Climate and Central Banks:

An Analysis of Monetary Policy in Response to Climate Change

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Abstract

This paper explores the impact of climate shocks on monetary policy. Starting from a theoretical framework, the evolution of the understanding of climate risk by monetary authorities is analyzed and then econometric models are used to investigate a possible relationship between climate variables and interest rates.

Contents

Introduction

"Climate change is one of the greatest challenges faced by humankind this century, as illustrated by measurements of global warming and the frequency of extreme weather events"[1].

The first activities that decreed the beginning of environmental deterioration date back to the second half of the 19th century, with the first industrial revolution. The massive use of coal led to deforestation and large-scale pollution, caused by huge emissions of smoke and CO2.

In the 1930s, CFCs became widespread, refrigerant gases that would be recognized, several decades later, as the main cause of the ozone hole, as well as among the most powerful greenhouse gases.

The first concerns about the environmental impact of human actions emerged in the 1970s, when the Club of Rome warned the world that, at the current rate, resources would run out within a century, leading to an uncontrollable global decline [2].

In 1987, the Brundtland Report formalized the current definition of sustainable development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3] .

In the last decade the issue of climate change has assumed primary relevance in the political debate.

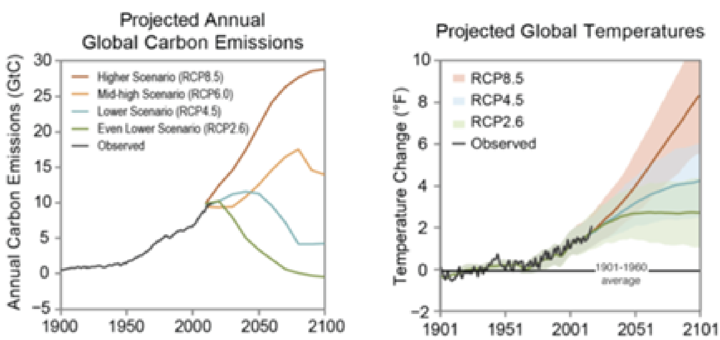

Figure 1

In Figure 1 [4], NOAA [5] projections for Annual Global Carbon Emissions and Global Temperatures are reported. A constant increase can be seen, from 1900 to the present day, in both graphs. In the best case scenarios, there is a reduction in Emissions and a stability in Global temperatures; however, the worst case scenarios are not compatible with a sustainable development scenario.

[1] "Climate change and monetary policy in the euro area" – ECB, pp.5
[2] Rif. "The limits to growth", The Club of Rome, pp. 23
[3] "Our Common Future", United Nations, pp. 37
[4] `https://dev-04-drupal-climate.woc.noaa.gov/news-features/understanding-climate/climate-change-global-tempera`
[5] National Oceanic and Atmospheric Administration

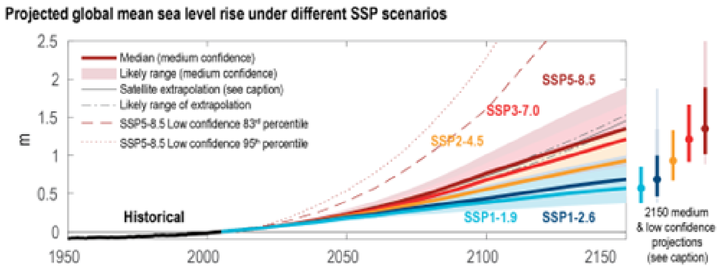

Figure 2

Figure 2 [6] shows the estimates of sea level rise under different scenarios related to glacier melting. These events inevitably impact the real economy, which can be conceptualized as "the dynamics of production, consumption, trade, technology, institution and human capital" [7]. In this context, where climate shocks influence macroeconomic variables, the role of central banks become increasingly important. Several studies have analyzed the effectiveness of central bank actions on the real economy, which concluded that monetary policy can stabilize the real economy only in the short term, since long term stability requires structural changes [8].

The paper proposes a study of the impact of climate events on macroeconomic variables and the role of monetary policy in their stabilization in the short term.

[6] https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-9/

[7] "The Real Economy: Conceptualization and Dynamics", Mohammad Omar Farooq, pp. 1

[8] Rif. "Introduction to U.S. Economy: Monetary Policy", Congressional Research Service

1 Climate Shocks in Macroeconomic Theory

Climate change is an exogenous factor that affects aggregate supply and demand [9], the effects of which can be analysed through the AD-AS macroeconomic model.

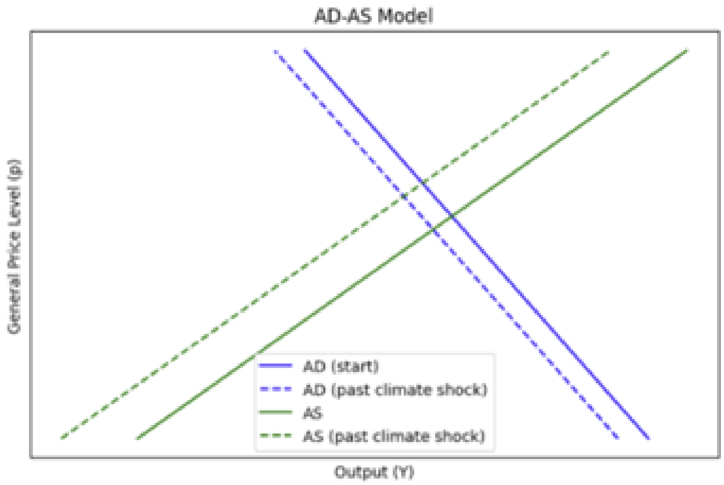

Figure 3

Aggregate demand (AD) is subject to contraction, caused by uncertainty that reduces investments (I) and by increase in energy and food prices that reduces consumption (C):

$$Y^D = C + I + G + (X - M)$$

On the aggregate supply (AS) side, extreme climate shocks, such as hurricanes and droughts, temporarily reduce production capacity and increase distribution costs, causing the AS line to shift to the left and causing agricultural and energy prices to rise in the short run [10]:

$$Y = A \cdot F(K, L)$$

In aggregate, it is possible to observe a reduction in aggregate supply that is more marked than demand, justified by a contraction in production in the short term and an inflationary trend, caused by the increase in food and energy prices.

Further complicating the analysis, we proceed by considering the STVAR [11] macroeconomic model, which is a model that “extend the conventional vector autoregressive (VAR) models by allowing for smooth transitions between regimes, each of which is characterized by a linear vector

[9] Rif. “Eye of the Storm The impact of Climate”, FMI
[10] Rif. “Eye of the Storm The impact of Climate”, FMI
[11] Smooth Transition Vector AutoRegressive

autoregression with different autoregressive coefficients or error term covariance matrices."[12]
In a study conducted by the Federal Reserve Bank of Richmond, the use of STVAR model shows how a climate shock alters several macroeconomic variables. In particular, the following are observed [13]:

- A drop in industrial production, with effects lasting for about 20 months
- An increase in unemployment, the effects of which last up for 40 months
- An increase in inflation, caused by the increase in food and energy prices
- A drop in consumption, measured by the PCE [14] index

Following the joint analysis of the AD-AS model and the STVAR model, the same conclusion is observed: a climate shock produces significant effects on the short run macroeconomic equilibrium, causing a simultaneous variation in production, prices, employment and consumption.

[12] https://arxiv.org/html/2403.14216v1
[13] Rif. "Severe Weather and the Macroeconomy", Federal Reserve Bank of Richmond, pp. 18 - 25
[14] Personal Consumption Expenditures

2 Climate Change and Monetary Authorities

In recent years, major international monetary authorities have recognized the potential systemic impact that climate change has on macroeconomic stability. According to a 2024 paper by Bilal and Känzig [15] , focusing on global temperatures rather than localized data leads to estimates of significantly more pronounced effects on global growth.

In this regard, the paper shows that a 1° C increase could reduce global GDP by up to 12%, an estimate higher than traditional assessments. This difference is mainly caused by the increase in the frequency of extreme weather events, which persistently affect productivity and capital stock.

Monetary policy, therefore, finds itself having to integrate climate risk into its forecasting models and intervention strategies. If these phenomena influence the main macroeconomic variables such as production, inflation and investments, it is necessary to consider the influences on prices and on the solidity of the financial system.

The first international monetary authority to recognise climate change as a systemic risk was the Bank of England, which, in 2015, called it a "tragedy of the horizon"[16] . It was also the first central bank to launch a climate stress test, when in 2019 it assessed the resilience of UK financial institutions to the risk associated with climate change. In 2017, at the initiative of Bank of France, the NGFS [17] was established, with the aim of involving monetary and supervisory authorities in the management of risk linked to climate change [18] . The NGFS has the task of providing standardised climate scenarios to assess the macroeconomic impacts resulting from climate change, making a distinction between physical risks, resulting directly from climate events, and transition risks, resulting from the introduction of regulations linked to environmental sustainability.

In 2021, the ECB officially recognized climate change as a systemic risk, launching the first climate stress test on the European macroeconomic system. The results highlight the need to adopt policies that favor an orderly transition, in order to avoid unsustainable costs for businesses. With the publication of the document "Eye of the Storm", the International Monetary Fund highlighted how climate shocks significantly affect inflation and production. The study in question confirms that climate change represents a destabilizing element for the macroeconomic system, underlining the need for an adequate transition plan towards sustainable growth.

[15] Rif. "The Macroeconomic Impact of Climate Change: Global vs Local Temperature", Bilal e Känzig (2024)

[16] Rif. "Breaking the Tragedy of the Horizon – climate change and financial stability", Bank of England

[17] Network for Greening the Financial System

[18] `https://www.ngfs.net/en/about-us/origin-and-purpose`

3 An Empirical Analysis on Climate Shocks and Interest Rates

In light of the actions taken by monetary authorities, the interaction between climate change and the macroeconomic system is becoming increasingly important. Therefore in addition to the direct reactions of the system to climate shocks, it is also relevant to analyze the movements adopted by monetary authorities to counteract these phenomena. We therefore proceed with an empirical analysis of the existence of a relationship between climate shocks and the level of the interest rate through an econometric approach. Specifically, using macroeconomic and climate data, we will build on Python:

- An Ordinary Least Squares model (OLS)
- An ARIMAX model

The goal is to verify if climate shocks impact the decisions of monetary authorities.

3.1 Graphic Analysis

We consider the variables related to the number of extreme weather events and the variation in the interest rate in the same period.

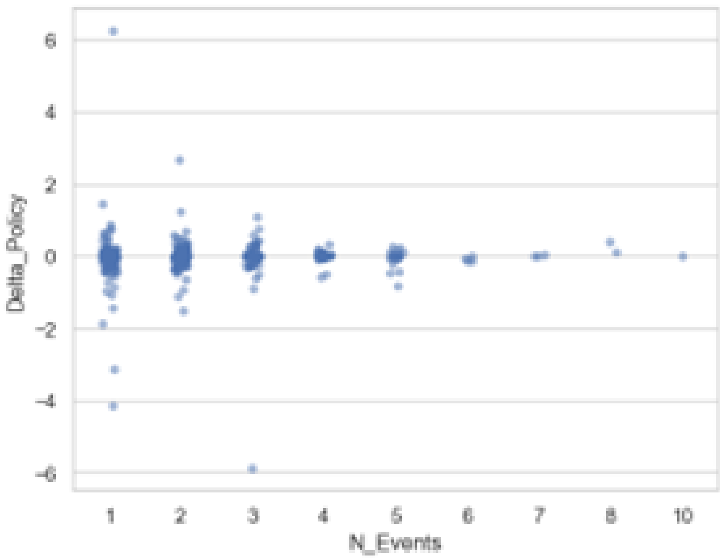

Figure 4

From the scatter plot (Figure 4), it is possible to observe that there is no clear relationship between the variables, with the observations being mostly concentrated on the zero value. Considering the variable related to the anomalous temperature [19] instead of the number of

[19] Difference from average temperature; a one month lag is inserted to reflect a delay in any monetary policy response.

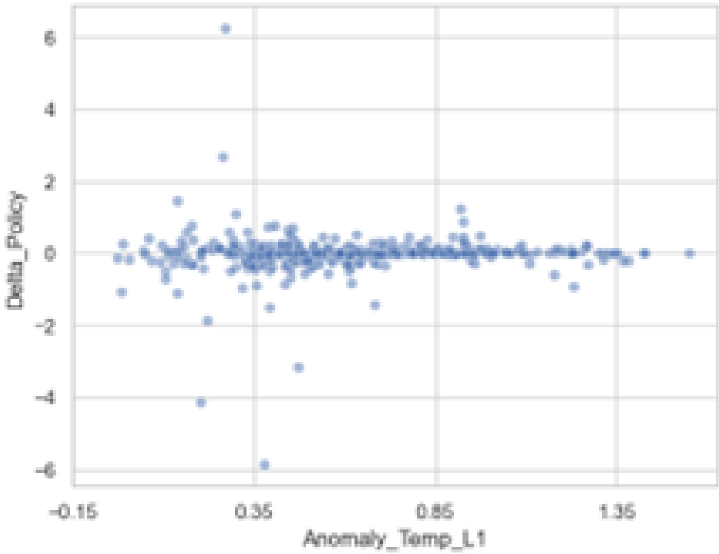

Figure 5

extreme events, in Figure 5 is possible to see again that there does not appear to be a significant relationship.

3.2 OLS Analysis

We proceed with the implementation of a model based on the Ordinary Least Squares method (OLS), where we set:

- Independent variables: presence of extreme weather events and anomalous temperature with a lag of 1 month
- Dependent variable: interest rate

$$\text{Policy\_Rate}_t = \beta_0 + \beta_1 \cdot \text{Dummy\_Events}_t + \beta_2 \cdot \text{Anomaly\_Temp\_L1}_t + \varepsilon_t$$

```
                            OLS Regression Results
==============================================================================
Dep. Variable:            Policy_Rate   R-squared:                       0.308
Model:                            OLS   Adj. R-squared:                  0.307
Method:                 Least Squares   F-statistic:                     12.58
Date:                Sun, 20 Apr 2025   Prob (F-statistic):           0.000434
Time:                        20:50:04   Log-Likelihood:                -1052.8
No. Observations:                 431   AIC:                             2110.
Df Residuals:                     429   BIC:                             2118.
Df Model:                           1
Covariance Type:                  HAC
=================================================================================
                    coef    std err          z      P>|z|      [0.025      0.975]
---------------------------------------------------------------------------------
Dummy_Events      7.6708      1.191      6.442      0.000       5.337      10.005
Anomaly_Temp_L1  -6.0760      1.713     -3.546      0.000      -9.434      -2.718
==============================================================================
Omnibus:                       62.334   Durbin-Watson:                   0.110
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               99.838
Skew:                           0.897   Prob(JB):                     2.09e-22
Kurtosis:                       4.530   Cond. No.                         4.70
==============================================================================
```

Figure 6

Following the results, a low R-squared value is observed, synonymous with the fact that the variables considered don't sufficiently explain the variance of the model, despite the p-value being significant for both variables.

It should be noted that, despite the extremely low value of the Durbin – Watson test suggesting a strong Autocorrelation and the extremely high value of the Jarque – Brera test suggesting a non-normality of the residuals, the HAC method was used, whose function is to make the standard errors more robust.

3.3 ARIMAX Analysis

Following the analysis using the Ordinary Least Squares method, we proceed with the use of an ARIMAX model, with the aim of verifying whether extreme events or anomalous temperatures have a significant impact on monetary policy choices. We therefore proceed with an ARIMAX (4,0,3) model, selected thanks to the "pmdarima" library of Python, which, in accordance with the AIC [20] criterion, identifies the model with the best compromise between complexity and explanatory capacity.

$$\begin{aligned}\text{Policy\_Rate}_t &= \beta_0 + \beta_1 \cdot \text{Dummy\_Events}_t + \beta_2 \cdot \text{Anomaly\_Temp\_L1}_t \\ &+ \phi_1 y_{t-1} + \phi_2 y_{t-2} + \phi_3 y_{t-3} + \phi_4 y_{t-4} \\ &+ \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \theta_3 \varepsilon_{t-3} + \varepsilon_t\end{aligned}$$

In order to ensure statistically reliable results, the model was estimated using a robust covariance matrix.

[20] Akaike Information Criterion.

Below, in Figure 7, the results are observed:

```
                               SARIMAX Results
==============================================================================
Dep. Variable:            Policy_Rate   No. Observations:                  431
Model:               SARIMAX(4, 0, 3)   Log Likelihood                -218.559
Date:                Tue, 22 Apr 2025   AIC                            457.118
Time:                        10:28:03   BIC                            497.685
Sample:                             0   HQIC                           473.141
                                - 431
Covariance Type:                  opg
=====================================================================================
                        coef    std err          z      P>|z|      [0.025      0.975]
-------------------------------------------------------------------------------------
Dummy_Events          7.6027      4.881      1.558      0.119      -1.964      17.170
Anomaly_Temp_L1      -0.1011      0.167     -0.605      0.545      -0.429       0.227
ar.L1                 0.9707      0.018     53.433      0.000       0.935       1.006
ar.L2                 0.3373      0.020     17.216      0.000       0.299       0.376
ar.L3                -0.5863      0.026    -22.252      0.000      -0.638      -0.535
ar.L4                 0.2714      0.019     14.617      0.000       0.235       0.308
ma.L1                -1.1113      0.455     -2.444      0.015      -2.003      -0.220
ma.L2                -1.8363      0.244     -7.525      0.000      -2.315      -1.358
ma.L3                -0.1055      0.187     -0.564      0.573      -0.472       0.261
sigma2                0.0387      0.013      2.875      0.004       0.012       0.065
=====================================================================================
Ljung-Box (L1) (Q):                   0.03   Jarque-Bera (JB):              12527.03
Prob(Q):                              0.86   Prob(JB):                          0.00
Heteroskedasticity (H):               0.08   Skew:                             -1.91
Prob(H) (two-sided):                  0.00   Kurtosis:                         29.26
=====================================================================================
```

Figure 7

21

Following the analysis, non-significant p-values of the climate variables considered emerge. On the other hand, it is noted that the interest rate shows a strong dependence on past values. Finally, although the test values show a non-normality and a non-constant variance in the residuals, a robust covariance matrix allows us to consider the results reliable.

[21]The model is a SARIMAX without the Seasonality component; therefore, it is an ARIMAX.

Conclusions

This paper focused on the research for a relationship between climate shocks and monetary policy, paying particular attention to the number of extreme events that occurred and to temperature anomalies with respect to the level of interest rate.

Following a theoretical argument, the empirical analysis showed the absence of statistically significant relationship between the climate variables and the level of the interest rate. Instead, it emerged that the latter strongly depends on its past values.

Considering the growing climate instability, it cannot be excluded that, in the future, a more evident relationship between climate and monetary variables may emerge. Therefore, it will be appropriate to delve deeper into the topic in question using a larger amount of data and more advanced econometric models.

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Sitography

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