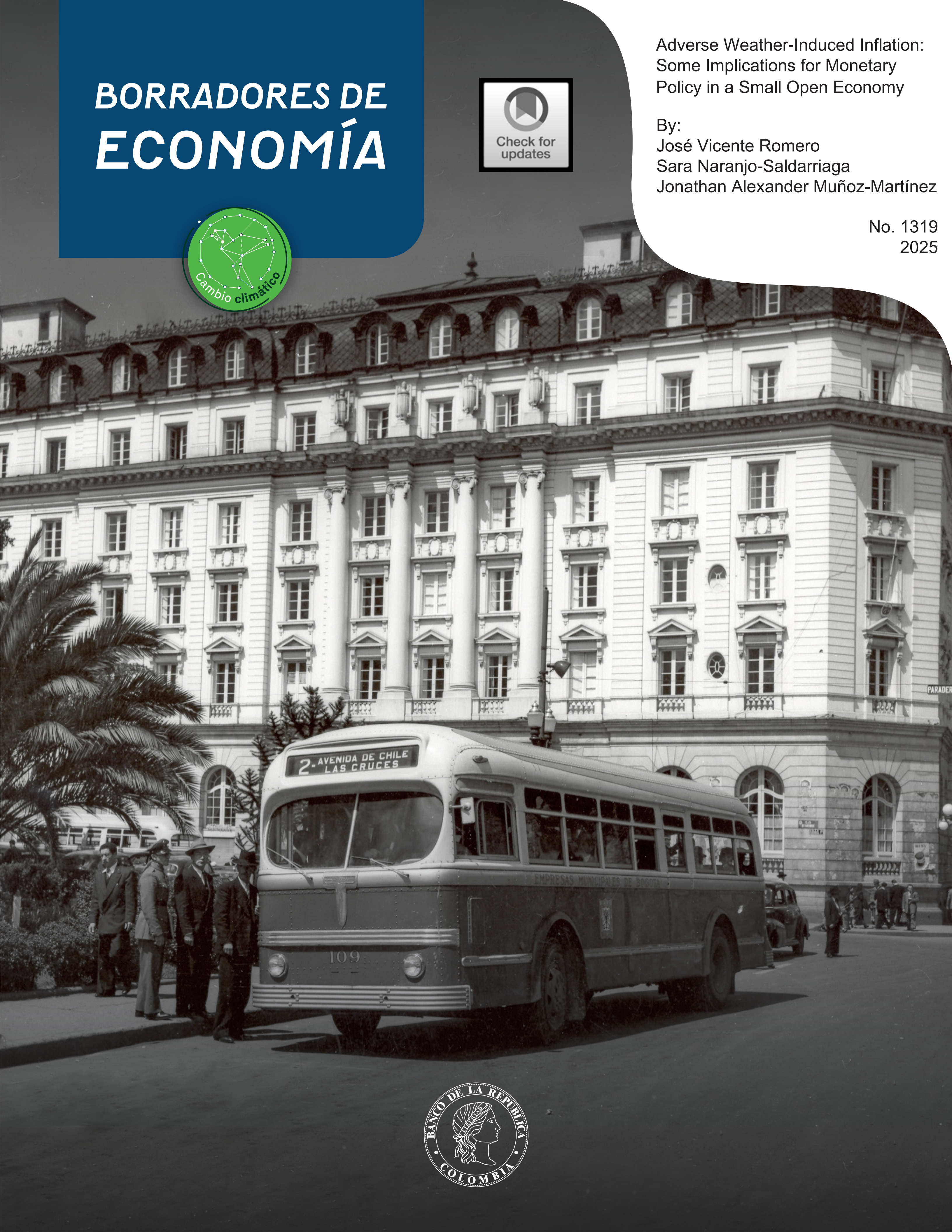
By:
José Vicente Romero
Sara Naranjo-Saldarriaga
Jonathan Alexander Muñoz-Martínez

No. 1319
2025



BANCO DE LA REPUBLICA
COLOMBIA

Adverse Weather-Induced Inflation: Some Implications for Monetary Policy in a Small Open Economy[*]

José Vicente Romero[†] Sara Naranjo-Saldarriaga[‡]
Jonathan Alexander Muñoz-Martínez[§]

Abstract

This paper examines the macroeconomic impacts of adverse weather shocks on the Colombian economy, with a specific focus on agricultural output, food prices, and headline inflation. Drawing on empirical evidence from events such as the 2015–2016 El Niño, we document that these shocks tend to reduce agricultural output and increase inflation while having a limited effect on aggregate GDP growth. Motivated by these stylized facts, we develop a small open economy New Keynesian model for Colombia that introduces a mechanism in which weather shocks alter the relative prices of agricultural and non-agricultural goods. This framework allows us to capture the inflationary pressures induced by adverse climate events in a structural setting. Under our proposed calibration, food inflation, headline inflation, and inflation expectations rise in response to the shock, prompting the monetary authority to raise the interest rate to anchor inflation expectations.

Keywords: Extreme Weather events, El Niño Southern Oscillation (ENSO), Inflation, Small Open Economy New Keynesian Models.

JEL Codes: Q54, E52, E31, E32.

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[*] We want to thank Professor Emanuele Campiglio and the Graduate Institute Geneva for its support and guidance to this project. We also thank the valuable comments of Julián Pérez-Amaya, and the participants of the XXIV Banco de la República Internal Research Seminar and the Better Policy Project Virtual Research Seminar.

[†] Corresponding author. Research Economist, Banco de la República, jromerch@banrep.gov.co.

[‡] Economist - Specialized Professional, Banco de la República, snaransa@banrep.gov.co.

[§] Economist - Specialized Professional, Banco de la República, jmunozma@banrep.gov.co.

Inflación Inducida por Choques Climáticos: Algunas Implicaciones para la Política Monetaria en una Economía Pequeña y Abierta

José Vicente Romero[*] Sara Naranjo-Saldarriaga[†]
Jonathan Alexander Muñoz-Martínez[‡]

Resumen

Este documento examina los impactos macroeconómicos de choques climáticos adversos sobre la economía colombiana, con un enfoque específico en la producción agrícola, los precios de los alimentos y la inflación total. A partir de la evidencia empírica, documentamos que estos choques tienden a reducir la producción agrícola y aumentar la inflación, aunque con un efecto limitado sobre el crecimiento del PIB total. Motivados por estos hechos estilizados, se desarrolla un modelo neokeynesiano para una economía pequeña y abierta que introduce un mecanismo mediante el cual los choques climáticos afectan los precios relativos de bienes agrícolas y no agrícolas. Este marco permite capturar las presiones inflacionarias inducidas por eventos climáticos adversos de manera estructural. Bajo la calibración propuesta para Colombia, la inflación de alimentos, la inflación total y las expectativas de inflación aumentan en respuesta al choque, lo que lleva a la autoridad monetaria a incrementar parcialmente la tasa de interés con el fin de anclar las expectativas de inflación.

Palabras clave: Eventos climáticos extremos, Fenómeno de El Niño (ENSO), Inflación, Economía pequeña y abierta, Modelos neokeynesianos.

Códigos JEL: Q54, E52, E31, E32.

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[*] Investigador, Banco de la República, jromerch@banrep.gov.co.

[†] Profesional Especializado, Banco de la República, snaransa@banrep.gov.co.

[‡] Profesional Especializado, Banco de la República, jmunozma@banrep.gov.co.

1 Introduction

Understanding the impact of weather shocks on the economy has become increasingly relevant, as these phenomena can affect GDP growth, agricultural sector performance, and inflation. This increased relevance is underscored by a recent surge in studies within the economic research agenda examining these impacts (e.g., Bilal and Stock (2025), Nalban and Zanna (2025), NGFS (2024) Berg et al. (2023), Gallic and Vermandel (2020), Mohaddes et al. (2023), Callahan and Mankin (2023), Berg et al. (2023), Cevik and Jalles (2023),Gallic and Vermandel (2020),Andersson et al. (2020), Acevedo et al. (2020), Kim et al. (2025), Natoli (2023), Romero and Naranjo-Saldarriaga (2022)). Nonetheless, due to the heterogeneous nature of weather-related shocks and their varying impacts across sectors and geographies, more consensus has yet to be reached on whether these shocks predominantly affect the supply or demand side of the economy. From a policy perspective, as climate change potentially alters the frequency and intensity of adverse weather events, these shocks could become a more frequent source of business cycle fluctuations in the years to come (Gallic and Vermandel (2020)). This risk underscores the importance of examining the various transmission mechanisms through which these shocks impact the economy.

In Colombia, weather fluctuations associated with the El Niño Southern Oscillation (ENSO) can trigger droughts (during El Niño phases) and floods (during La Niña phases). Previous ENSO episodes have had a significant impact on Colombia's economy, primarily affecting food prices, inflation, and agricultural output.

The objective of this study is to examine the macroeconomic implications of ENSO weather shocks in Colombia. We employ a BVAR-X model and a two-sector Small Open Economy New Keynesian (SOE-NK) model specifically designed for a small open economy. The model incorporates weather shocks, allowing us to investigate their influence on agricultural output and inflation. Thus, our study's contribution to the literature is threefold: first, it adds to the existing empirical literature on the macroeconomic effects of weather shocks; second, it introduces these shocks into a macroeconomic model for a small open economy that helps us dissect the transmission channels of these shocks and the role of monetary policy; and third, the model is suitable for short-term policy analysis and understanding the trade-offs that these shocks may impose. Notably, the model's structure aligns with the small open-economy DSGE models routinely used at central banks in emerging markets.

The remainder of this study is organized as follows. In Section 2, we present a brief overview of the significance of ENSO fluctuations and review the recent empirical literature linking weather shocks to GDP growth and inflation. In Section 3, we outline the primary stylized facts regarding ENSO fluctuations, economic activity, and inflation in Colombia. We employ a BVAR-X model to observe that adverse ENSO shocks result in increased food prices and headline inflation, along with a decrease in agricultural production; however, their impact on overall GDP appears negligible. Section 4 introduces a SOE-NK model with several notable features. It integrates the impact of weather shocks on the agricultural sector, following the approach of Gallic and Vermandel (2020), by incorporating a damage function. It assumes price rigidities in the agricultural and non-agricultural sectors by including intermediate firms, aggregate firms, capital producers for each sector, and Calvo Pricing, resulting in prices that do not coincide with marginal costs. The model also takes into account total aggregate firms and incorporates a monetary policy rule as an integral part of its structure. It assumes imperfect pass-through, influencing each sector's pricing of imported goods. In addition, we present a methodological approach to calibrate the damage function using impulse response matching of ENSO shocks on headline and food inflation. In Section 5, we present the dynamics of the model in response to ENSO shocks. Lastly, Section 6 outlines the conclusions.

2 Significance of ENSO Fluctuations, Weather Shocks, and Economic Activity

The El Niño-Southern Oscillation (ENSO) is a recurring climatic pattern characterized by temperature changes in the waters and shifts in atmospheric pressure in the Pacific Ocean. Figure 1 depicts the sea-surface temperature anomalies during the potent 2015-2016 El Niño episode, one of the most substantial occurrences since 1950 (L'Heureux, 2016). Figure 2 presents the evolution of the Oceanic Niño Index (ONI), which measures sea surface temperature anomalies in the Pacific Ocean based on a threshold of +/- 0.5 degrees Celsius.

This phenomenon influences global weather and climate patterns, resulting in environmental and societal consequences, thereby underscoring its significance as mentioned by McPhaden et al. (2020). However, it is essential to understand that ENSO's characteristics are shaped by the long-term average background climatic conditions within which it evolves (Masson-Delmotte et al., 2021). Since the Industrial Revolution in the mid-18th century, these background conditions have undergone significant transformation, primarily due to human activities. This shift has accelerated in recent decades, with human activities pushing heat-trapping greenhouse gas concentrations in the atmosphere to unprecedented levels.

In this context, the risks and uncertainties underscore the need to understand the potential mechanisms through which ENSO fluctuations will evolve and how they may impact the economy. According to the 2021 IPCC report (Masson-Delmotte et al., 2021), climate models do not provide a consensus on a systematic change in the amplitude of ENSO sea surface temperature variability under medium confidence scenarios. However, rainfall variability related to ENSO is likely to increase significantly by the latter half of the 21st century. Recent research by the US National Oceanic and Atmospheric Administration (NOAA) suggests that under aggressive greenhouse gas emission scenarios, the frequency of extreme El Niño and La Niña events could potentially double by the end of the century, changing from approximately one event every 20 years to one every ten years. Furthermore, the intensity of these events may become even more potent than those witnessed today (McPhaden et al., 2020).

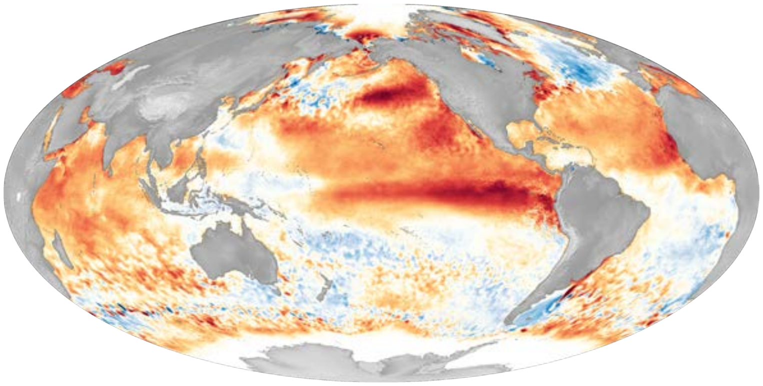

Figure 1: A very strong El Niño in 2015-2016 – large 'red tongue' in equatorial Pacific. Source: NOAA/NESDIS.

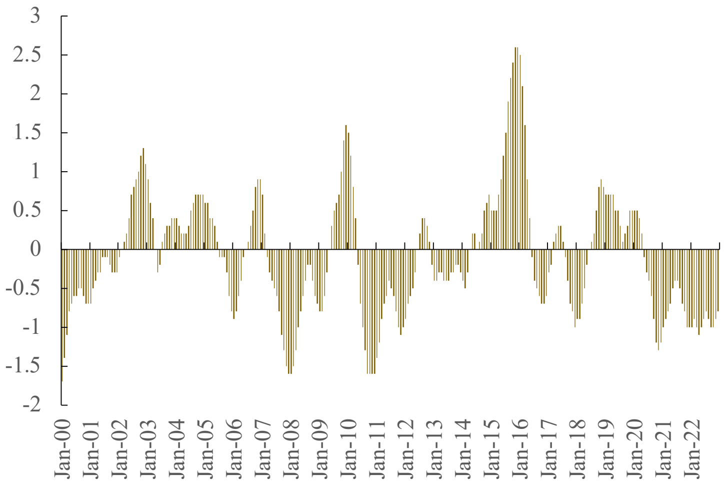

Figure 2: ENSO fluctuations. Sea surface temperature anomalies in Celsius degrees. Source: NOAA/NESDIS.

Recent research has highlighted the heterogeneous effects that ENSO fluctuations and extreme El Niño events can have on economic activity. For instance, Callahan and Mankin (2023) shows that El Niño persistently reduces economic growth and that national economies are sensitive to El Niño even when warming is taken into account, arguing that future global economic growth could decline due to the anthropogenic intensification of ENSO variability. Cashin et al. (2017) show evidence of considerable heterogeneities in the responses of different countries to El Niño shocks. While Australia, Chile, Indonesia, India, Japan, New Zealand, and South Africa face a short-lived fall in economic activity in response to an El Niño shock, other countries (including the United States and the European region) experience a growth-enhancing effect. Furthermore, most countries in their sample experience short-term inflationary pressures as energy and non-fuel commodity prices increase.

3 Some Stylized Facts for Colombia

In Colombia, ENSO fluctuations typically lead to decreases in agricultural output and increases in food and headline inflation without significantly affecting total GDP growth. Given the country's heavy reliance on hydroelectric energy generation, these fluctuations also significantly impact electricity prices. Key studies documenting these stylized facts for Colombia, particularly the effects of El Niño on prices, are encapsulated in works by Bejarano-Salcedo et al. (2020), Romero et al. (2017), Abril-Salcedo et al. (2020), and Romero and Naranjo-Saldarriaga (2022). These studies have consistently found that adverse weather events associated with El Niño significantly increase food and headline inflation. Specifically, the range of estimates of the impact of adverse ENSO events in these studies on food inflation varies between 1.16 and 7.3 percentage points and between 0.2 to 1.2 percentage points for headline inflation, depending on the intensity of the El Niño phenomenon. Furthermore, Romero et al. (2017) projected that an adverse El Niño event could result in a 0.6% negative impact on GDP.

There is also a growing literature on specific crops that may be affected by these fluctuations. For example, Bastianin et al. (2018) demonstrate that despite the overall agricultural sector being affected by El Niño, La Niña events (i.e., negative shocks to ENSO) depress Colombian coffee production and exports while increasing prices, underscoring the complex nature of these shocks. To synthesize the stylized facts regarding overall economic activity and prices since 2000, we present a BVAR-X model in the subsequent section, enabling us to assess the recent historical impact of ENSO fluctuations on Colombia's agricultural sector and inflation.

To better understand the impact of ENSO shocks on the Colombian economy, we use BVAR-X. The proposed model takes the following form:

$$y_t = Ay_{t-1} + Bx_t + \mu_t \tag{1}$$

In this model, the vector y_t comprises:

$$y_t = \begin{pmatrix} \pi^*_t \\ \tilde{y}^*_t \\ \tilde{z}^*_t \\ agri_t \\ \tilde{y}_t \\ \tilde{\pi}^{food}_t \\ \tilde{\pi}^{headline}_t \end{pmatrix} \tag{2}$$

Here, π^*_t, $\tilde{y}^*_t$, $\tilde{z}^*_t$, $\widetilde{agri}_t$, and $\tilde{y}_t$ correspond to external quarterly inflation of the main trading partners, external output gap, real exchange rate, total output and agricultural sector gaps, respectively. Each variable is presented as a deviation from a long-term trend.[1] The variables $\pi_t^{\widetilde{food}}$ and $\pi_t^{\widetilde{headline}}$ represents food inflation, detrended using the inflation target.[2]

The exogenous matrix X_t in our model includes the ENSO fluctuations. For the rest of the system, we identify shocks using Cholesky decomposition, with agricultural output and food inflation positioned as the most contemporaneously endogenous variables. We estimate our model using quarterly data from 2000Q1 to 2019Q4. The inclusion of data from the post-COVID-19 period did not significantly impact the results related to the activity. However, the effect on inflation series requires additional controls to assess better the strong international supply shocks that affected global inflation during the last five years.[3] Standard information criteria were used to determine the lag structure, which in most cases suggested four lags for our quarterly model. Our BVAR-X models were estimated using an independent Normal-Wishart prior, assuming that the variance-covariance matrix Σ is unknown. This type of BVAR-X model has previously been used to study the impact of ENSO fluctuations in Colombia, particularly on different measures of inflation expectations (Romero and Naranjo-Saldarriaga, 2022).

Our BVAR-X model reveals several stylized facts about the impact of ENSO shocks on the Colombian economy. Figure 3 illustrates the response of selected variables to a shock of one degree Celsius in the ENSO index. Our findings suggest a substantial increase in inflation, indicating a significant effect on consumer prices. This obser-

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[1] The empirical exercise results shown here uses the HP filter. Additional exercises employing alternative detrending methods, such as the Hamilton filter, lead to similar qualitative results.

[2] Alternative specifications using only food inflation obtained similar qualitative and quantitative results. Generally, and by the literature for Colombia, ENSO fluctuations—particularly those related to El Niño—tend to impact inflation.

[3] Several elements make the analysis of the relation between ENSO, inflation, and food inflation between 2021 and 2024 challenging and beyond the scope of our exercise. Among these, there was a strong increase in global inflation during 2021-2022, driven by the impact of relative food price inflation, trade, and geopolitical shocks, as well as an unusually long and intense La Niña event and the elimination of measures taken on some prices to mitigate the economic impact of COVID-19.

vation is consistent with existing Colombian literature. We also note a decline in agricultural output, underscoring the sector's vulnerability to weather shocks. Despite these observable impacts on the agricultural sector, the overall effect on GDP appears relatively muted. It is not statistically significant in our sample, underscoring the complex nature of the effects of weather shocks on different economic sectors. However, impulse responses reveal a slight decrease in our measure of economic activity. In summary, ENSO shocks in Colombia can be viewed as supply shocks (cost-push) where increases in the ENSO index (evidenced by higher sea surface temperatures in the Pacific Ocean) lead to inflation, reductions in the agricultural sector, and a slight impact on overall economic activity (included as an output gap in our BVAR-X model).

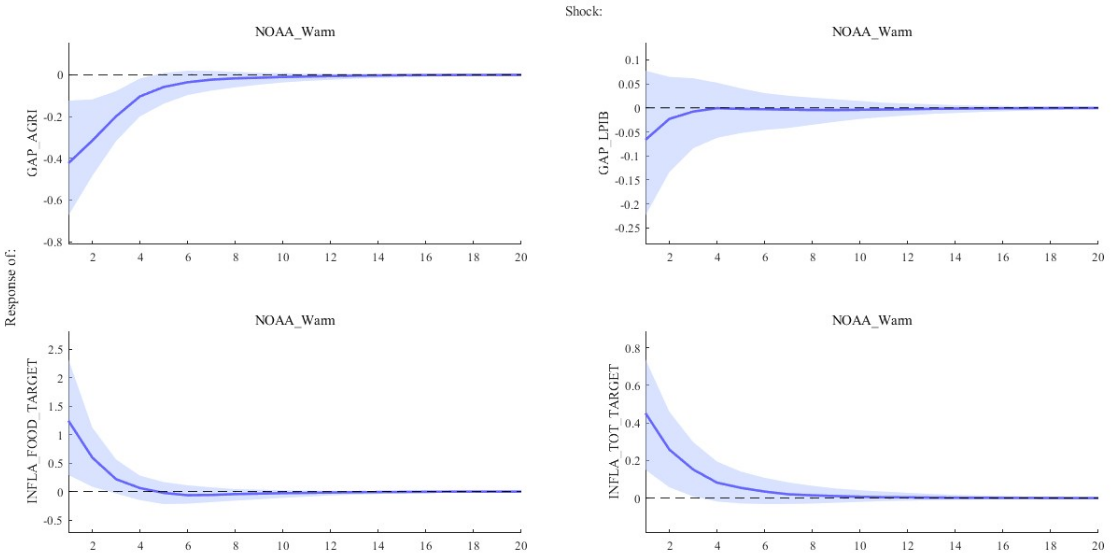

Figure 3: Impulse responses of selected variables to a 1 Celsius degree shock in the ENSO index (68% confidence intervals). Source: Authors' calculations.

4 Model

Our model is a two-sector, two-good economy in a small, open economy setup with a flexible exchange rate regime. In our analysis of the macroeconomic implications of weather shocks, we further refine the model established by Gallic and Vermandel (2020) by incorporating several significant new features. Firstly, we acknowledge the presence of price rigidities in both sectors under consideration, namely the agricultural and non-agricultural sectors. This feature is achieved by introducing intermediate firms, aggregate firms, and capital producers for each sector, leading to a model where prices are not equivalent to marginal costs. We demonstrate this by incorporating Calvo Pricing.

Additionally, we introduce a monetary policy rule, specifically adopting a Taylor Rule, which has been calibrated in line with prior studies conducted in the Colombian context. Lastly, we acknowledge the influence of an imperfect pass-through effect, which is particularly evident in the imported goods of each sector. This effect arises from our model's small open economy (SOE) setup and price rigidities. This inclusion helps us capture more realistically how changes in international prices are translated into domestic prices. This factor can be highly influential in the context of weather-related shocks.

Figure 4 illustrates a simplified model structure, where households receive revenues from agricultural and non-agricultural firms, as well as government transfers. Households consume a mix of locally produced agricultural and non-agricultural goods, as well as imported goods. They also pay taxes and invest in local and external bonds. Agricultural and non-agricultural sectors maximize their profits in the first production stage, while distributors create price rigidities. The agricultural sector is directly affected by weather shocks, which increase marginal production costs, resulting in higher food inflation and reduced agricultural output. In the following subsection, we will present the main structure of our model.

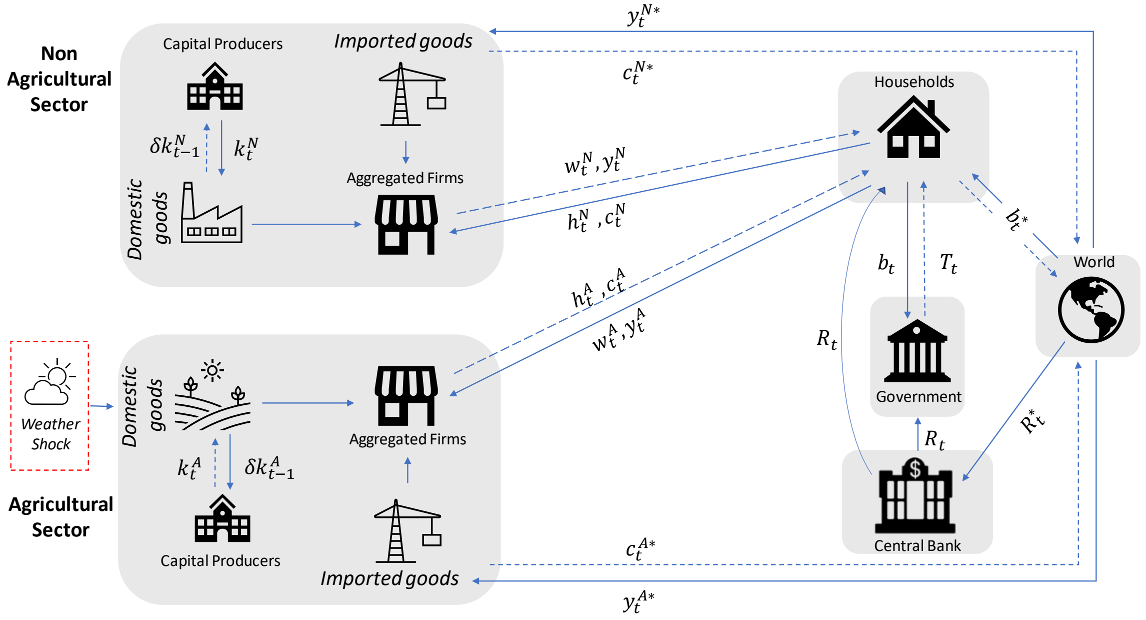

Figure 4: Model structure. Source: Authors' design.

4.1 Households

Following Gallic and Vermandel (2020), we use a standard household maximization process. The economy consists of a continuum of identical households, indexed by $j\ in[0,1]$. These households consume, save, and work in the two productive sectors. The representative household maximizes its expected sum of utilities given by:

$$E_t \sum_{\tau=0}^{\infty} \left[\frac{1}{1-\sigma}(C_{JT+\tau} - bC_{t-1+\tau})^{1-\sigma} - \frac{\chi \varepsilon^{H}_{t+\tau}}{1+\sigma_H} h^{1+\sigma_H}_{jt+\tau} \right] \tag{3}$$

Here, $\beta \in [0,1]$ represents the discount factor, C_{jt} is the consumption index that aggregates domestic and imported agricultural and non-agricultural consumption, $b \in [0,1]$ represents consumption habits, h_{jt} is a labor effort index for the agricultural and non-agricultural sectors, and $\sigma > 0$ and $\sigma_H > 0$ denote consumption aversion and labor disutility coefficients, respectively. The labor supply between the agricultural and non-agricultural sectors exhibits imperfect substitutability, which is captured by a Constant Elasticity of Substitution (CES) labor disutility index of hours worked in the non-agricultural and agricultural sectors:

$$h_{jt} = \left[(h^{N}_{jt})^{1+\iota} + (h^{A}_{jt})^{1+\iota} \right]^{\frac{1}{1+\iota}} \tag{4}$$

The parameter $\iota \geq 0$ represents the substitutability between sectors, accounting for the costs associated with labor reallocation.

The budget constraint for the representative household is represented and expressed in nominal terms:

$$\begin{gathered} \sum_{s=(N,A)} W^{s}_{t} h^{s}_{t} + R_{t-1} B_{o,t-1} + s_t R^{*}_{t-1} B^{*}_{t-1} - T_t + \\ P^{N}_{t} \xi^{N}_{t} + P^{A}_{t} \xi^{A}_{t} + P^{CN}_{t} \xi^{CN}_{t} + P^{CA}_{t} \xi^{CA}_{t} \geq P_t C_t + B_t + s_t B^{*}_{t} + P^{N} s_t \phi(B^{*}_{t}) \end{gathered} \tag{5}$$

In this equation, W^{s}_{t} represents wages in sector s at time t, h^{s}_{t} denotes labor effort in sector s at time t, R_{t-1} represents the nominal return on domestic bonds, $B_{o,t-1}$ represents the holdings of domestic bonds, s_t is the nominal exchange rate, R^{*}_{t-1} represents the nominal return on foreign currency-denominated bonds, B^{*}_{t-1} represents the holdings of foreign currency-denominated bonds, T_t represents government taxes, $P^{N}_{t} \xi^{N}_{t}$ and $P^{A}_{t} \xi^{A}_{t}$ represent benefits coming from the non-agricultural and agricultural sectors, respectively, $P^{CN}_{t} \xi^{CN}_{t}$ represents benefits associated with non-agricultural consumption, $P_t^{CA}\xi_t^{CA}$ represents benefits associated with agricultural consumption, $P_t C_t$ represents the cost of consumption, B_t represents savings, $s_t B_t^*$ represents foreign currency savings and $\phi(B_t^*) = 0.5\Xi_\beta (b_t^*)^2$[4] represent a bond premium risk cost.

The representative household allocates total consumption C_{jt} between two types of consumption goods produced by the non-agricultural (N) and agricultural (A) sectors determined by a CES bundle:

$$C_{jt} = \left[(1-\varphi)^{\frac{1}{\mu}}(C_{jt}^N)^{\frac{\mu-1}{\mu}} + (\varphi)^{\frac{1}{\mu}}(C_{jt}^A)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{6}$$

Each index C_{jt}^N, C_{jt}^A is also a composite consumption subindex composed of domestically and foreign produce goods:

$$C_{jt}^{d,s} = (1-\alpha_s)\left(\frac{P_t^{d,s}}{P_t^s}\right)^{-\mu_s} C_{jt}^s$$

Where α is the share of foreign goods, μ is the elasticity of substitution between home and foreign goods, and $s = N, A$. The demands can be expressed as a fraction of the total consumption index adjusted by their respective relative prices:

$$C_{jt}^N = (1-\varphi)\left(\frac{P_t^N}{P_t}\right)^{-\mu} C_{jt} \tag{7}$$

$$C_{jt}^A = \varphi\left(\frac{P_t^A}{P_t}\right)^{-\mu} C_{jt} \tag{8}$$

Where φ represents the share of every sector consumption over the total.

4.2 Non-agricultural sector

In our Non-agricultural sector, we have a standard setup. There are four types of good producers:

1. **Producers of domestic goods:**

   In each period t, the domestic good Y_t^N is produced by a perfectly competitive firm combining intermediate goods according to the production function:

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[4] the parameters $\xi_\beta > 0$ denotes the magnitude of the cost paid by the domestic households when purchasing a foreign bond

$$Y_t^N = \left(\int_0^1 Y_{j,t}^{N(1-\frac{1}{\epsilon_{Nd}})} dj \right)^{\frac{\epsilon_{Nd}}{\epsilon_{Nd}-1}} \tag{9}$$

Where ϵ_{Nd} is the elasticity of substitution between goods varieties.

As a result, the demand for the intermediate good j and the price of the domestic good is determined by:

$$Y_{j,t}^N = \left(\frac{p_{j,t}^{Nd}}{p_t^{Nd}} \right)^{-\epsilon_{Nd}} Y_t^{Nd} \tag{10}$$

$$p_t^{Nd} = \left(\int_0^1 (p_{j,t}^{Nd})^{1-\epsilon_{Nd}} dj \right)^{\frac{1}{1-\epsilon_{Nd}}} \tag{11}$$

Where Y_t^{Nd} is the demand of the domestic non-agricultural final good.

2. **Producers of intermediate goods:** They operate in monopolistic competition and set prices as in Calvo (1983). Their output is a homogeneous good that we call domestic output; they use labor and capital as production inputs. The households demand the first one, and the second one is rented to capital producers.

$$Y_{j,t}^N = z_{y,t}^N (K_{j,t-1}^N)^\alpha \left(h_{j,t}^N \right)^{1-\alpha} \tag{12}$$

where $\alpha, \in (0, 1)$. α is the capital share of total output, K_{t-1}^N is the capital,$1-\alpha$ is the share of labor in production and $z_{y,t}^N$ is an exogenous transitory productivity shock.

3. **Producers of intermediate imports goods:** There is a continuum $z \in (0, 1)$ of imported good producers that use homogeneous imports goods to produce differentiated intermediate goods. They operate in a monopolistic competition environment, producing imported goods for consumption and utilizing non-transformed imports as inputs. Their production function is given by:

$$Y_t^{Nf}(z) = Im_t(z) \tag{13}$$

The demand for the good z is:

$$Y_{t+s}^{Nf}(z) = \left(\frac{P_{t+s}^{Nf}(z)}{P_{t+s}^{Nf}} \right)^{-\epsilon_{Nf}} Y_{t+s}^{Nf} \tag{14}$$

Where ϵ_{Nf} is the elasticity of substitution across z goods in the production of a final imported good. It can also be define as: $Y_t^{Nf} = C_t^{Nf}$.

4. **Non-agricultural capital producers:** These firms seek to maximize profits and operate in a perfectly competitive market. At the end of the period, they buy the depreciated physical capital stock $(1-\delta)k_{t-1}$ from the intermediate firms and use I_t^N to produce a new stock k_t^N, which is sold to intermediate firms that is used for production in the next period.

   The following maximization problem describes the capital production technology:

$$maxE_t\left[\sum_{s=0}^{\infty}(\beta)^s\frac{\Lambda_{t+s}}{\Lambda_t}\left[r_{t+s}^{Nk}K_{t-1+s}^N-P_{t+s}^{Nd}I_{t+s}^N\right]\right] \tag{15}$$

   Where K_{t-1}^N is per-capital, the stock of non-agricultural capital available at time t, δ is the depreciation rate. The stock of capital evolves according to the following equation:

$$K_{t+s}^N=(1-\delta)\,K_{t+s-1}^N+z_{Nx,t+s}I_{t+s}\left(1-f\left(\frac{I_{t+s}^N}{I_{t+s-1}^N}\right)\right) \tag{16}$$

   with $f(.)$ as a quadratic cost function given by $f\left(\frac{I_t^N}{I_{t-1}^N}\right)=\frac{a}{2}\left(\frac{I_t^N}{I_{t-1}^N}-1\right)^2$. The investment first order condition is defined as:

$$P_t^{Nd}=Q_t^Nz_{x,t}\left[1-f\left(\frac{I_t^N}{I_{t-1}^N}\right)-I_t^Nf'\left(\frac{I_t^N}{I_{t-1}^N}\right)\right]-\beta E_t\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)Q_{t+1}^Nz_{x,t+1}f'\left(\frac{I_{t+1}^N}{I_t^N}\right) \tag{17}$$

   Moreover, the optimal condition for capital is:

$$Q_t^N=\beta E_t\left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)\left[r_{t+1}^{Nk}+(1-\delta)Q_{t+1}^N\right] \tag{18}$$

4.3 Agricultural sector

As mentioned in Bilal and Stock (2025), a "*key component of economic fundamentals is the set of structural damage functions that map climatic outcomes such as global mean temperature, local temperature or precipitations, into losses to economic outcomes*." In this context, our model incorporates a channel through which the agricultural sector is affected by adverse weather conditions, as outlined in the framework developed by Gallic and Vermandel (2020).

To account for the influence of ENSO fluctuations on agricultural goods' production, we assume that the weather shock variable related to ENSO, ϵ_t^W, follows a stochastic AR(1) process given by:

$$\log(\epsilon_t^W) = \rho_W \log(\epsilon_{t-1}^W) + \sigma_W \eta_t^W, \qquad \eta_t^W \sim N(0,1). \tag{19}$$

In 19, we proposed a simple AR(1) process for the ENSO fluctuation, where $\rho_W \in [0,1)$ is the persistent of the weather (ENSO) related shock and $\sigma_W \geq 0$ is the standard deviation. Analogously to the non-agricultural sector, we have four types of good producers:

1. **Producers of domestic goods:** The domestic good Y_t^A is produced by a perfectly competitive firm combining intermediate goods according to the production function:

$$Y_t^A = \left(\int_0^1 \left(Y_{j,t}^A \right)^{1-\frac{1}{\epsilon_H}} dj \right)^{\frac{\epsilon_{Ad}}{\epsilon_{Ad}-1}} \tag{20}$$

   where ϵ_{Ad} is the elasticity of substitution between goods varieties. The resulting demand for the intermediate good j and the price of the domestic good are:

$$Y_{j,t}^A = \left(\frac{p_{j,t}^{Ad}}{p_t^{Ad}} \right)^{-\epsilon_{Ad}} Y_t^{Ad} \tag{21}$$

$$p_t^A = \left(\int_0^1 (p_{j,t}^A)^{1-\epsilon_A} \, dj \right)^{\frac{1}{1-\epsilon_{Ad}}} \tag{22}$$

   Where Y_t^{Ad} is the demands of the domestic agricultural final good.

2. **Producers of intermediate goods:** They employ the Cobb-Douglas production function to describe the relationship between agricultural output (y_{it}^A), land (l_{it}), physical capital inputs (k_{it-1}), and labor inputs (h_{it}):

$$y_{it}^A = [\Omega(\epsilon_t^W) l_{it-1}]^{\omega} \left[\epsilon_t^Z \left(K_{it-1}^A \right)^{\alpha_a} \left(\kappa_A h_{it}^A \right)^{1-\alpha_a} \right]^{1-\omega}, \tag{23}$$

   Where $\Omega(\epsilon_t^W)$ represents a damage function capturing the influence of exogenous weather conditions on agricultural production, following the approach of Nordhaus (1991):

$$\Omega(\epsilon_t^W) = (\epsilon_t^W)^{-\theta}, \tag{24}$$

   Where θ determines the elasticity of land productivity with respect to weather conditions. In the model, the damage function decreases agricultural output when the agricultural sector is affected by an ENSO shock. It increases the marginal cost of agricultural production, thus affecting agricultural (food) prices.

In line with Gallic and Vermandel (2020), we incorporate time-varying land productivity to account for the damage inflicted during these episodes and the time required to restore average productivity levels. We assume that each farmer owns his proportion of the land with productivity that follows an endogenous law of motion:

$$\ell_{it} = \left[(1-\delta_l) + \nu(x_{it})\right]\ell_{it-1}\Omega(\epsilon_t^W) \tag{25}$$

Where x_{it} represents the farm's expenditure to maintain farmland productivity[5], and $\nu(.)$ denotes the associated cost function. There are no concrete studies or micro-evidence about the function form of the land cost, but in line with Gallic and Vermandel (2020) we adopt a conservative approach where: $\nu(x_{it}) = \frac{\tau}{\phi}x_{it}^{\phi}$ the parameters τ and ϕ represents the amount of per capita land, and the returns of the land, respectively.

Finally, the law of motion for physical capital in the agricultural sector is given by:

$$i_{it}^A = k_{it}^A - (1-\delta_k)k_{it-1}^A, \tag{26}$$

where δ_k represents the depreciation rate of physical capital.

3. **Producers of intermediate imports goods:** There is a continuum $z \in (0, 1)$ of imported good producers that use homogeneous imports goods to produce differentiated intermediate goods. The technology is given by:

$$Y_t^{Af}(z) = Im_t^A(z) \tag{27}$$

The demand for the good z is:

$$Y_{,t+s}^{Af}(z) = \left(\frac{P_{t+s}^{Af}(z)}{P_{t+s}^{Af}}\right)^{-\epsilon_{Af}} Y_{t+s}^{Af}$$

Where ϵ_{Af} is the elasticity of substitution across z goods in producing a final imported good. It can also be define as: $Y_t^{Af} = C_t^{Af}$.

4. **Agricultural capital producers:** Similar to the non-agricultural sector, capital production technology is described by the following maximization problem:

$$maxE_t\left[\sum_{s=0}^{\infty}(\beta)^s\frac{\Lambda_{o,t+s}}{\Lambda_{o,t}}\left[r_{t+s}^{Ak}K_{t-1+s}^A - P_{t+s}^N I_{t+s}^A\right]\right] \tag{28}$$

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[5] x_{it} represent all the spending used to maintain the farmland productivity such as pesticides, herbicides, seed, fertilizers, water, and others

Their optimal investment decision is:

$$P_t^N = Q_t^A z_{x,t} \left[1 - f\left(\frac{I_t^A}{I_{t-1}^A}\right) - I_t^A f'\left(\frac{I_t^A}{I_{t-1}^A}\right)\right] - \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t}\right) Q_{t+1}^A z_{x,t+1} f'\left(\frac{I_{t+1}^A}{I_t^A}\right) \tag{29}$$

Moreover, their optimal capital decision is:

$$Q_t^A = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t}\right)\left[r_{t+1}^{kA} + (1-\delta) Q_{t+1}^A\right] \tag{30}$$

4.4 Price rigidities

Our modeling framework for price stickiness is analogous to the one employed in the primary Central Bank's structural model (PATACON, González-Gómez et al. (2011)). We incorporate a Calvo pricing mechanism, which captures firms' behavior in setting their prices. In our model, only a randomly selected fraction $(1-\theta)$ of firms can optimize their prices, while the remaining firms adjust their prices according to an inflation rule. Specifically, the price adjustment rule for these firms is given by the expression:

$$P_t^{Sf}(z) = P_{t-1}^{sf}(z)\pi_{t-1}^{\iota_{sf}}\bar{\pi}^{1-\iota_{sf}}, \qquad s = A, NA,$$

Where ι_{Af} represents a parameter controlling the degree of price indexation, this approach allows for heterogeneity in price adjustment behavior among firms, which aligns with empirical evidence and introduces realistic dynamics into our model.

Moreover, the application of Calvo pricing is extended to foreign firms to introduce an element of imperfect pass-through (PT). By applying Calvo pricing to foreign firms, we capture the phenomenon where changes in international prices do not fully translate into domestic prices due to various factors. This imperfect pass-through effect arises from a combination of our model's small open economy (SOE) setup and the price rigidities associated with Calvo pricing. The incorporation of imperfect pass-through allows us to more accurately represent how changes in international prices impact domestic prices, which is particularly relevant in studying small open economy models. By accounting for these effects, our model captures a more realistic interplay between domestic and international price dynamics, providing valuable insights into the macroeconomic consequences of weather-related shocks.

4.5 Monetary policy

The monetary policy in our model is based on the same Taylor Rule employed in the primary Central Bank's structural model. Under the inflation targeting regime, the central bank controls the short-term nominal interest rate and sets it according to the following rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\Phi R} \left[\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\Phi\Pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\Phi Y}\right]^{1-\Phi R} \frac{1}{\epsilon^M}, \tag{31}$$

where R_t represents the current short-term nominal interest rate, R_{t-1} is the lagged short-term nominal interest rate, $\bar{R}$ represents the neutral interest rate, Π_t represents the current inflation rate, $\bar{\Pi}$ denotes the target inflation rate, Y_t represents the current output level, $\bar{Y}$ denotes the long term output growth, ΦR, $\Phi\Pi$, and ΦY are the policy rule coefficients, and ϵ^M represents the monetary policy shock. This rule allows the central bank to adjust the nominal interest rate based on the current and lagged values of interest rates, inflation, and output, contributing to the control and stabilization of the macroeconomic variables in our model.

4.6 Fiscal Policy

The public authority in our model consumes some non-agricultural output G_t, issues debt b_T at a real interest rate r_t, and charges lump sum taxes T_t. Public spending is assumed to be exogenous $G_t = Y_t^N g_{\epsilon t}^G$, where $g \in [0,1)$ is a fixed fraction of non-agricultural goods g affected by a standard AR(1) stochastic shock:

$$log(\epsilon_t^G) = \rho_G log(\epsilon_{t-1}^G) + \sigma_G \eta_t^G, \qquad \eta_t^G \sim N(0,1), \tag{32}$$

where $1 \geq \rho_G \geq 0$ and $\sigma_G \geq 0$. This shock captures variations in absorption which are not taken into account in our setup such as political cycles and international demand in intermediate markets.

The government budget constraint equates spending plus interest payment on existing debt to new debt issuance and taxes:

$$G_t + r_{t-1} b_{t-1} = b_t + T_t \tag{33}$$

4.7 Foreign economy

Following Gallic and Vermandel (2020), the external sector is represented by four equations that determine an endowment economy with exogenous foreign consumption. In each period, foreign households solve the following optimization problems:

$$\max_{c_t^*, b_t^*} E_t \left[\sum_{\tau=0}^{\infty} \beta^{\tau} \epsilon_{t+\tau}^* log(c_{t+\tau}^*) \right] \tag{34}$$

$$s.t \qquad r_{t-1}^* b_{t-1}^* = c_t^* + b_t^* \tag{35}$$

Where $\epsilon_{t+\tau}^*$ is define as:

$$log(\epsilon_t^*) = \rho_{\epsilon^*} log(\epsilon_{t-1}^*) + \sigma_{\epsilon^*} \eta_t^{\epsilon^*} \tag{36}$$

The exogenous external consumption is determined as follows:

$$log(c_t^*) = (1 - \rho_c^*) log(\overline{c}_t^* + \rho_c^* log(c_{t-1}^*) + \sigma_c \eta_t^{c^*} \tag{37}$$

Where $\eta_t^{c^*} \sim N(0, 1)$, and the standard deviation of the shock is represented by $\sigma_c > 0$ and $\overline{c}_t^*$ is the steady state of the foreign economy consumption.
An increase in the foreign demand induces an increment in the exportation of Colombian goods, subsequently causing an appreciation of the foreign exchange rate. On the other hand, a temporary preferences shock, $\eta_t^{e^*} \sim N(0, 1)$, affects the household's discount factor, leading to a decrease in the foreign real interest rate and, consequently, a decrease in capital flows. The budget constraint comprises consumption and purchasing domestic bonds, which are remunerated at a predetermined real rate r_{t-1}^*. Under the assumption of no specific sectoral shocks, all sectoral prices in the foreign economy are perfectly synchronized, denoted as $P_t^* = P_t^{A*} = P_t^{N*}$.

4.8 Aggregation and equilibrium conditions

The economy clearing market conditions are determined when supply equals aggregate demand. For the non-agricultural sector, it can be expressed in real terms as:

$$(1 - n_t) y_t^N = c_t^{d,N} + c_t^{exp,N} + g_t + i_t + n_t x_t + \phi(b_t^* \tag{38}$$

Where $c_t^{exp,N}$ are the non agricultural exports and are define as: $(1-\varphi)\alpha_N \left(\frac{p_t^{d,N}}{rer_t}\right)^{-\mu_N} c_t^*$.

For the agricultural sector, the clearing market condition can be expressed in real terms as:

$$n_t y_t^A = c_t^{d,A} + c_t^{exp,A} \tag{39}$$

Where $c_t^{exp,A}$ are the agricultural exports and are define as: $\varphi \alpha_A \left(\frac{p_t^{d,A}}{rer_t}\right)^{-\mu_A} c_t^*$.
The total supply for the non-agricultural and agricultural sector is given by $\int_1^{n_t} y_i t^N \, di =$

$(1-n_t)y_t^N$ and $\int_{n_t}^{0} y_i t^A \, di = n_t y_t^A$ respectively, and the aggregate real production is given by:

$$y_t = (1-n_t)p_t^N y_t^N + n_t p_t^A y_t^A \tag{40}$$

Given the fact that we include intermediate inputs, such as land expenditures, we can define the GDP as:

$$gdp_t = y_t - p_t^N n_t x_t \tag{41}$$

Finally, the total amount of real foreign debt depends on the real return of past debts and the trade balance:

$$b_t^* = r_{t-1}^* \frac{rer_t^*}{rer_{t-1}^*} b_{t-1}^* + tb_t \tag{42}$$

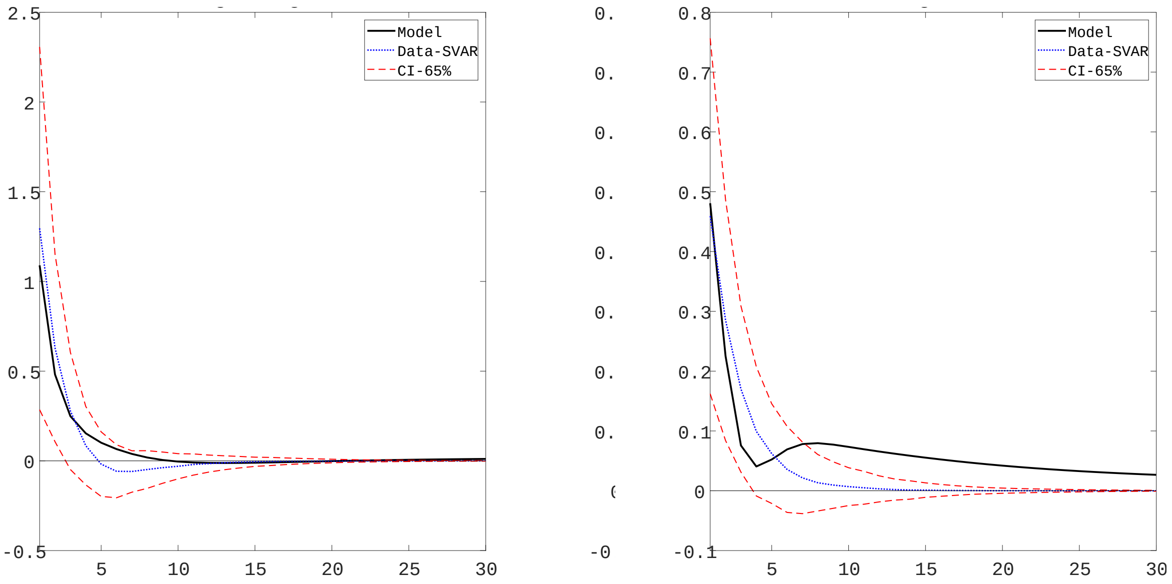
$$tb_t = p_t^N \left[(1-n_t)y_t^N - g_t - i_t - n_t x_t - \phi(b_t^*)\right] + p_t^A n_t y_t^A - c_t \tag{43}$$

4.9 Calibration/Estimation

The approach to calibrate was twofold. On the first hand, the main parameters of the model were obtained from the PATACON model, one of the main models used by the Central Bank of Colombia to comprehensively represent the Colombian economy (González-Gómez et al. (2011)). Given the unique structure of the two sectors in our model—agricultural and non-agricultural—we leveraged historical series from the Colombian national accounts and production function estimates specific to Colombia to determine the sectoral ratios and shares.

On the other hand, we adopted the following methodology to calibrate the parameter θ in the damage function. This parameter quantifies the impact of weather shocks on the agricultural sector. First, we estimated the off-model persistence parameter of the AR(1) process for ENSO fluctuations (Eq. 19). Second, we employed an Impulse Response Matching strategy, aligning the model's agricultural (food) and total inflation responses to an ENSO shock, as presented in the stylized facts section of this study. Using the structural characteristics of our model, we estimate the elasticity of land productivity with respect to weather conditions (θ), minimizing the discrepancy between the Impulse Response Function (IRF) derived from the BVAR and the IRF obtained from our model. Figure 5 shows the result of this approach.

This methodological framework ensured that the calibrated model accurately replicated key stylized facts of the Colombian economy, as reflected in the PATACON model. Leveraging the flexibility of the IRF matching technique, we reconciled econometric estimates with the macroeconomic structure of our model. Table 1 summarizes the core parameters used in this model.



(a) IRF-Matching on Agricultural Inflation.

(b) IRF-Matching on Total Inflation.

Figure 5: IRF Matching Output. Source: Authors' calculations.

Parameter	Economical Meaning	Value	Bibliography
β	Discount factor	0.9951	(González-Gómez et al., 2011)
b	Consumption habits	0.5945	(González-Gómez et al., 2011)
ι	Labor sectoral cost	2.9	(Gallic and Vermandel, 2020)
α	Share of capital in output	0.4	(González-Gómez et al., 2011)
g	Share of spending in GDP	0.22	Commonly used in RBC literature
φ	Share of agricultural goods in consumption basket	0.15	Observed over the sample period
$\bar{H}^N = \bar{H}^A$	Hours worked	1/3	Commonly used in RBC literature
$\bar{l}$	Land per capita	0.11	Hectares of arable land (per person), FAO data from the World Bank
α_N	Openness of non-agricultural market	0.35	Author's calculation
α_A	Openness of agricultural market	0.22	Author's calculation
δ_k	Capital depreciation rate	0.0138	(González-Gómez et al., 2011)
δ_N	Depreciation of non-agricultural capital	0.025	(González-Gómez et al., 2011)
δ_A	Depreciation of agricultural capital	0.033	(Gallic and Vermandel, 2020)
δ_l	Depreciation of land	0.05	(Gallic and Vermandel, 2020)
ϕ	Land expenditure cost	1.6	(Gallic and Vermandel, 2020)
ω	Share of labor in agricultural output	0.1289	(Gallic and Vermandel, 2020)
ρ_W	Persistence of weather shock	0.7	Author's calculation
θ	Elasticity of land productivity to weather conditions	10.29	Author's calculation

Table 1: Calibrated parameters on a quarterly basis.

5 Results

This section shows the dynamics of the model to a transitory ENSO (adverse weather) shock in the model presented in Section 4[6]. As shown in Figure 6, the transitory ENSO shock makes land less productive, which in our structure is reflected by increased land cost and lower land efficiency. This is translated into higher marginal costs for the agricultural sector, resulting in lower agricultural output and higher agricultural prices. In our model, the shock in ENSO affects the relative prices of the agricultural and non-agricultural sectors[7]. Notably, the ENSO shock increases agricultural relative prices while the non-agricultural relative prices decrease. The magnitude in which this change in relative prices impacts GDP growth and its composition, given that there is some degree of substitution. This channel is important because it also helps explain why weather shocks related to ENSO have a limited impact on output besides the agricultural sector's share of overall output.

Under our baseline parametrization, food and headline inflation expectations increased due to the shock. In these settings, the monetary policy authority must react to this shock by increasing interest rates. While the direct effect on economic activity remains modest, the policy response induces a mild output gap contraction (Figure 6). This pattern aligns with the characterization of ENSO shocks as primarily supply-side disturbances, where inflationary pressures dominate output effects in small open economies like Colombia.

It is important to note that these quantitative results correspond to a transitory shock of one standard deviation in the ENSO series. As we have seen, extreme weather events may become more persistent and frequent, as evidenced by the 2014-2016 episode, during which sea surface temperature anomalies in the Pacific Ocean led to the ENSO index reaching 2.4 degrees. As mentioned in An et al. (2020), "*the ENSO is characterized by being irregular or non-periodic and asymmetric between El Niño and La Niña with respect to amplitude, pattern, and temporal evolution*." One approach, although limited, to analyze scenarios of more intense adverse ENSO fluctuations consists of simulating a shock with higher magnitude and persistence, calibrated to match the characteristics of a particularly severe event. The results, shown in Figure 7, demonstrate how the model transmission channels propagate these amplified shocks.

The intensified shock leads to more extensive damage to land productivity through the damage function, which increases agricultural marginal costs. Given the prolonged persistence of the shock, these effects compound over time, resulting in a more pronounced contraction of agricultural output than in the baseline scenario.

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[6] That corresponds to 1 Celsius degree in ENSO's historical series of sea surface temperatures anomalies in the Pacific Ocean.

[7] In the model, relative prices are defined as the ratio of each sector's price to the overall price index.

The price adjustments are similarly magnified, with agricultural prices rising sharply and remaining at elevated levels for an extended period. This places sustained pressure on headline inflation, necessitating a stronger monetary policy response that, although effective in stabilizing prices, leads to a decline in economic activity.

The shock's propagation through relative prices follows the same mechanisms as in the baseline scenario but with amplified magnitude. The agricultural sector experiences a considerable and more persistent price increase, while the non-agricultural sector sees a more significant price reduction. The results are consistent with empirical observations from the 2014–2016 El Niño episode, during which Colombia experienced prolonged agricultural disruptions and inflationary pressures.

The model successfully captures key stylized facts about ENSO shocks in Colombia, including their characterization as adverse supply shocks, the predominant impact on the agricultural sector, and the inflation-output trade-offs facing policymakers. When shocks persist, as in our extreme scenario, they create more enduring inflationary pressures that warrant stronger monetary policy responses, though with greater output costs. These findings highlight the importance of considering the persistence and magnitude of shocks when evaluating potential climate-related macroeconomic vulnerabilities.

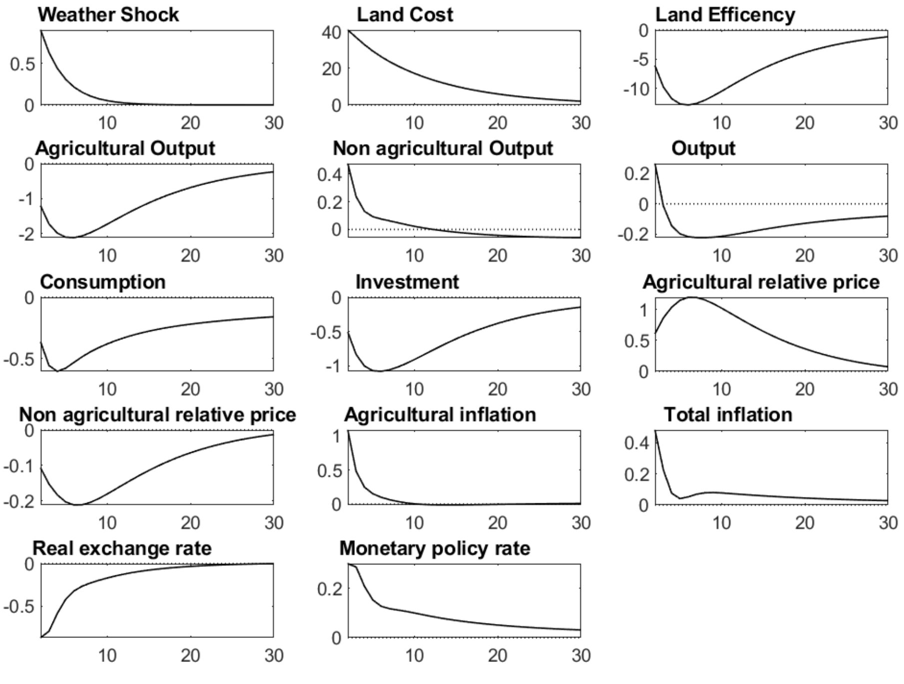

Figure 6: IRF to a one Celsius degree shock in the ENSO index.

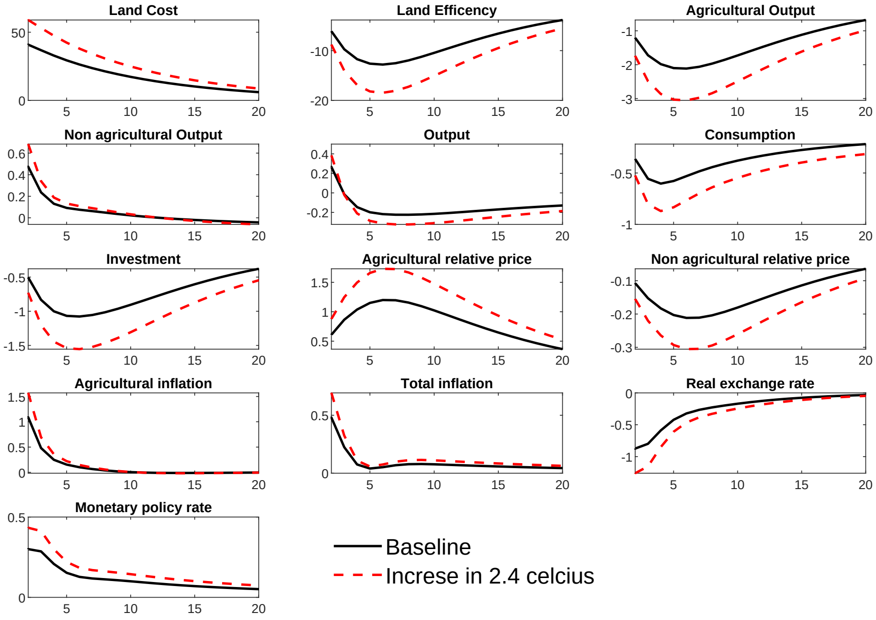

Figure 7: IRF: Weather shock

6 Concluding Remarks

Our study provides an initial attempt to integrate ENSO-related weather shocks into a small open-economy New Keynesian model calibrated for Colombia. Our approach lays a foundation for future research by developing a two-sector DSGE model that accommodates weather shocks while maintaining significant compatibility with the Colombian Central Bank's primary structural model.

Our empirical observations using the BVAR-X model corroborate the importance of weather shocks in shaping Colombia's economic landscape, particularly within the agricultural sector, and their implications for inflation. This evidence suggests that incorporating such factors into macroeconomic models is important, especially given the intensification of climate-related issues. Our model introduces a channel in which relative prices (agricultural vs. non-agricultural) are affected by weather shocks, allowing us to better incorporate the empirical evidence into a structural model for Colombia that includes price rigidities and monetary policy. With our proposed parameterization, food inflation, headline inflation, and inflation expectations increased as a result of the shock. In these settings, the monetary policy authority should react to this shock by increasing the interest rates to anchor inflation expectations.

However, this research represents a starting point rather than a conclusion. Future research efforts should refine our initial model by exploring potential extensions. Furthermore, it is important to note that the estimates and exercises performed in this study only cover a relatively recent period and may change in the future.

For one, while our model views weather shocks on a relatively aggregate level, future work should aim to distinguish between different types of weather events and their impacts. Second, expanding the model to include other sectors vulnerable to weather shocks can provide a more comprehensive analysis. These areas of future research would enable us to observe potential intersectoral effects and their implications for economic policy. Finally, future studies might explore alternative estimation approaches to the model's key parameters. In conclusion, our study highlights the importance of integrating weather shocks into macroeconomic modeling to gain a comprehensive understanding of the Colombian economy.

References

Abril-Salcedo, D. S., Melo-Velandia, L. F., and Parra-Amado, D. (2020). Nonlinear relationship between the weather phenomenon el niño and colombian food prices. *Australian Journal of Agricultural and Resource Economics*, 64(4):1059–1086.

Acevedo, S., Mrkaic, M., Novta, N., Pugacheva, E., and Topalova, P. (2020). The effects of weather shocks on economic activity: what are the channels of impact? *Journal of Macroeconomics*, 65:103207.

An, S.-I., Tziperman, E., Okumura, Y. M., and Li, T. (2020). Enso irregularity and asymmetry. *El Niño Southern Oscillation in a changing climate*, pages 153–172.

Andersson, M., Morgan, J., and Baccianti, C. (2020). Climate change and the macro economy. *ECB Occasional Paper*.

Bastianin, A., Lanza, A., and Manera, M. (2018). Economic impacts of el niño southern oscillation: evidence from the colombian coffee market. *Agricultural economics*, 49(5):623–633.

Bejarano-Salcedo, V., Caicedo-García, E., Lizarazo-Bonilla, N. F., Julio-Román, J. M., and Cárdenas-Cárdenas, J. A. (2020). Hechos estilizados de la relación entre el niño, la niña y la inflación en colombia. Technical report, Banco de la Republica de Colombia.

Berg, K. A., Curtis, C. C., and Mark, N. (2023). Gdp and temperature: Evidence on cross-country response heterogeneity. Technical report, National Bureau of Economic Research.

Bilal, A. and Stock, J. H. (2025). Macroeconomics and climate change. *NBER Working Paper Series*.

Callahan, C. W. and Mankin, J. S. (2023). Persistent effect of el niño on global economic growth. *Science*, 380(6649):1064–1069.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary Economics*, 12(3):383–398.

Cashin, P., Mohaddes, K., and Raissi, M. (2017). Fair weather or foul? the macroeconomic effects of el niño. *Journal of International Economics*, 106:37–54.

Cevik, S. and Jalles, J. T. (2023). Eye of the storm: The impact of climate shocks on inflation and growth. Technical report, International Monetary Fund.

Gallic, E. and Vermandel, G. (2020). Weather shocks. *European Economic Review*, 124:103409.

González-Gómez, A., Lavan, M., Prada-Sarmiento, J. D., and Rodríguez-Guzmán, D. A. (2011). Policy analysis tool applied to colombian needs: Patacon model description. Technical report, Banco de la República.

Kim, H. S., Matthes, C., and Phan, T. (2025). Severe weather and the macroeconomy. *American Economic Journal: Macroeconomics*, 17(2):315–341.

L'Heureux, M. (2016). The 2015-16 el niño. In *Science and technology infusion climate bulletin NOAA's national weather service. In: Proceedings of the 41st NOAA annual climate. Diagnostics and prediction workshop*, pages 3–6.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M., et al. (2021). Climate change 2021: the physical science basis. *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*, 2.

McPhaden, M. J., Santoso, A., and Cai, W. (2020). *El Niño Southern Oscillation in a changing climate*, volume 253. John Wiley & Sons.

Mohaddes, K., Ng, R. N., Pesaran, M. H., Raissi, M., and Yang, J.-C. (2023). Climate change and economic activity: evidence from us states. *Oxford Open Economics*, 2.

Nalban, V. and Zanna, L.-F. (2025). Qpm-based analysis of weather shocks and monetary policy in developing countries. *IMF Working Papers*.

Natoli, F. (2023). The macroeconomic effects of temperature surprise shocks. *Bank of Italy Temi di Discussione (Working Paper) No*, 1407.

NGFS (2024). Climate macroeconomic modelling handbook. Technical report, Network for Greening the Financial System.

Romero, G., Leon, S. F. M., Salcedo, L. C. R., Álvarez, A. C., Giraldo, C. D., and Diaz, S. L. C. (2017). Efectos económicos de futuras sequías en colombia: estimación a partir del fenómeno el niño 2015. Technical report, Departamento Nacional de Planeación.

Romero, J. V. and Naranjo-Saldarriaga, S. (2022). Weather shocks and inflation expectations in semi-structural models. *Borradores de Economía: No. 1218*.