Optimal Monetary Policy and Weather Shocks in Small Open Economies

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Abstract

Climate change has led to an increase in extreme weather events, causing significant challenges for macroeconomic stability and monetary policy, particularly in small open economies (SOEs). This paper investigates the optimal monetary policy response to weather shocks in an SOE framework, using a Dynamic Stochastic General Equilibrium (DSGE) model calibrated for Turkey. The model includes sectoral price rigidities, trade openness, and climate-related productivity shocks affecting agricultural output. We evaluate alternative monetary policy rules, including those that target aggregate inflation, sector-specific inflation, and output stabilization. Our findings suggest that an aggressive monetary policy response to agricultural inflation mitigates short-term economic disruptions and accelerates recovery, albeit at the cost of a deeper initial contraction. The Ramsey-optimal policy prioritizes inflation stability while minimizing the long-term persistence of weather-induced output losses. Our results offer insights into the role of monetary policy in addressing climate-induced economic fluctuations in SOEs, highlighting the importance of tailored monetary policies that account for sectoral heterogeneities.

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1 Introduction

Over the past decade, climate change has increasingly manifested through more frequent and intense extreme weather events, such as heatwaves, droughts, and heavy rainfall (Clarke et al., 2022). These phenomena carry profound implications for macroeconomic stability, particularly in the realm of price dynamics and inflation control (Faccia et al., 2021; Lucidi et al., 2024). Weather shocks impact economic activity through various channels, with agricultural output being among the most affected. As temperature and precipitation patterns directly influence crop yields, disruptions in agricultural productivity can lead to sharp increases in food prices, contributing to inflation volatility. This sectoral sensitivity to adverse weather events, which is often more pronounced than, exacerbates output losses and intensifies inflationary pressures (Acevedo et al., 2020). Such dynamics pose significant challenges for policymakers, who must contend with the heightened uncertainty surrounding climate-related economic disruptions (Natoli, 2022). Traditional monetary policy strategies, such as leaning against the wind to stabilize inflation, may prove insufficient or suboptimal in responding to these shocks. Consequently, the role of central banks in devising and implementing adaptive monetary policies becomes crucial, as they navigate the complex interplay between weather shocks, macroeconomic stability, and inflation control (Batten et al., 2020; Boneva et al., 2022).

Thus, to examine the impact of climate change on macroeconomic variables, a large and continually corpus of literature has focused on the role of environmental and fiscal policies (Fischer and Springborn, 2011; Heutel, 2012; Angelopoulos et al., 2010, 2013; Busato et al., 2024). Nevertheless, relatively little attention has been given to the role of monetary policy in addressing climate change. Annicchiarico et al. (2015, 2017) and Economides and Xepapadeas (2019) represent remarkable contributions, even if they focus on the interplay between environmental and monetary policies. Another research stream investigates the link between weather shocks and business cycles. For instance, Gallic and Vermandel (2020) have examined the impact of a weather shock on macroeconomic variables by estimating a Dynamic Stochastic General Equilibrium (DSGE) model for the New Zealand economy. Existing studies, such as those by Keen and Pakko (2011), have focused predominantly on the effects of natural disasters, often overlooking their implications for agriculture. Additionally, Cantelmo et al. (2023) used a DSGE model to analyze the channels through which natural disaster shocks affect macroeconomic outcomes and welfare in disaster-prone countries. However, despite their contributions, these studies neglect the critical role of monetary policy and its objectives in responding to weather shocks.

Furthermore, the short-term adverse effects of climate change on inflationary pressures are more pronounced and complex in countries with a high dependency on foreign trade, where climate extreme events translate into output losses and a deterioration in competitiveness (Economides and Xepapadeas, 2019). However, most of the literature uses closed economy models or large open economy models to examine the monetary policy impacts of climate change, not adequately considering the impact of climate change on small open economies (SOEs). Bejarano and Rodriguez (2024) represent a first attempt to address this question by exploring the effect of climate change on monetary policy in SOEs. However, the role of monetary policy in mitigating the negative effects of extreme weather events in SOEs remains unresolved and requires further investigation. This unresolved issue represents the core pursuit of our analysis in this paper.

In light of these premises, this paper aims to address the following research questions: (i) How should central bankers respond to weather shocks in SOEs?; and (ii) What is the optimal monetary policy response to a weather shock in SOEs? To answer these questions, we employ an Environmental Dynamic Stochastic General Equilibrium (E-DSGE) model, following the framework of Gallic and Vermandel (2020), which we expand to include sticky prices and alternative monetary policy responses. Our model is designed for a small open economy and incorporates the following agents: households, the agricultural sector, the non-agricultural sector, the foreign economy, and a government setting monetary policy. To assess the impact of climate change on monetary policy, we use data from Turkey to calibrate and estimate our model, using the Standardized Precipitation Evapotranspiration Index (SPEI). Furthermore, we focus specifically on the monetary policy response to weather shocks by comparing alternative Taylor Rules—based on total and sectoral inflation—to an optimal policy path defined by a social planner in a Ramsey model.

We contribute to the literature on climate change and the macroeconomic consequences of weather anomaly events in three ways. First, this paper identifies how central bankers address challenges related to extreme meteorological events by identifying the optimal monetary policy in an economy facing weather shocks. In doing this, we extend Gallic and Vermandel (2020) by including sticky prices à la Rotemberg (1982) for agricultural and non-agricultural goods. This feature allows us to explore the role of inflation in response to weather shocks. Second, we complete our analysis with a full range of monetary policy adoption by comparing the performances of different Taylor rule specifications and a Ramsey model. This marks a novel contribution to the current literature, as there is a limited exploration of monetary policy's role in this context. Third, we have developed and estimated a DSGE model for a small open economy, Turkey. This setting implies that Turkey's macroeconomic variables can be impacted by external shocks, but shocks occurring within the country do not have a significant effect on the rest of the world. By addressing these issues, this paper makes a valuable contribution to the broader theoretical literature on the macroeconomic effects of climate change, filling gaps in current research and providing a comprehensive framework for policymakers by examining the efficiency of various monetary policy instruments in response to increasingly frequent extreme weather events.

The remainder of this work is structured as follows. Section 2 introduces the model, while Section 3 presents the calibration and the estimation procedure. Section 4 shows and discusses the results, while Section 5 presents the conclusions of the work.

2 The Model

This section introduces a Dynamic Stochastic General Equilibrium (DSGE) model tailored to capture the key characteristics of the Turkish economy. The model builds upon the framework developed by Gallic and Vermandel (2020), extending it to incorporate features such as price stickiness, monopolistic competition, and monetary policy. The economy is modeled as a small open economy composed of several agents: households, agricultural and non-agricultural intermediate and final goods firms, and a foreign sector. Agricultural intermediate firms produce a unique good using a combination of capital, labor, and land. In addition, this sector is subject to exogenous weather shocks that affect land productivity. Non-agricultural intermediate firms produce a distinct good using labor and capital. Both types of firm experience price rigidity, modeled as quadratic adjustment costs following the Rotemberg (1982) approach. Final goods producers aggregate output from the intermediate sectors and operate under conditions of monopolistic competition. The foreign country is not affected by domestic macroeconomic shocks, but it impacts Turkey through changes in the trade balance and exchange rates. Finally, the model is driven by a weather shock, a monetary policy shock, two sector-specific technology shocks, a preference shock and a foreign shock.

2.1 Households

In this framework, households consume and supply labor to both the agricultural and non-agricultural sectors. Households maximize their utility, which depends on consumption and labor supply, as represented by the following utility function:

$$U_t = \left[\frac{(C_t)^{1-\sigma}}{1-\sigma} - \chi \frac{(h_t)^{1+\sigma_H}}{1+\sigma_H} \right]$$

Where C_t is the consumption index, $\sigma > 0$ represents the coefficient of relative risk aversion, and $\sigma_H > 0$ represents the disutility of labor. The variable h_t is the labor effort index that aggregates labor supplied to the agricultural and non-agricultural sectors. Labor supply is influenced by a shift parameter $\chi \geq 0$, which determines the steady-state level of hours worked. As in Gallic and Vermandel (2020), we assume an imperfect substitutability of labor between the two sectors, with labor supply defined as:

$$h_t = \left[h_{N,t}^{1+\iota} + h_{A,t}^{1+\iota} \right]^{\frac{1}{1+\iota}}$$

Here, $h_{N,t}$ and $h_{A,t}$ represent the hours worked in the non-agricultural and agricultural sectors, respectively. The parameter $\iota \geq 0$ governs the degree of substitutability between labor in these two sectors. When $\iota = 0$, labor is perfectly substitutable across sectors, resulting in a strong negative correlation between sectoral labor inputs. Positive values of ι reflect increasing sector-specificity, implying a less responsive reallocation of labor across sectors in response to wage differentials.

The law of motion for agricultural capital is:

$$i_{A,t}(i) = k_{A,t}(i) - (1-\delta_k)\, k_{A,t-1}(i) \tag{1}$$

Households maximize their utility function subject to the following real budget constraint:

$$\sum_{s=N,A} w_{s,t} h_{s,t} + r_{t-1} b_{t-1} + rer_t^* r_{t-1}^* b_{t-1}^* - T_t \geq C_t + b_t + rer_t^* b_t^* + p_{N,t} rer_t \Phi(b_t^*) \tag{2}$$

Their income consists of labor income with real wages $w_{N,t}$ and $w_{A,t}$, income from real risk-free domestic bonds b_t remunerated at the domestic interest rate r_{t-1}, and foreign bonds b_t^* remunerated at the foreign rate r_{t-1}^*, adjusted by the real exchange rate rer_t^*. The term T_t represents lump sum taxes. The risk premium on foreign bonds is given by $\Phi(b_{jt}^*) = 0.5\chi_B (b_{jt}^*)^2$, paid in terms of domestic non-agricultural goods at the relative price $p_t^N =$

P_t^N/P_t. The parameter $\chi_B \geq 0$ determines the magnitude of the cost that households incur when purchasing foreign bonds. The real exchange rate is derived from the nominal exchange rate e_t and the ratio of foreign to domestic prices:

$$rer_t^* = e_t^* \frac{P_t^*}{P_t} \tag{3}$$

Households allocate their total consumption C_t between non-agricultural and agricultural goods, denoted as $C_{N,t}$ and $C_{A,t}$ respectively. The Constant Elasticity of Substitution (CES) consumption bundle is expressed as:

$$C_t = \left[(1-\varphi)^{\frac{1}{\mu}} C_{N,t}^{\frac{\mu-1}{\mu}} + \varphi^{\frac{1}{\mu}} C_{A,t}^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}$$

where $\mu \geq 0$ denotes the elasticity of substitution between the two types of goods, and $\varphi \in [0,1]$ is the share of agricultural goods in the household's total consumption basket. Each type of good, $C_{N,t}$ and $C_{A,t}$, is itself a composite of domestically and foreign-produced goods:

$$C_{s,t} = \left[(1-\alpha_s)^{1/\mu_s} C_{s,t}^{\frac{\mu_s-1}{\mu_s}} + \alpha_s^{1/\mu_s} C_{s^*,t}^{\frac{\mu_s-1}{\mu_s}} \right]^{\frac{\mu_s}{\mu_s-1}}$$

Here, α_s represents the fraction of foreign-produced goods in the consumption bundle of good s, where s refers to either the non-agricultural or agricultural sector.

From the minimization of total consumption expenditure, we obtain the demand for each type of good, which is a fraction of the total consumption index adjusted by its relative price:

$$C_{N,t} = (1-\varphi) \left(\frac{P_{N,t}^C}{P_t} \right)^{-\mu} C_t$$

$$C_{A,t} = \varphi \left(\frac{P_{A,t}^C}{P_t} \right)^{-\mu} C_t$$

$$c_{s,t} = (1-\alpha_s) \left(\frac{P_{s,t}^C}{P_{s,t}^C} \right)^{-\mu_s} C_{s,t}$$

$$c_{s*,t} = \alpha_s \left(e_t^* \frac{P_{s^*,t}^C}{P_{s,t}^C} \right)^{-\mu_s} C_{s^*,t}$$

Households maximize the utility function subject to the budget constraint. The first-order conditions with respect to C_t, $h_{A,t}$, $h_{N,t}$, b_t, and b_t^* are:

$$\lambda_t = \varepsilon_t^C \left(C_t \right)^{-\sigma}, \tag{1}$$

$$\chi \left(h_t \right)^{\sigma_h} \left(\frac{h_{A,t}}{h_t} \right)^{\iota} = w_{A,t} \lambda_t, \tag{2}$$

$$\chi \left(h_t \right)^{\sigma_h} \left(\frac{h_{N,t}}{h_t} \right)^{\iota} = w_{N,t} \lambda_t, \tag{3}$$

$$1 = \beta \frac{\lambda_{t+1}}{\lambda_t r_t}, \tag{4}$$

$$\frac{rer^*_{t+1}}{rer^*_t} = \frac{r_t}{r^*_t} \left[1 + p_{N,t} \Phi' \left((b^*_t) \right)\right]. \tag{5}$$

Equation (1) represents the marginal utility of consumption, with λ_t being the shadow price associated with the budget constraint (2). Equations (2) and (3) express the marginal rate of substitution between consumption and the labor-leisure trade-off in the agricultural and non-agricultural sectors, respectively. Equation (4) is the Euler equation, and (5) represents the real exchange rate dynamics.

2.2 Firms

2.2.1 Final Good Firms

The model incorporates a perfectly competitive aggregator in each sector, combining sector-specific goods into a composite good $y_{s,t}$ according to a CES function:

$$y_{s,t} = \left[\int_0^{n_s} \left(y_{s,t}(i) \right)^{(\sigma_s - 1)/\sigma_s} di \right]^{\sigma_s/(\sigma_s - 1)}, \quad s = A, N,$$

where $n_A = n$ is the fraction of the green sector, $n_N = 1 - n$, and $y_{s,t}(i)$ represents the intermediate good produced by firm i in sector $s = A, N$, priced at $P_{s,t}(i)$.

Cost minimization delivers the demand schedule for each variety:

$$y_{s,t}(i) = \left(\frac{P_{s,t}(i)}{P_{s,t}} \right)^{-\sigma} y_{s,t},$$

From the zero-profit condition, we obtain the aggregate production sector price index, at which the aggregator sells units of each sector's output index:

$$P_{s,t} = \left[\int_0^1 \left(P_{s,t}(i) \right)^{(\sigma - 1)/\sigma} di \right]^{\sigma/(\sigma - 1)}.$$

2.2.2 Agricultural sector

The agricultural firms employ a Cobb-Douglas production function to produce a single good, utilizing the following productive inputs: land, capital, and labor.

$$y_{A,t}(i) = \left[\Omega(\varepsilon^w_t) l_{t-1}(i) \right]^{\omega} \left[\varepsilon^z_t \left(k_{A,t-1}(i) \right)^{\xi_A} \left(\kappa_A h_{A,t}(i) \right)^{(1-\xi_A)} \right]^{1-\omega} \tag{4}$$

The production function $y_{A,t}(i)$ for the intermediate agricultural good combines land $l_{t-1}(i)$, subject to weather conditions $\Omega(\varepsilon^w_t)$, physical capital $k_{A,t-1}(i)$, and labor demand $h_{A,t}(i)$. Production is affected by an economy-wide technology shock ε^z_t, which follows an AR (1) process that impacts both sectors. The parameter $\omega \in [0, 1]$ represents the elasticity of output to land, $\xi \in [0, 1]$ denotes the share of physical capital in agricultural production, and $\kappa_A \geq 0$ is a technology parameter determined endogenously in the steady state. The damage function is defined as $\Omega(\varepsilon_t^W) = \left(\varepsilon_t^W\right)^{-\theta}$, where θ represents the elasticity of land productivity with respect to weather. The assumption of fixed land in the agricultural sector allows for time-varying efficiency, which follows the endogenous law of motion:

$$l_t(i) = \left[(1-\delta_l) + \frac{\tau}{\phi} X_t^{\phi}\right] \Omega(\varepsilon_t^W) l_{t-1}(i) \tag{5}$$

where $\delta_l \in (0,1)$ represents the decay of land productivity. The functional form $\frac{\tau}{\phi} X_t^{\phi}$ denotes land costs, which signify the expenses associated with maintaining farmland productivity. X_t encompasses agricultural spending on inputs like pesticides, fertilizers, and water to sustain productivity, where $\tau \geq 0$ and $\phi \geq 0$. The parameter τ determines the per capita land in the steady state. The economy-wide technology shock follows an AR(1) process:

$$\log(\varepsilon_t^Z) = (1-\rho_Z)\log(\varepsilon_{ss}^Z) + \rho_Z \log(\varepsilon_{t-1}^Z) + \eta_t^Z, \tag{6}$$

where $\rho_Z \in (0,1)$ is the persistence of the shock process, and η_t^Z is the standard deviation of the white noise, following a standard normal distribution. The weather shock follows:

$$\log(\varepsilon_t^W) = (1-\rho_W)\log(\varepsilon_{ss}^W) + \rho_W \log(\varepsilon_{t-1}^W) + \eta_t^W, \tag{7}$$

where $\rho_W \in (0,1)$ signifies the persistence of the shock process, quantifying the duration of the shock's effects. η_t^W represents the standard deviation of the shock, following a standard normal distribution.

where $\delta_k \in (0,1)$ is the depreciation rate of physical capital and $i_{A,t}(i)$ is the investment of the representative farmer.

Agricultural firms maximize the following real profit with respect to labor, capital, land, land costs, and prices:

$$d_{A,t}(i) = p_{A,t}(i)y_{A,t}(i) - r_{A,t}^k k_{A,t-1}(i) - w_{A,t}h_{A,t}(i) - p_{N,t}x_t(i) - \Gamma_{P_D}(P_{A,t}, y_{A,t}) \tag{8}$$

where $p_{s,t} = P_{s,t}/P_t$ and subject to $y_{s,t}(i) = \left(\frac{P_{s,t}(i)}{P_{s,t}}\right)^{-\sigma} y_{s,t}$,the production technology function (Eq. 4). In addition, agricultural firms face quadratic nominal price-adjustment costs, as in Rotemberg (1982):

$$\Gamma_{P_D}(P_{A,t}, y_{A,t}) = \frac{\kappa_A^P}{2}\left(\frac{P_{A,t}(i)}{P_{A,t-1}(i)} - 1\right)^2 P_{A,t}y_{A,t}, \tag{9}$$

First-order conditions provide the optimal demand for labor, capital, the land expenditures and prices:

$$w_{A,t} = (1-\omega)(1-\xi_A)mc_{A,t}\frac{Y_{A,t}}{h_{A,t}} \tag{10}$$

$$r_{A,t} = (1-\omega)(\xi_A)mc_{A,t}\frac{Y_{A,t}}{h_{A,t}} \tag{11}$$

$$\frac{p_{N,t}}{\tau X_t^{\phi-1}\ l_{t-1}\ \Omega\left(\varepsilon_t^W\right)} = E_t \left\{\Lambda_{t,t+1} \ \left(\omega\frac{mc_{A,t+1}Y_{t+1}^A}{l_t} \ + \frac{p_{t+1}^N}{\tau X_{t+1}^{\phi-1} l_t} \ \left[(1-\delta_l)+\frac{\tau}{\phi}X_{t+1}^{\phi}\right]\right)\right\} \tag{12}$$

$$(1-\sigma_A)+\sigma_A mc_{A,t} = \kappa_A^P\left(\Pi_{A,t}-1\right)\Pi_{A,t} - \beta\mathbb{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left[\kappa_A^P\left(\Pi_{A,t+1}-1\right)\left(\Pi_{A,t+1}\right)^2\frac{y_{A,t+1}}{y_{A,t}}\right], \tag{13}$$

The left-hand side of Equation (12) represents the current marginal cost of land maintenance, while the right-hand side corresponds to the sum of the marginal product of land productivity with the value of land in the next period. A weather shock deteriorates the expected marginal benefit of the land and raises the current cost of land maintenance.

2.2.3 Non-Agricultural Sector

These firms are similar to agricultural firms except in their technology, as they do not require land inputs to produce goods and are not directly affected by weather. Each representative non-agricultural firm has the following Cobb-Douglas technology:

$$y_{N,t}(i) = \varepsilon_t^Z\left(k_{t-1}^N(i)\right)^{\xi_N}\ \left(h_{N,t}(i)\right)^{(1-\xi_N)} \tag{14}$$

where $y_t^N(i)$ is the production of intermediate goods firms that combines physical capital $k_{it-1}^N(i)$, labor demand $h_t^N(i)$ and technology ε_t^z. The parameters ξ and $1-\xi$ represent the output elasticity of capital and labor, respectively. where $\delta_{N,k}\in(0,1)$ is the depreciation rate of physical capital and i_{it}^N is investment from non-agricultural firms.

Non-Agricultural firms maximize the following real profit with respect to labor, capital and prices:

$$d_{N,t}(i) = p_{N,t}(i)y_{N,t}(i) - r_{N,t}^k k_{N,t-1}(i) - w_{N,t}h_{N,t}(i) - \Gamma_{P_D}(P_{N,t},y_{N,t}) \tag{15}$$

where $p_{s,t} = P_{s,t}/P_t$ and subject to $y_{s,t}(i) = \left(\frac{P_{s,t}(i)}{P_{s,t}}\right)^{-\sigma} y_{s,t}$,the production technology function (Eq. **??**). In addition, agricultural firms face quadratic nominal price-adjustment costs, as in Rotemberg (1982):

$$\Gamma_{P_N}(P_{N,t},y_{N,t}) = \frac{\kappa_N^P}{2}\left(\frac{P_{N,t}(i)}{P_{N,t-1}(i)}-1\right)^2 P_{N,t}y_{N,t}, \tag{16}$$

First-order conditions provide the optimal demand for labor, capital, the land expenditures and prices:

$$w_{N,t} = (1-\xi_N)mc_{N,t}\frac{Y_{N,t}}{h_{N,t}} \tag{17}$$

$$r_{N,t} = (\xi_N)mc_{N,t}\frac{Y_{N,t}}{h_{N,t}} \tag{18}$$

$$(1-\sigma_N)+\sigma_N mc_{N,t} = \gamma_A^P\left(\Pi_{N,t}-1\right)\Pi_{N,t} - \beta\mathbb{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left[\kappa_N^P\left(\Pi_{N,t+1}-1\right)\left(\Pi_{N,t+1}\right)^2\frac{y_{N,t+1}}{y_{N,t}}\right], \tag{19}$$

2.3 Foreign Economy

The foreign economy is influenced solely by its own consumption shocks, remaining unaffected by disturbances in the domestic economy. The log consumption of the foreign economy at time t is given by:

$$\log\left(c_t^*\right) = (1-\rho_*)\log\left(c_{ss}^*\right) + \rho_*\log\left(c_{t-1}^*\right) + \eta_t^{C^*} \tag{20}$$

where $\eta_t^{C^*}$ follows a standard normal distribution, i.e., $\eta_t^* \sim \mathcal{N}(0,1)$. The parameter ρ_* captures variations of the foreign demand. Here, $\rho_* \in [0,1)$ is the root of the process, c_j^* is the state foreign consumption, and $\sigma_* \geq 0$ is the standard deviation of the shock.

The objective function is defined as:

$$\max_{C_t^*, b_j^*} E_t \left\{ \sum_{\tau=0}^{\infty} \beta^\tau \varepsilon_{t+\tau}^P \log\left(c_{t+\tau}^*\right) \right\} \tag{21}$$

subject to the budget constraint

$$r_{t-1}^* b_{t-1}^* = c_t^* + b_t^* \tag{22}$$

where ε_t^P is the time preference shock, which is defined as:

$$\log(\varepsilon_t^P) = (1-\rho_P)\log(\varepsilon_{ss}^P) + \rho_P\log(\varepsilon_{t-1}^P) + \eta_t^P, \tag{23}$$

with $\eta_t^P \sim \mathcal{N}(0,1)$. The budget constraint comprises consumption and domestic bonds purchased, the latter at a predetermined rate r_{t-1}^*.

2.4 Government authority and Monetary Policy

The public authority consumes a certain amount of non-agricultural output, denoted by G_t, issues debt b_t at a real interest rate, and levies taxes T_t. Public spending is assumed to be exogenous and is given by $G = Y_t^N g \varepsilon_t^g$, where $g \in [0,1)$ is a fixed fraction of non-agricultural goods. The government demand shock follows an autoregressive process of order one:

$$\log(\varepsilon_t^G) = (1-\rho_G)\log(\varepsilon_{ss}^G) + \rho_G\log(\varepsilon_{t-1}^G) + \eta_t^G, \tag{24}$$

where $\rho^g \in (0,1)$ is the persistence of the shock process, and η_t^g is the standard deviation of the white noise that follows standard normal distribution. The government's budget constraint is defined as:

$$G_t + r_{t-1}b_{t-1} = b_t + T_t \tag{25}$$

2.5 Aggregation and equilibrium

First, the market clearing condition for non-agricultural goods is determined when the aggregate supply is equal to aggregate demand:

$$(1-n_t)y_t^N = (1-\varphi)\left[(1-\alpha_N)\left(\frac{P_t^N}{P_{C,t}^N}\right)^{-\mu}\left(\frac{1}{e_t^N}\frac{P_t^N}{P_{C,t}^N}\right)^{-\mu} C_t + \alpha_N\left(\frac{P_t^N}{P_{C,t}^N}\right)^{-\mu} C_t^*\right] + G_t + i_t + n_t x_t + \Phi(b_t^*),$$

where the total supply of home non-agricultural goods is given by $\int_0^{1-n_t} y_{it}^N di = (1-n_t)y_t^N$. Aggregate investment, with $\int_0^1 i_{it}^N di = (1-n_t)i_t^N$, is given by: $i_t = (1-n_t)i_t^N + n_t i_t^A$. The total number of hours worked: $h_t = (1-n_t)h_t^N + n_t h_t^A$. Aggregate real production is given by:

$$y_t = (1-n_t)p_t^N y_t^N + n_t p_t^A y_t^A.$$

In addition, the equilibrium of the agricultural goods market is given by:

$$n_t y_t^A = \varphi\left((1-\alpha_A)\left(\frac{P_t^A}{P_{C,t}^A}\right)^{-\mu_A}\left(\frac{P_t^A}{P_{C,t}^A}\right)^{-\mu} C_t + \alpha_A\left(\frac{1}{e_t^A}\frac{P_t^A}{P_{C,t}^A}\right)^{-\mu_A} C_t^*\right),$$

In this equation, the left side denotes the aggregate production, while the right side denotes respective demands from home and foreign (i.e., imports) households. In detail, n_t is an AR(1):

$$\log(n_t) = (1-\rho_N)\log(n_{ss}) + \rho^n \log(n_{t-1}) + \eta_t^N, \tag{26}$$

where $\rho_N \in (0,1)$ is the persistence of the shock process, and η_t^N is the standard deviation of the white noise that follows a standard normal distribution.

Aggregate real production is given by:

$$y_t = p_{N,t}y_{N,t} + p_{A,t}y_{A,t} \tag{27}$$

Given the presence of intermediate inputs, the GDP is given by:

$$gdp_t = Y_t - p_{N,t}n_t x_t \tag{28}$$

The law of motion for the total amount of real foreign debt is:

$$b_t^* = r_{t-1}^* \frac{rer_t^*}{rer_{t-1}^*} b_{t-1}^* + tb_t \tag{29}$$

where tb_t is the real trade balance that can be expressed as follows:

$$tb_t = p_{N_t}\left[(1-n_t)Y_{N_t} - G_t - I_t - n_t X_t - (b_t^*)\right] + p_{A_t} n_t Y_{A_t} - C_t \tag{30}$$

The monetary policy is set according the following taylo rule:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\phi_r}\left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{gdp_t}{gdp}\right)^{\phi_y}\right]^{(1-\phi_r)} \tag{31}$$

where non-indexed variables refer to steady-state levels, $\phi_r \in [0,1)$ denotes the interest rate smoothing parameter. The coefficients $\phi_\pi \in [0,1)$ and $\phi_y \in [0,1)$ quantify the responsiveness of the nominal interest rate to deviations in inflation and aggregate output, respectively.

3 Calibration and Estimation

This section outlines the model's parametrization procedure, distinguishing between two categories of parameters. The first category encompasses calibrated non-policy parameters, where calibration is applied to parameters for which the available data is either non-informative or weakly informative, as per Guerrón-Quintana and Nason (2013). The second category includes parameters estimated through a Bayesian estimation framework. This approach is adopted to enhance the robustness and rigor of the parametrization, ensuring that the model reflects both empirical evidence and theoretical coherence effectively.

3.1 Calibration

The standard parameters of the DSGE model are calibrated on a quarterly basis. Consistent with previous literature (e.g., Annicchiarico and Dio, 2015), we assign the capital share to 0.33 of the production function in both sectors. The international portfolio cost is set at 0.0007, following the values reported by Gallic and Vermandel (2020). In line with the broader literature, the capital depreciation rate is calibrated at 0.025, and investment adjustment costs are set at 4. The discount factor, β, is fixed at 0.99. Additionally, the land-to-employment ratio ($l = 0.25$) is based on the ratio of arable land (hectares per person) in Turkey, as derived from FAO data provided by the World Bank. We calibrate the degree of openness of the economy in both sectors ($\alpha_N = \alpha_A = 0.35$), which corresponds to the average share of exports of goods and services in gross output for both sectors in Turkey in 2023. The share of agricultural goods in the household consumption basket is set at $\varphi = 13\%$, reflecting the observed average over the sample period from 1998Q1 to 2019Q4. The remaining parameters are estimated using Bayesian methods to ensure a data-consistent estimation process.

3.2 Bayesian Estimation

Specific parameters that are pertinent to the agricultural sectors, previously unexplored in past literature—are estimated using Bayesian techniques.[1]. Table 2 reports the prior and posterior distributions of the parameters for Turkey. Overall, our prior distributions are either relatively diffuse or consistent with earlier contributions to Bayesian estimations, such as Smets and Wouters (2007) and Gallic and Vermandel (2020).

3.2.1 Data

In the estimation process, we utilize quarterly data for Turkey covering the period 1998:Q1 to 2019:Q4. To account for weather patterns, we employ the Standardized Precipitation Evapotranspiration Index (SPEI), which incorporates both precipitation and potential evapotranspiration (PET) to assess drought conditions. The multiscalar nature of SPEI enables the

[1]The Bayesian methodology can be implemented by merging the likelihood function with the prior distributions of the model's parameters, resulting in the posterior density function. The Metropolis-Hastings sampling technique is utilized to extract the posterior distributions. The model is resolved using a linear approximation of the model's policy function. The Kalman filter is employed to construct the likelihood function and calculate the sequence of errors (Adjemian, 2011).

Parameters	Value	Description	Source
δ_k	0.025	Depreciation rate	Standard in Literature
χ_b	0.0007	International portfolio cost	Gallic and Vermandel(2020)
κ_I	4.00	Adjustment costs on investments	Gallic and Vermandel(2020)
h_s	0.33	Hours worked	Standard in Literature
l	0.25	Land per capita	World Bank Data
α_s	0.35	Share of imported goods	World Bank Data
φ	0.13	Share of agricultural goods in consumption	Data

Table 1: Calibrated Parameters

identification of various types of drought and their impacts across different systems (Vicente-Serrano et al., 2012, 2013). The SPEI is computed by normalizing the difference between precipitation and PET using a three-parameter log-logistic distribution, which effectively handles frequent negative values, particularly in arid and semi-arid regions where moisture deficits are common (Středová et al., 2011; Vicente-Serrano et al., 2010). The resulting SPEI values typically range from $\gamma < x < -\infty$, where γ is the origin parameter of the distribution. The log-logistic distribution is favored for its superior fit for extreme negative values (Hernandez and Uddameri, 2014). For calculating PET, we apply the Hargreaves (1994) method, using an average latitude of 39 degrees for Turkey. [2]

To analyze the dynamic interplay between weather shocks and economic fluctuations in Turkey, we examine five key observable macroeconomic variables: real gross domestic product (GDP), real consumption, real agriculture production, consumer price index (CPI), and foreign real GDP. For the latter, the real GDP of the European Union (EU-28) serves as a proxy. Each macroeconomic series is first logarithmically transformed and subsequently detrended using the Hodrick-Prescott filter to isolate cyclical components from long-term trends.

3.2.2 Prior Distributions

Starting from the shock processes section, the standard errors of the innovations follow an inverse gamma distribution with a mean of 1 and a standard deviation of 2, as in Smets and Wouters (2007). The persistence of the shock process is assumed to follow a beta distribution with a mean between 0.7 and a standard deviation of 0.1, as in Gallic and Vermandel (2020) and Smets and Wouters (2007). Turning to the structural parameters, as in Gallic and Vermandel (2020), substitution parameters μ, μ_N, and μ_A are each assumed to follow a Gamma distribution with a mean of 2.5 and a standard deviation equal to 1. According to Smets and Wouters (2007), risk aversion parameters (σ and σ^*) are assumed to follow a Normal distribution with a mean of 2 and a standard deviation of 0.35. Following Smets and Wouters (2007), the parameters indicative of the labor disutility, denoted as (σ), follow a Normal distribution with a mean of 2 and standard deviation 0.5. The share of capital in

[2]SPEI (Vicente-Serrano et al., 2010) is based on the difference between precipitation and evaporation over periods of 3, 6, 9, 12, 24, or 48 months. First, rainfall data is fitted to a Gamma distribution and then transformed into a standard normal distribution to obtain SPEI values.

the production function of both types of households (ξ_A and ξ_N) follows a beta distribution with 0.3 as the prior mean and 0.1 as the standard deviation.

3.2.3 Posterior Distribution

Table 3 reports the estimation results that summarize the posterior distributions' means and the 5*th* and 95*th* percentiles. While a portion of the results aligns with the established business cycle literature for developing nations, as exemplified by Gallic and Vermandel (2020), it is noteworthy to highlight several observations concerning the means of the posterior distributions of selected structural parameters.

These observations provide valuable insights into the underlying dynamics of the model. First, we find a positive and significant posterior mean for θ, equal to 0.44. Furthermore, this value holds significance as the confidence interval is positive. This indicates that the estimated parameter is statistically different from zero, providing evidence for the effect of weather on agricultural productivity and the real economy. The land expenditure cost posterior mean (ϕ) equals 2.46, implying that the returns to scale for land expenditures reside within the range of a quadratic to a cubic functional form. This suggests a non-linear relationship between land expenditure and returns, with increasing returns up to a certain point, beyond which the returns may start to diminish or increase at a decreasing rate. This observation provides valuable insights into the underlying dynamics of land utilization and its impact on economic output. Unlike Gallic and Vermandel (2020), regarding the labor reallocation parameter ι in the utility function of households, the data favor a low costly labor reallocation across sectors. Upon examining the parameters of the consumption basket for both household types, it is observed that households of the HM category exhibit a higher consumption of agricultural goods compared to their Ricardian counterparts. Furthermore, it is noteworthy that the degree of openness in the non-agricultural market is less pronounced for both household types when contrasted with the agricultural market. These latter findings align with the empirical observations made by Gallic and Vermandel (2020).

4 Results

This section analyzes the transmission of an adverse weather shock within a small open economy, using the Turkish economy as a representative case. Turkey represents a relevant case study as it is characterized by its status as a small and open economy with strong global economic ties, a net debtor position, and an independent monetary policy framework. Moreover, Turkey is expected to face severe adverse effects from global climate change (Aktaş, 2014). For instance, between 1970 and 2000, total runoff and precipitation decreased by approximately 21% and 19.3%, respectively. These impacts on water availability are attributed to a combination of reduced precipitation and increased evapotranspiration (Babaoğlu et al., 2023).

4.1 Weather Shock Propagation

In this section, we present the simulated Bayesian Impulse Response Functions (BIRFs) for key macroeconomic variables to analyze the propagation mechanism of a weather-related

Parameters	Prior Mean	Prior Std	Shape	Posterior Mean	90% **CI**
Structural					
ϕ_y	0.125	0.10	$\mathcal{G}$	0.0516	0.0022 - 0.1056
ϕ_π	1.500	0.10	$\mathcal{G}$	1.5126	1.3604 - 1.6779
θ	0.000	500.00	$\mathcal{U}$	4.8169	0.0160 - 9.4178
ψ_X	1.000	1.00	$\mathcal{N}$	1.6175	1.1582 - 2.0790
ω	0.200	0.08	$\mathcal{B}$	0.1658	0.0847 - 0.2458
α_A	0.300	0.10	$\mathcal{B}$	0.4379	0.2261 - 0.6203
α_N	0.300	0.10	$\mathcal{B}$	0.2123	0.1215 - 0.3015
δ_L	0.200	0.07	$\mathcal{B}$	0.1976	0.0877 - 0.3084
ϕ	2.000	0.75	$\mathcal{N}$	2.0141	0.9557 - 2.9352
σ^*	2.000	0.35	$\mathcal{N}$	1.4342	1.0921 - 1.7876
σ	2.000	0.35	$\mathcal{N}$	2.2430	1.8705 - 2.5688
μ	2.500	1.00	$\mathcal{G}$	1.4790	0.8749 - 2.0393
μ_A	2.500	1.00	$\mathcal{G}$	0.0917	0.0341 - 0.1431
μ_N	2.500	1.00	$\mathcal{G}$	0.5620	0.4509 - 0.6827
ρ_a	0.500	0.20	$\mathcal{B}$	0.8151	0.7184 - 0.9282
ρ_{aA}	0.500	0.20	$\mathcal{B}$	0.7491	0.6497 - 0.8654
ρ_w	0.500	0.20	$\mathcal{B}$	0.3038	0.1720 - 0.4549
ρ_c	0.500	0.20	$\mathcal{B}$	0.4944	0.1983 - 0.8460
ρ_{cf}	0.500	0.20	$\mathcal{B}$	0.8316	0.7390 - 0.9291
ρ_m	0.500	0.20	$\mathcal{B}$	0.9076	0.8622 - 0.9556
ϵ_a	1.000	2.00	inv $\mathcal{G}$	4.2229	3.1381 - 5.1313
ϵ_{aA}	1.000	2.00	inv $\mathcal{G}$	5.0123	3.3005 - 6.9143
ϵ_w	1.000	2.00	inv $\mathcal{G}$	0.7561	0.6599 - 0.8494
ϵ_m	1.000	2.00	inv $\mathcal{G}$	0.9517	0.4170 - 1.3723
ϵ_{cf}	1.000	2.00	inv $\mathcal{G}$	0.8348	0.7266 - 0.9427
ϵ_c	1.000	2.00	inv $\mathcal{G}$	2.2159	1.7587 - 2.6261

Table 2: Notes: The column entitled "Shape" indicates the prior distributions using the following acronyms: $\mathcal{N}$ describes a normal distribution, $\mathcal{G}$ a Gamma, inv $\mathcal{G}$ an inverse Gamma, $\mathcal{U}$ a Uniform, and $\mathcal{B}$ a Beta.

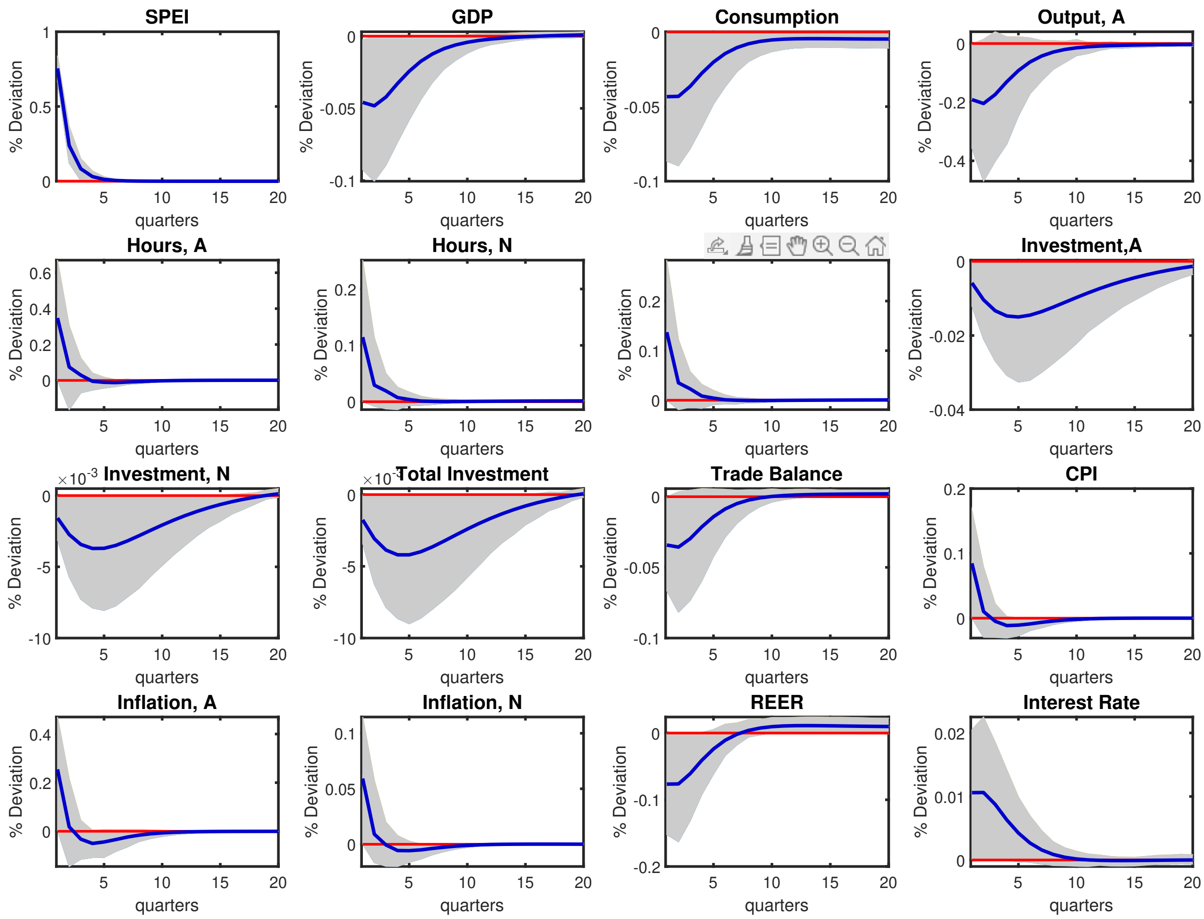

Figure 1: Bayesian Impulse Response Functions for the estimated DSGE. Notes: Blue lines are the Impulse Response Functions (IRFs) generated when parameters are drawn from the mean posterior distribution, the gray areas are their 90 confidence intervals.

shock in Turkey. Figure 1 illustrates the dynamic effects of a negative weather shock, i.e. a reduction in net precipitation (precipitation minus evapotranspiration)—and its transmission through the real economy. Firstly, the drought event propagates through the real economy by adversely impacting agricultural productivity and, consequently, agricultural output, which declines by 0.2%. This reduction arises as adverse weather conditions diminish the effectiveness of land as an input in the agricultural production process. To mitigate this loss, in line with Gallic and Vermandel (2020) farmers increase the use of non-agricultural inputs, to restore land productivity and offset the decline in agricultural output (e.g. Farmers may use more pesticides, as droughts are often followed by pest outbreaks). As a consequence, the surge in non-agriculture goods has a positive side effect on non-agricultural production, which shows an increase of 0.1%. The overall impact on aggregate GDP, consumption, and investment is negative. In response to the decline in income, households compensate by increasing the number of hours worked not only in the agricultural sector but, in line with Branco and Féres (2020), also in non-agricultural sectors.

The simultaneous decline in agricultural production and the increase in non-agricultural output lead to significant changes in the sectoral price structure. The negative weather shock reduces productivity in the agricultural sector and raises production costs, thereby exerting upward pressure on prices. Although relative prices across sectors are negatively correlated, the price of non-agricultural goods also rises in response to the drought, underscoring the spillover effects of inflation. This result contrasts with the findings of Gallic and Vermandel (2020), suggesting that price stickiness may influence the propagation of such shocks across sectoral prices. The overall effect on the Consumer Price Index is positive, resulting in an increase of 0.1%. In response to the rise in inflation, the monetary policy-maker adjusts by raising the interest rate.

In line with García-Verdú et al. (2019), farmers may increase the use of imported intermediate inputs to face climate-related productivity declines and this strategy appears to shield low-income countries from the negative impacts of weather shocks on agricultural total factor productivity. At an international level, the decline in domestic agricultural production generates trade balance deficits and a depreciation of the domestic currency: as both output and price competitiveness of the agricultural sector deteriorate, Turkey's exports decline. However, the decline in the relative price of non-agricultural fuels the external demand for non-agricultural, thus explaining why this sector experiences a boom. Taken together, the effect of the agricultural sector outweighs the other sector, through a fall in the trade balance and the current account. In the meantime, the domestic real exchange rate depreciates driven by the depressed competitiveness of farmers, which helps in restoring their competitiveness.

4.2 Alternative Monetary Policy Rules

This section investigates the dynamic response of the economy to a weather shock, modeled within a decentralized competitive equilibrium framework. The analysis assumes that monetary policy is implemented according to three alternative Taylor rules, each tailored to emphasize distinct sectors or economic aggregates. Incorporating different Taylor rule specifications enables a deep examination of how sectoral heterogeneity and shock-specific dynamics interact with monetary policy. In addition to the standard Taylor rule (Eq. 31), we consider the following monetary policy rules:

- Agricultural Inflation Rule (AIR):

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\phi_r} \left[\left(\frac{\pi_{A,t}}{\pi_A}\right)^{\phi_\pi} \left(\frac{y_{A,t}}{y_A}\right)^{\phi_y}\right]^{(1-\phi_r)} \tag{32}$$

- Core Inflation Rule (CIR):

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\phi_r} \left[\left(\frac{\pi_{N,t}}{\pi_N}\right)^{\phi_\pi} \left(\frac{y_{N,t}}{y_N}\right)^{\phi_y}\right]^{(1-\phi_r)} \tag{33}$$

The Standard Taylor Rule (Eq. 31) targets deviations in aggregate inflation and GDP, offering a generalized, non-sector-specific policy framework. The Agricultural Taylor Rule (Eq.32) emphasizes inflation and output in the agricultural sector, addressing the unique

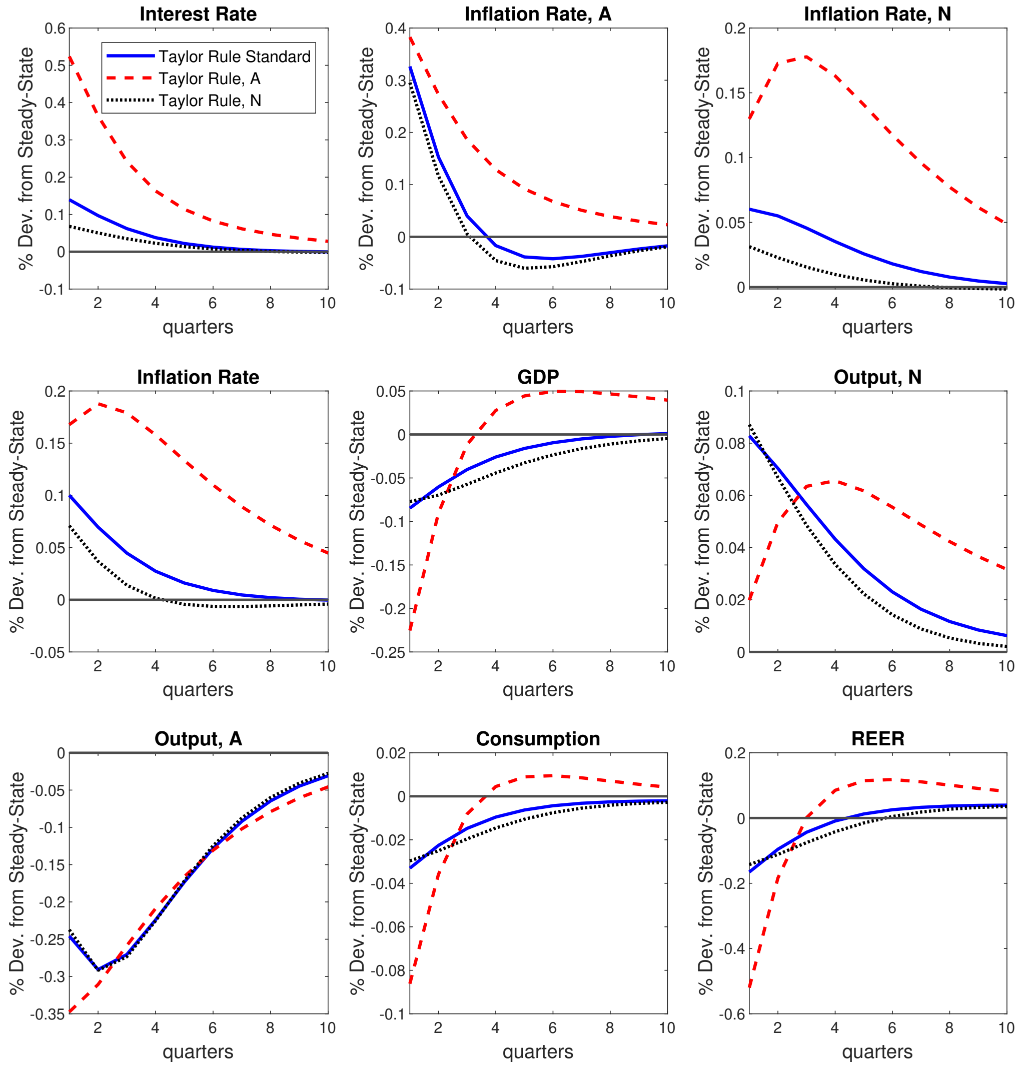

Figure 2: Impulse Response Functions for the estimated DSGE at the posterior mean under alternative Taylor Rules ($\phi_\pi = 1.5, \phi_y = 0.125, \phi_r = 0$).

vulnerabilities of this climate-sensitive sector. Finally, the Core Inflation Rule (Eq.33) targets inflation and output within the non-agricultural sector, highlighting its dynamics and the spillover effects of a weather shock on the broader economy. For our initial exercise, we set $\phi_\pi = 1.5$, $\phi_y = 0.125$ and $\phi_r = 0$. The parameter values are selected to correspond with standard calibrations frequently employed in the monetary policy literature. This approach encompasses a monetary policy framework in which the interest rate reacts strongly to inflation deviations, moderately to output deviations, and without smoothing, emphasizing the immediate effects of monetary policy responses to inflation and output.

Figure 2 shows the response of selected macroeconomic variables to an adverse weather shock of 1%. The standard Taylor rule (solid line) follows a relatively moderate path, raising the interest rate to approximately 0.15% deviation from steady-state in the early quarters following the shock. Over time, the interest rate declines gradually as the economy converges back to equilibrium. In contrast, the Taylor rule tied to agricultural inflation (Taylor Rule, A, red dashed line) exhibits a more aggressive initial response, with the interest rate peaking at 0.5%, reflecting the stronger inflationary pressures in the agricultural sector. This higher initial interest rate likely reflects the central bank's attempt to counteract sharp increases in agricultural prices, which can rapidly transmit to the broader economy. On the other hand, the Taylor rule responding to non-agricultural inflation (Taylor Rule, N, black dotted line) results in a more subdued interest rate response. The interest rate peaks at around 0.1%, suggesting that inflationary pressures in the non-agricultural sector are initially less pronounced. This more gradual adjustment reflects a weaker immediate pass-through from the non-agricultural price sector to overall inflation.

Under the Taylor Rule which responds to agricultural sector measures, the agricultural inflation rate initially rises sharply, peaking at 0.4% above its steady-state level. This spike reflects the supply-side constraints in the agricultural sector, which drive up prices. Notably, the more aggressive monetary tightening under this rule contributes to an initial decline in agricultural output, exacerbating inflationary pressures in the short run before stabilizing around the 10th quarter. The non-agricultural inflation rate also experiences a noticeable rise in the early quarters. This spillover effect suggests that tighter monetary policy aimed at stabilizing agricultural inflation inadvertently affects the broader economy by reducing agricultural output, which in turn raises input costs in the non-agricultural sector. Thus, we observe that targeting agricultural inflation can have unintended consequences in non-agricultural markets due to the strong interdependence between sectors.

The overall inflation rate under the Non-Agricultural framework and the standard Taylor Rule exhibits a smoother trajectory, suggesting that a more balanced approach to inflation targeting can help minimize short-term economic disruptions. However, this monetary policy appears less effective in mitigating economic pressures during the propagation of the weather shock. This highlights a critical trade-off between output stability and inflation control across different sectors, with distinct short-term and long-term gains and losses. Although an Agricultural Taylor Rule generates ambiguous short-run effects, characterized by higher inflation and lower GDP, this policy enables the economy to recover more quickly from the weather shock. This suggests that while the immediate costs of such a rule may include heightened price pressures and reduced output, its responsiveness to sector-specific dynamics can facilitate a faster return to equilibrium.

The standard Taylor rule (solid line) offers a middle ground, managing to stabilize overall inflation without producing large fluctuations in sector-specific inflation rates. Agricultural inflation remains relatively contained, and non-agricultural inflation gradually returns to steady-state after a modest peak. This suggests that the standard rule is more robust to sector-specific shocks and can balance both inflation and output stability without exacerbating sectoral imbalances.

The results highlight the importance of considering sectoral linkages when designing monetary policy. The Agricultural Taylor Rule delivers a more aggressive response in the interest rate but also triggers stronger inflationary pressures in the short term. The rapid increase in agricultural inflation could stem from a reduction in agricultural output, which tightens supply and raises prices, thus propagating inflationary pressures into the non-agricultural sector. This spillover effect underscores the interconnectedness of sectors and the need for a more comprehensive policy approach when responding to sector-specific inflation shocks. In contrast, the Core Inflation Rule and standard Taylor rule results in more subdued interest rate adjustments and milder inflation dynamics, which may offer greater short-term stability. However, this approach appears less effective in containing the propagation of a weather shock in its aftermath.

4.2.1 Welfare Analysis

This section compares the performance of alternative monetary policy regimes using welfare as metric. In detail, we consider the following welfare function:

$$\mathcal{W}_t = \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t)^{1-\sigma}}{1-\sigma} - \chi \frac{(h_t)^{1+\sigma_H}}{1+\sigma_H} \right] \tag{34}$$

Equation (34) represents the unconditional expectation of the lifetime utility function of households. To evaluate the welfare effects, we consider the percentage deviation of welfare from a baseline Taylor rule that is based on aggregate macroeconomic variables ($\phi_\pi = 1.5$, $\phi_y = 0.125$, $\phi_r = 0.5$). Tables (??) present the moments generated by the model, considering only a weather shock with a standard deviation set to 0.1%.

ϕ_π	ϕ_y	ϕ_r	HIR	$\Delta\bar{\mathcal{W}}_1$ (%)	$\Delta\bar{\mathcal{W}}_2$ (%)	$\Delta\bar{\mathcal{W}}_3$ (%)
1.5000	0	0	-632.5654	0.3537	0.3642	0.3525
1.5000	0	0.5000	-637.0031	-0.3453	-0.3486	-0.3450
1.5000	0.1250	0	-632.6910	0.3341	0.3396	0.3377
1.5000	0.1250	0.5000	-634.8107	0.0000	0.0041	0.0006
1.5000	0.5000	0	-633.7711	0.1638	0.1454	0.1752
1.5000	0.5000	0.5000	-632.3667	0.3851	0.3535	0.4038
2.5000	0	0	-640.5080	-0.8977	-0.9371	-0.8900
2.5000	0	0.5000	-635.6865	-0.1379	-0.1359	-0.1383
2.5000	0.1250	0	-625.4609	1.4733	1.5506	1.4662
2.5000	0.1250	0.5000	-630.8910	0.6177	0.6496	0.6152
2.5000	0.5000	0	-637.6931	-0.4542	-0.4634	-0.4572
2.5000	0.5000	0.5000	-635.3997	-0.0928	-0.0924	-0.0913

Table 3: Percentage deviations in welfare for alternative monetary policy rules with respect to the standard Taylor rule calibration. Note: $\Delta\bar{\mathcal{W}}_1$, $\Delta\bar{\mathcal{W}}_2$, and $\Delta\bar{\mathcal{W}}_3$ represent, respectively, percentage welfare deviations for headline, agricultural, and core inflation rules relative to the benchmark welfare level (standard Headline Rule: $\phi_\pi = 1.5$, $\phi_y = 0.125$, $\phi_r = 0.5$).The model is simulated for 200 realizations of shock sequences, each comprising 10,000 periods, with the first 100 observations from each realization discarded.

The table provides a detailed comparison of the welfare effects across different monetary policy rules by varying the Taylor rule parameters (ϕ_π, ϕ_y, ϕ_r). Policies with higher inflation responsiveness ($\phi_\pi = 2.5$) generally result in larger welfare losses compared to the baseline ($\phi_\pi = 1.5$). However, exceptions occur when combined with a moderate response to output ($\phi_y = 0.125$) or no response to interest rate smoothing ($\phi_r = 0$), leading to notable welfare improvements in each Taylor rule. For output gap responsiveness, moderate ($\phi_y = 0.125$) or high ($\phi_y = 0.5$) values lead to welfare improvements compared to no response ($\phi_y = 0$).

For instance, when $\phi_\pi = 1.5$ and $\phi_r = 0.5$, increasing ϕ_y from 0 to 0.125 improves welfare (e.g., $\Delta\bar{\mathcal{W}}_1 = 0.3341\%$ to 0.3851%). Similarly, introducing interest rate smoothing ($\phi_r = 0.5$) typically results in modest welfare improvements, particularly when paired with moderate output gap responsiveness. At $\phi_\pi = 1.5$, increasing ϕ_r from 0 to 0.5 reduces welfare losses, as shown by smaller deviations and improvements in baseline welfare values.

The combination of $\phi_\pi = 2.5$, $\phi_y = 0.125$, $\phi_r = 0$ yields the highest welfare improvements ($\Delta\bar{\mathcal{W}}_1 = 1.4733\%$) among all policy variations. Conversely, the combination of $\phi_\pi = 2.5$, $\phi_y = 0.5$, $\phi_r = 0$ generates substantial welfare losses ($\Delta\bar{\mathcal{W}}_1 = -0.4542\%$).

This table presents the top five positive welfare deviations (in percentage) from the benchmark Taylor rule, ranking the alternative monetary policy rules based on their performance. The configurations are ranked by their welfare improvement, with the highest deviation listed first. Notably, the rule characterized by $\phi_\pi = 2.5$, $\phi_y = 0.125$, and $\phi_r = 0.0$ appears in the top three ranks across all rule types (Agricultural, Standard, and Non-Agricultural), indicating its robust welfare-enhancing properties across different sectors. Additionally, the fourth and fifth ranks demonstrate the role of higher smoothing ($\phi_r = 0.5$) and output responsiveness ($\phi_y = 0.5$) in improving welfare. This ranking underscores the importance of tailoring policy rules to specific economic structures, with the agricultural Taylor rule configuration showing strong welfare gains under moderate output responsiveness.

In conclusion, the table illustrates that moderate output and interest rate responsiveness enhance welfare outcomes. However, overly strong inflation targeting ($\phi_\pi = 2.5$) can have adverse effects unless paired with balanced output responsiveness. These findings emphasize the need to tailor monetary policy rules to balance inflation stabilization and welfare maximization, particularly under weather-induced economic disturbances.

Rank	ϕ_π	ϕ_y	ϕ_r	Taylor Rule Type
1	2.5000	0.1250	0.0000	AIR
2	2.5000	0.1250	0.0000	HIR
3	2.5000	0.1250	0.0000	CIR
4	2.5000	0.1250	0.5000	AIR
5	1.5000	0.5000	0.5000	HIR

Table 4: Taylor Rules Ranking

4.3 Ramsey Monetary Policy

This section derives the optimal monetary policy response to a weather shock in a small open economy (SOE). Specifically, we examine the "Ramsey" monetary policy framework to evaluate the policymaker's optimal response, considering that the economy faces exogenous shocks related to weather conditions. Under this framework, a Ramsey monetary policymaker adjusts the interest rate to maximize social welfare over time, aiming to mitigate the adverse

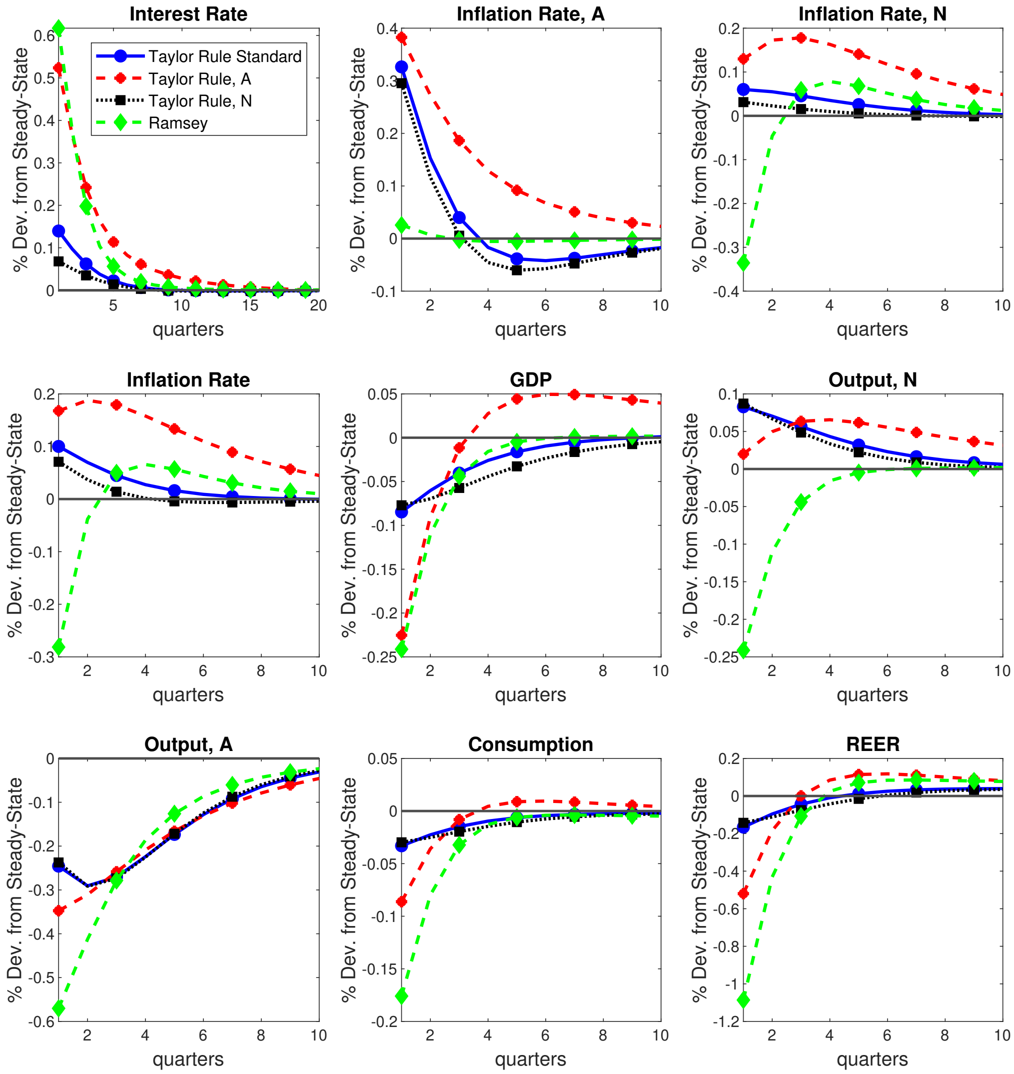

Figure 3: Impulse Response Functions to a one percent weather shock for the estimated DSGE at the posterior mean under alternative Taylor Rules and the optimal monetary policy

effects of extreme weather events on the economy. We assume that the Ramsey planner's decisions on monetary policy are binding and announced in the first period. Consequently, the Ramsey planner maximizes equation (34), subject to the constraints imposed by the equilibrium conditions of the market economy.

Figure 3 presents the response of the economy to an adverse weather shock with the Ramsey optimal policy in comparison with alternative Taylor rule according to Eqs. (31),(32) and (33). We observe that the Ramsey planner prioritizes price stability in the short run, resulting in a sharper initial increase in the interest rate compared to the decentralized economy following Taylor rules, followed by a more rapid decline. This reflects the Ramsey planner's prioritization of immediate stabilization to mitigate the adverse effects of the weather shock.

This latter, in turn, affects inflation rate in both sectors. Specifically, the Ramsey policymaker induces a more moderate increase in inflation within the agricultural sector compared to alternative policy frameworks. In contrast, the inflation rate in the non-agricultural sectors exhibits an opposite dynamic compared to the Taylor rules, with a notable reduction. This results in a reduction in overall inflation. However, the optimal policy shows a more significant reduction in aggregate and sectoral outputs, consumption and REER following the weather shock. In contrast, the optimal monetary policy enables the economy to recover more quickly from the weather shock, making its effects less persistent. However, the faster recovery trajectory under the Ramsey policy minimizes the long-term impacts of the shock. Both agricultural and non-agricultural outputs decline more significantly under the Ramsey framework initially, reflecting the trade-off between stabilizing prices and supporting output. The Ramsey policy results in a sharper initial GDP decline compared to Taylor rules, emphasizing the priority of price stability. However, the recovery is faster and more robust under the Ramsey framework, reducing the persistence of the weather shock's effects. However, the faster recovery trajectory under the Ramsey policy minimizes the long-term impacts of the shock. Still, the Ramsey monetary policy facilitates a faster recovery of international trade, allowing the real effective exchange rate to increase after three quarters. This swift adjustment in the REER not only supports external competitiveness but also contributes to stabilizing trade balances and mitigating the adverse effects of the weather shock on the economy. The accelerated adjustment of the REER under the Ramsey policy underscores the critical role of external competitiveness in mitigating the effects of adverse shocks. Policies that support trade balance recovery can complement monetary policy in stabilizing open economies. The faster recovery observed under the Ramsey policy demonstrates its effectiveness in reducing shock persistence.

4.3.1 Sensitivity Analysis

The model economy used to analyze optimal monetary policy exhibits inefficiencies typical of New Keynesian models, such as costly price adjustments and monopolistic competition. This section explores the optimal monetary policy response to a weather shock, considering varying price rigidities and substitution elasticity among differentiated goods.

Figure (4) presents the Ramsey optimal impulse response functions for different levels of price rigidities: $\kappa_j^P = 13.25$, $\kappa_j^P = 25.58$, and $\kappa_j^P = 56.60$.[3]In this analysis, we demonstrate that the intensity of the optimal monetary policy response increases with the degree of price rigidities. The inefficiencies introduced by imperfect price adjustments, make the decentralized allocation less efficient. This inefficiency necessitates a more robust adjustment in the optimal interest rate to counteract the effects of weather shocks. This implies a more pronounced decline in agricultural output, coupled with a less significant reduction in non-agricultural output, ultimately leading to a more substantial overall contraction in GDP. Consequently, higher price stickiness results in a smaller increase in the inflation rate within the agricultural sector and a more moderate decrease in inflation in the non-agricultural sectors.

Furthermore, Figure (5) illustrates the Ramsey optimal impulse response functions under varying levels of elasticity of substitution between differentiated goods: $\sigma_j = 2$, $\sigma_j = 6$, and $\sigma_j = 10$. This factor does not affect the optimal monetary policy response. However, the propagation of monetary policy varies across different parametrization of σ_j. Specifically,

[3]These values correspond to Calvo adjustment costs of 0.55, 0.65, and 0.75, respectively.

greater differentiation between goods, and thus higher monopolistic competition, reduces the negative spillover effect of a weather shock on the non-agricultural sector. This, in turn, results in a more pronounced decline in the inflation rate of the non-agricultural sector.

The analysis demonstrates that the optimal monetary policy response to a weather shock is sensitive to both price rigidities and the elasticity of substitution among differentiated goods. However, the results remain robust across these variations.

5 Conclusions

This paper has analyzed the role of monetary policy in response to a weather shock within a two-sector small open economy framework. Specifically, we estimated the model using the Turkish economy as a case study, representing a climate-vulnerable economy that simultaneously possesses the capacity to employ monetary policy as an economic policy instrument. This model has provided a comparative analysis of alternative Taylor rules in a decentralized equilibrium, focusing on aggregate variables, agricultural variables, and non-agricultural variables. In addition, we have conducted an optimal policy analysis by solving the model under the Ramsey centralized equilibrium framework.

Our results can be summarized as follows. Both the Taylor Rules and the Optimal Ramsey Policy suggest that the optimal response to a weather shock is an increase in the interest rate to mitigate inflationary pressures. However, the magnitude and persistence of this response differ across approaches. The agricultural Taylor Rule generates a more aggressive response, as the impact of weather shocks on both agricultural inflation and output is more pronounced compared to the standard Taylor Rule and the Core Inflation Rule. Furthermore, a more aggressive monetary policy response results in a deeper short-term recession, particularly in the agricultural sector and overall GDP. However, it also reduces the persistence of the negative effects of the weather shock on the economy, facilitating a recovery and boosting growth after approximately four quarters. The Optimal Ramsey Monetary Policy suggests an interest rate response that is quite similar to that of the agricultural Taylor Rule. Both approaches emphasize a stronger reaction to address the significant impact of weather shocks on agricultural inflation and output, highlighting the central role of the agricultural sector in shaping the optimal policy response. However, the macroeconomic response differs between these approaches. While both the Optimal Ramsey Policy and the agricultural Taylor Rule advocate for a robust interest rate adjustment, the broader economic dynamics, including output, inflation persistence, and sectoral spillovers, exhibit distinct patterns under each policy. The Optimal Ramsey Policy triggers a very slight response in agricultural inflation, a reduction in non-agricultural inflation, and an overall decline in total inflation. Agricultural output recovers more quickly, while non-agricultural output experiences a more prolonged decline. In terms of welfare, a standard Taylor Rule based on aggregate inflation and output is not the most effective response to a weather shock, as it fails to adequately address the sector-specific dynamics and welfare trade-offs induced by such shocks. We find that a Taylor Rule that strongly responds to agricultural inflation, is less sensitive to agricultural output, and lacks persistence is more effective at mitigating the negative impact of a weather shock in a decentralized equilibrium framework.

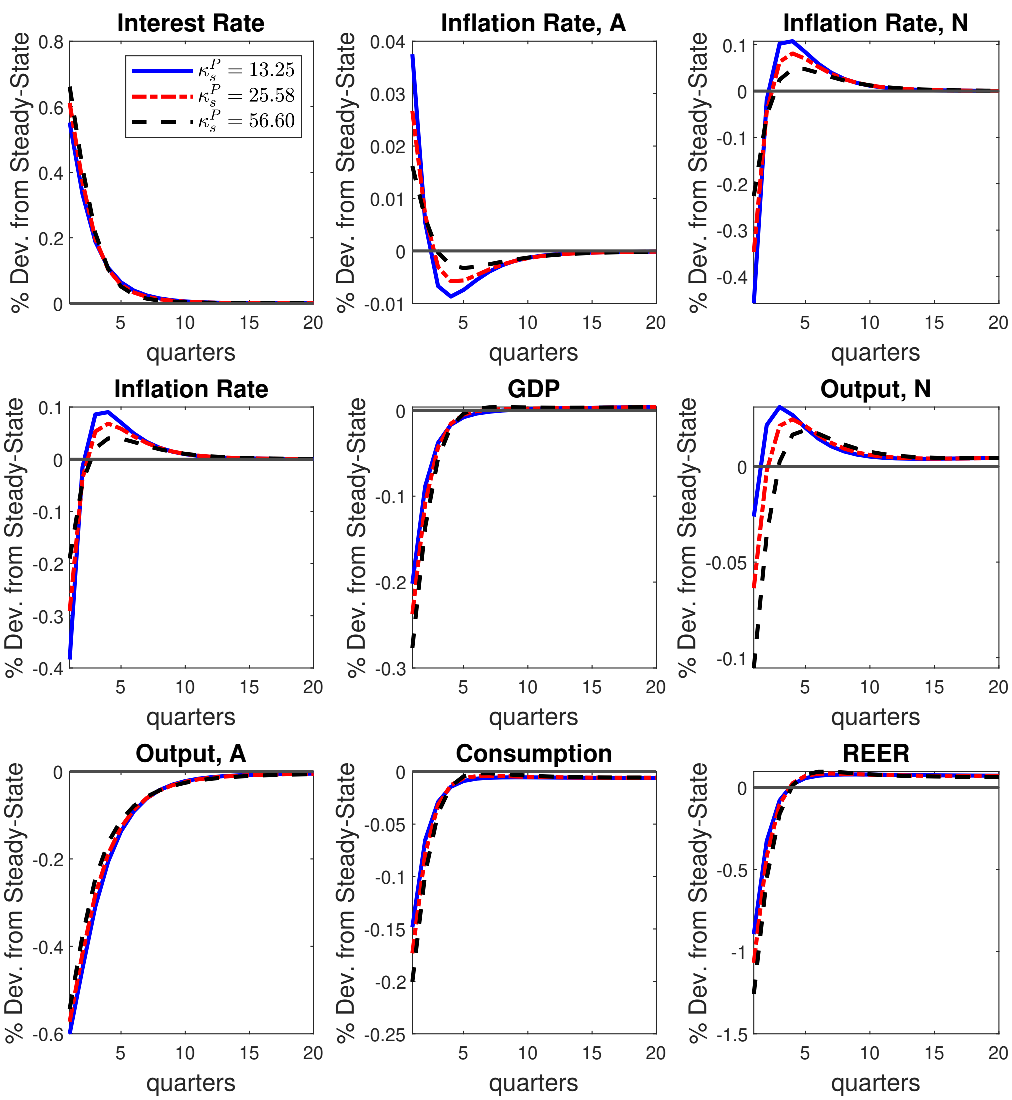

Figure 4: Ramsey Optimal Monetary Policy Following a 1% Weather Shock: Sensitivity Analysis on Price Stickiness

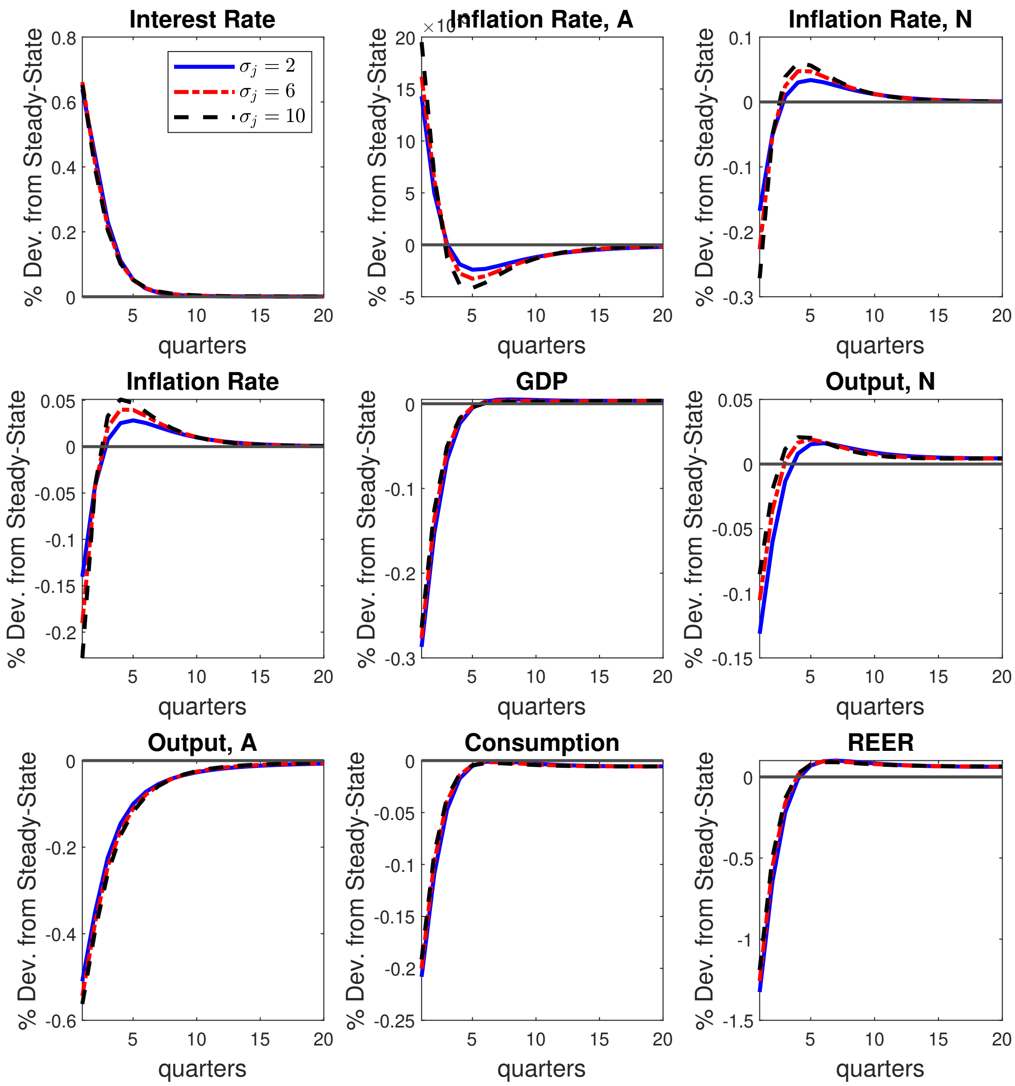

Figure 5: Ramsey Optimal Monetary Policy Following a 1% Weather Shock: Sensitivity Analysis on Monopolistic Competition

These differences underscore the importance of sectoral specificity in policy formulation. While a Taylor Rule focused on aggregate inflation and output underperforms in welfare terms, a Taylor Rule tailored to agricultural inflation with reduced sensitivity to agricultural output proves more effective in mitigating the adverse effects of weather shocks. This emphasizes the need for policymakers to carefully calibrate monetary policy to account for sectoral dynamics and the unique vulnerabilities of the agricultural sector, ensuring a more resilient and equitable economic response to climate-related shocks.

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