Exploring the presence of Nonlinearities in the Peruvian Economy - Monetary Policy Implications

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The views expressed are those of the author and do not necessarily reflect those of the Central Bank of Peru.

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Motivation

- We identify different sources of nonlinearities and structural breaks in the Peruvian economy and for the period 2002-2024.
- For that purpose we estimate five models: i) **M1**: Linear Bayesian VAR (BVAR), ii) **M2**: Time-Varying BVAR with Stochastic Volatility (SV), iii) **M3**: Time Varying Mean BVAR with SV, iv) **M4**: BVAR with SV and Volatility feedback, v) **M5**: Threshold BVAR with SV and Volatility feedback.
- We employ Minnesota-type priors in all cases.
- In each model we identify monetary policy shocks through a mixture of zero and sign restrictions.
- We extend models **M2** and **M5** addition pre-IT data (1995-2001): **M6** and **M7**, respectively.
- We also explore the dynamic effects of volatility (macroeconomic uncertainty) shocks.

Main results

- Estimated effects of monetary policy shocks are pretty similar across model versions, even though we introduce different non-linearities in order to include the Covid-19 episode. That is, the transmission mechanism of monetary policy is stable throughout the 2002-2024 episode.
- The inclusion of data from the Covid-19 pandemic and later (2020 onwards) can be carried out safely even for a constant coefficients model, since the errors from 2020 are compensated for by those from 2021.
- Stochastic Volatility (especially with volatility feedback) is enough to correct the downturn of the pandemic and other episodes of higher volatility.
- The estimated volatility for M4 and M5 can be interpreted as an aggregate macroeconomic uncertainty index. This index reaches its highest value during the Covid-19 pandemic episode (2020-2021) and, to a lesser extent, during the International Financial Crisis (2008-2009).
- The inclusion of pre-Inflation Targeting sample (1995-2001) do not change the previous results (**M6** and **M7**).
- Shocks in estimated volatility (**M7**) resemble those of a negative and persistent supply shock, where inflation rises and the economic activity goes down. The latter triggers the response of the central bank through rising the policy interest.

Peruvian Macroeconomic Data

- Monthly macroeconomic data from Peru for the period from January-2002 to July-2024.
- Peru: open economy with an Inflation Targeting scheme, with a reference interest rate and the administration of liquidity through its balance sheet, and a floating exchange rate (with FX Intervention). The evolution of commodity prices matter.
- The most relevant macroeconomic variables for Peru are:
  1. **Inflation**: Year-to-year growth rate in the Consumer Price Index of Metropolitan Lima (2021=100), i.e. Headline Inflation.
  2. **GDP Growth**: Year-to-year growth rate in the Monthly Gross Domestic Product Indicator (2007=100).
  3. **Terms of Trade**: Year-to-year growth rate in the Monthly Terms of Trade Indicator Index.
  4. **Interest Rate**: Monthly average of the Interbank Market interest rate in annual terms (in %).
  5. **M1 Growth**: Year-to-year growth rate in the Monthly Money Aggregate associated with Domestic Currency Liquidity: Cash + Liquid Deposits (in PEN Million).
  6. **ER Depr.**: Year-to-year growth rate in the Monthly end-of-period interbank market exchange rate. (PEN per USD).

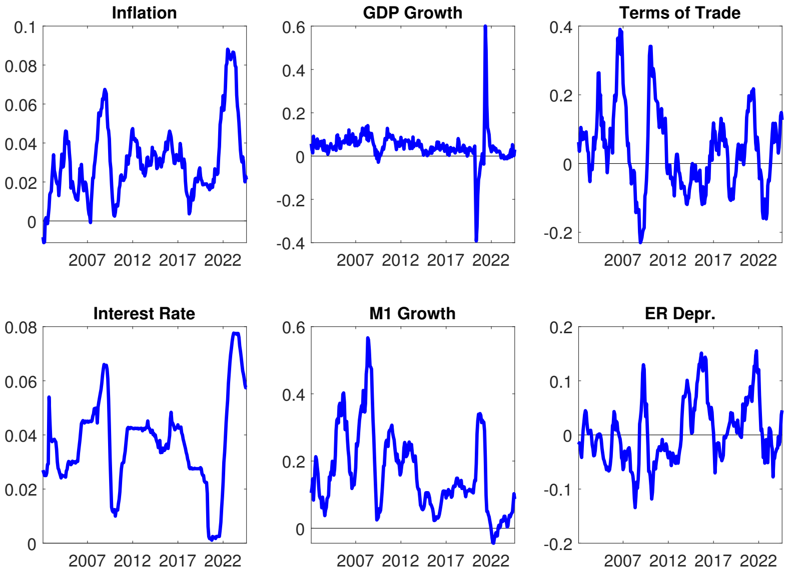

Figure: Peruvian Macroeconomic Data: 2002-2024

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The BVAR Model (M1)

Consider the model:

$$y_t = c + \sum_{k=1}^{p} B_k \left(y_{t-k} \right) + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \Omega\right) \tag{1}$$

- y_t: macroeconomic and financial variables
- $\Omega = A^{-1} \Sigma^2 A^{-1\prime}$

A Time Varying Coefficients BVAR-SV (M2)

The $VAR(p)$ model (Cogley and Sargent, 2005; Primiceri, 2005; Canova and Pérez Forero, 2015)

$$y_t = c_t + B_{1,t} y_{t-1} + ... + B_{p,t} y_{t-p} + u_t; t = 1, \ldots, T$$

$$y_{t(M \times 1)}, c_{t(M \times 1)}$$

$$B_{i,t(M \times M)}; i = 1, \ldots, p$$

$$u_t \sim N(0, \Omega_t)$$

$$\Omega_t = A_t^{-1} \Sigma_t \left(A_t^{-1}\right)'$$

where the structural shocks are given by ε_t:

$$u_t = A_t^{-1} \Sigma_t^{0.5} \varepsilon_t$$

$$\varepsilon_t \sim N(0, I_M)$$

$$\Rightarrow A_t \Omega_t A_t' = \Sigma_t$$

$$\Sigma_t = diag(\sigma_t)$$

The TV-Mean-BVAR-SV Model (M3)

Consider the model (Banbura and van Vlodrop, 2018; Pérez Forero, 2021):

$$y_t - \tau_t = \sum_{k=1}^{p} B_k \left(y_{t-k} - \tau_{t-k}\right) + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \Omega_t\right) \tag{2}$$

$$\tau_t = \tau_{t-1} + \eta_t, \qquad \eta_t \sim N\left(0, V_t\right) \tag{3}$$

$$z_t = \tau_t + g_t, \qquad g_t \sim N\left(0, G_t\right) \tag{4}$$

- y_t: macroeconomic and financial variables
- z_t: long-term expectations
- τ_t: time-varying mean
- $\Omega_t = A^{-1}\Lambda_t A^{-1\prime}$
- Λ_t, V_t, G_t: diagonal matrices - stochastic volatility

BVAR-SV-Mean Model (M4)

- Consider the following setup (Alessandri and Mumtaz, 2019):

$$y_t = c + \sum_{j=1}^{P} \beta y_{t-j} + \sum_{j=0}^{J} \gamma_1 ln\lambda_{t-j} + \Omega_t^{1/2} e_t \quad (5)$$

- y_t is the set of macroeconomic and financial variables.
- The volatility component λ_t can also be interpreted as an Uncertainty measure.

Threshold-BVAR Model (M5)

- Consider the following setup (Alessandri and Mumtaz, 2019):

$$y_t = \left(c_1 + \sum_{j=1}^{P} \beta_1 y_{t-j} + \sum_{j=0}^{J} \gamma_1 ln\lambda_{t-j} + \Omega_{1t}^{1/2} e_t \right) \tilde{S}_t + \left(c_2 + \sum_{j=1}^{P} \beta_2 y_{t-j} + \sum_{j=0}^{J} \gamma_2 ln\lambda_{t-j} + \Omega_{2t}^{1/2} e_t \right) \left(1 - \tilde{S}_t \right) \quad (6)$$

- where y_t is the set of macroeconomic and financial variables.
- The volatility component λ_t can also be interpreted as an Uncertainty measure.
- The covariance matrix is as follows:

$$\Omega_{1t} = A_1^{-1} H_t (A_1^{-1})' \quad (7)$$

$$\Omega_{2t} = A_2^{-1} H_t (A_2^{-1})' \quad (8)$$

  where A_1 and A_2 are matrices such that $vec\left(A_i\right) = S_A \alpha_i + s_A$ (Amisano and Giannini, 1997), with S_A and s_A being matrices governed by 0s and 1s (see also Canova and Pérez Forero (2015)).
- The regime indicator $\tilde{S}_t$ is defined by

$$\tilde{S}_t = 1 \iff P_{t-d} \leq Z^* \quad (9)$$

  where both the delay parameter d and the Threshold Z^* are unknown parameters.

Zero and Sign Restrictions for monetary policy shocks

Var / Shock	Mon. Policy	Cat.
Inflation	≤ 0	S
GDP	≤ 0	S
Terms of Trade	?	S
Interbank Rate	> 0	F
M2	≤ 0	F
ER Depr.	≤ 0	F

Table: Identification Restrictions
'S' means *slow* and 'F' means *fast*

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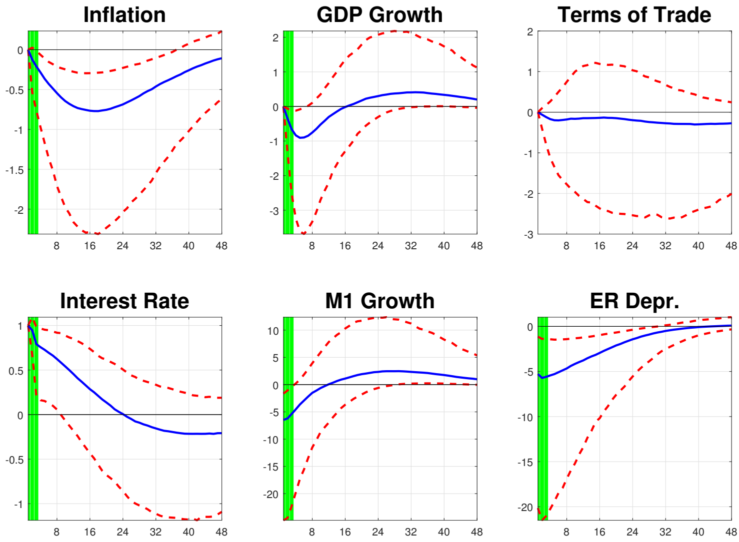

Figure: Monetary Shock (M1)

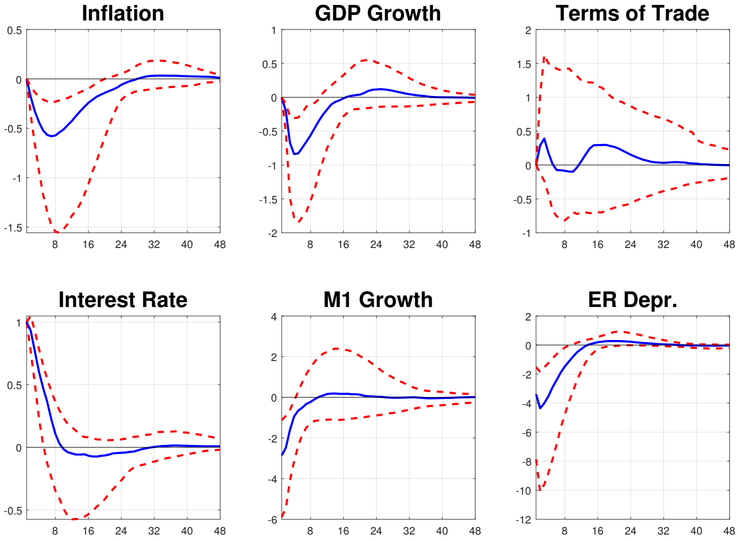

Figure: Monetary Shock (M2) - 2004

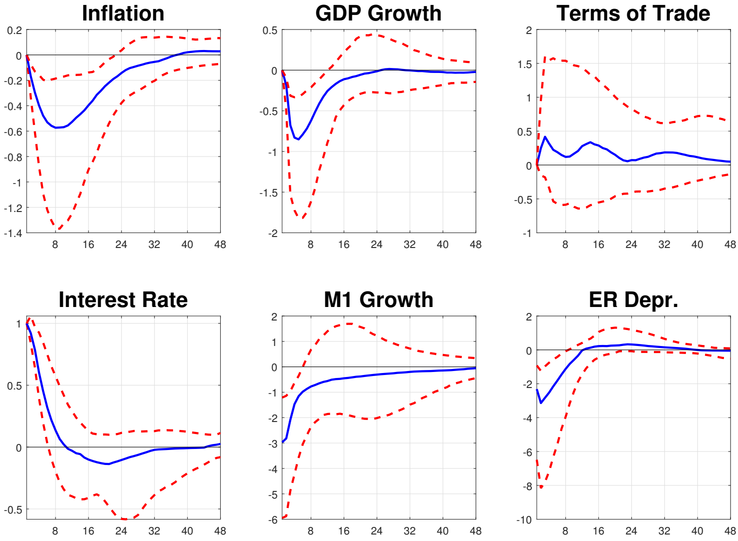

Figure: Monetary Shock (M2) - 2008

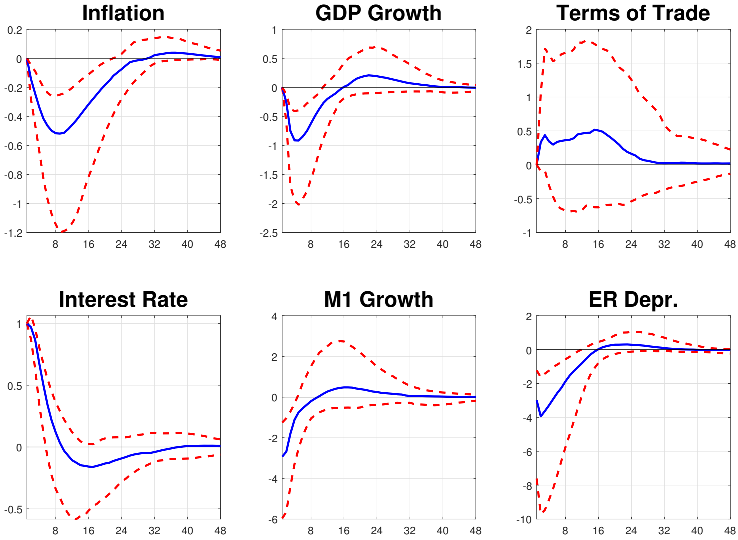

Figure: Monetary Shock (M2) - 2016

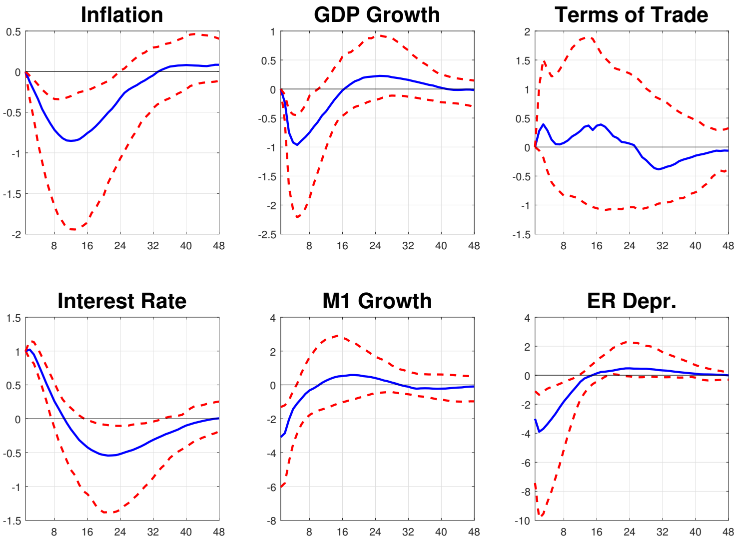

Figure: Monetary Shock (M2) - 2023

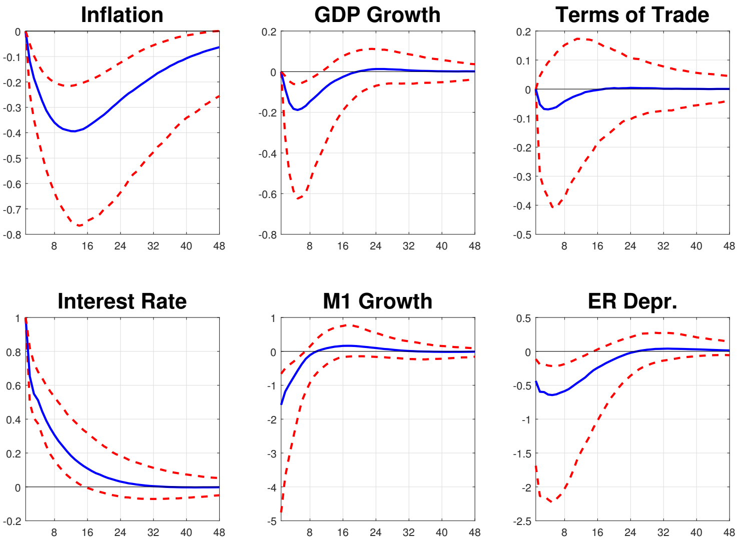

Figure: Monetary Shock (M3)

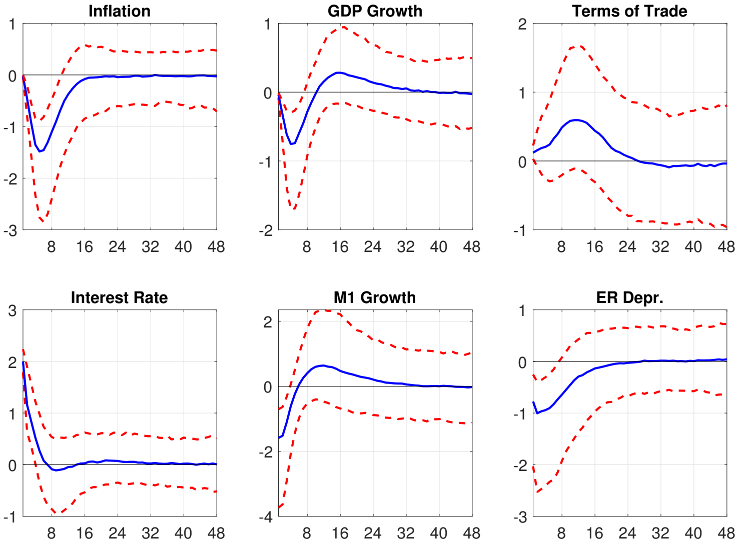

Figure: Monetary Shock (M4)

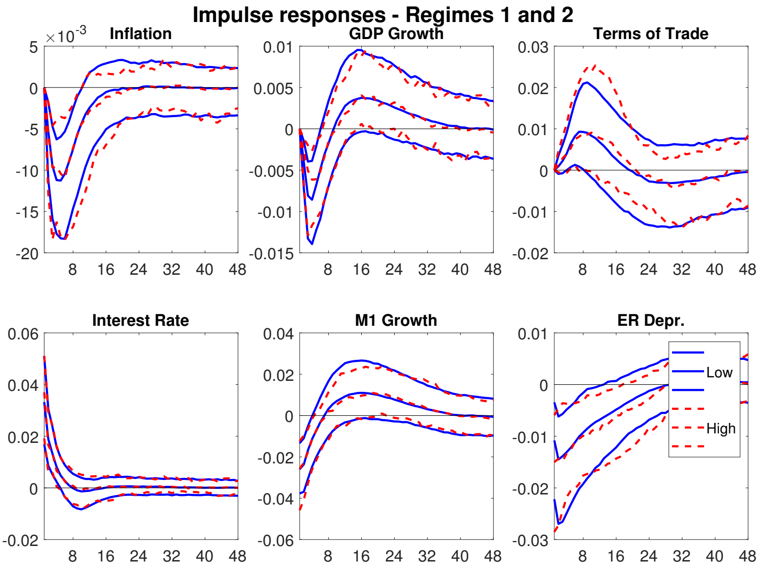

Figure: Monetary Shock (M5)

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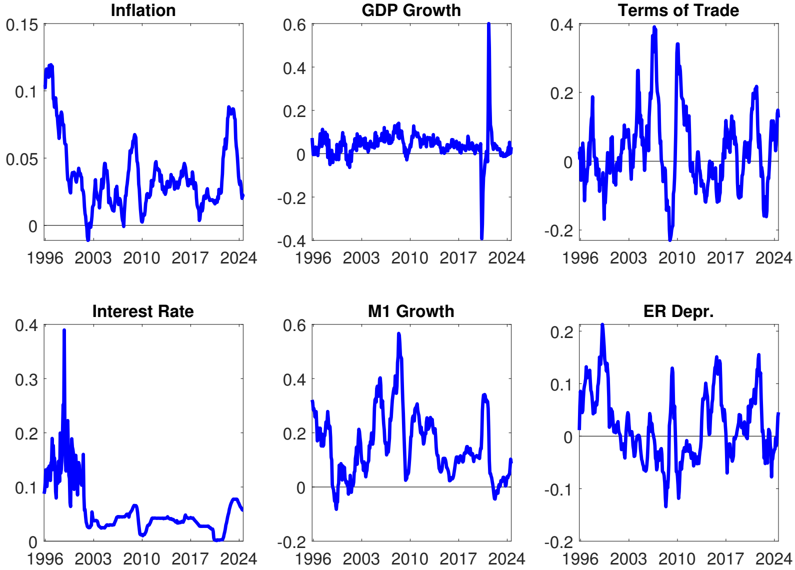

Figure: Peruvian Macroeconomic Data (1996-2024)

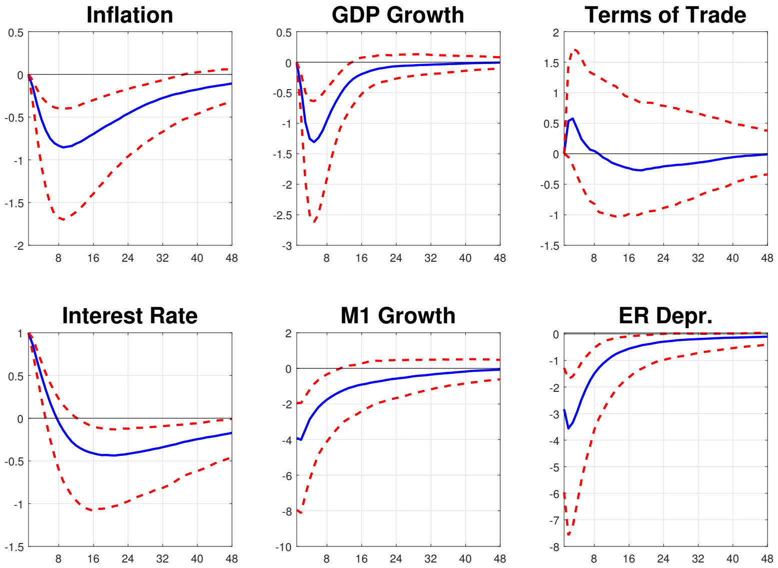

Figure: **M6**: Monetary Policy Shock in 1997 - Median value and 68% C.I.

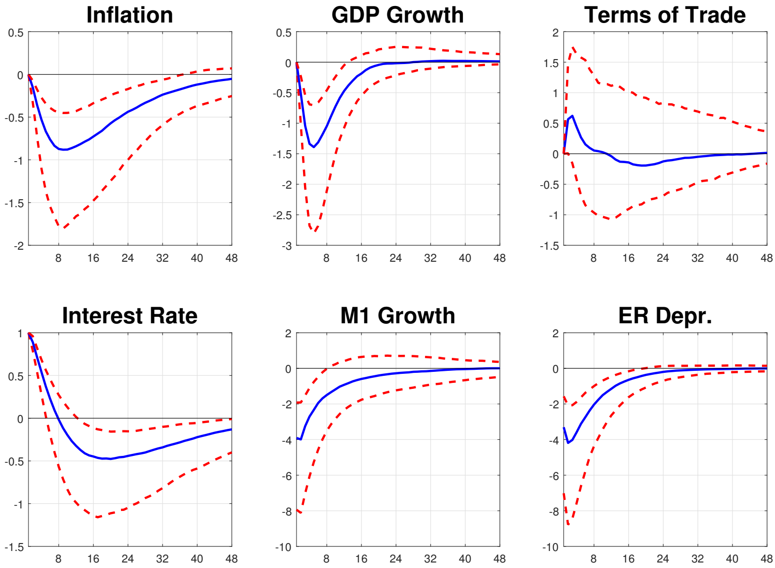

Figure: **M6**: Monetary Policy Shock in 2001 - Median value and 68% C.I.

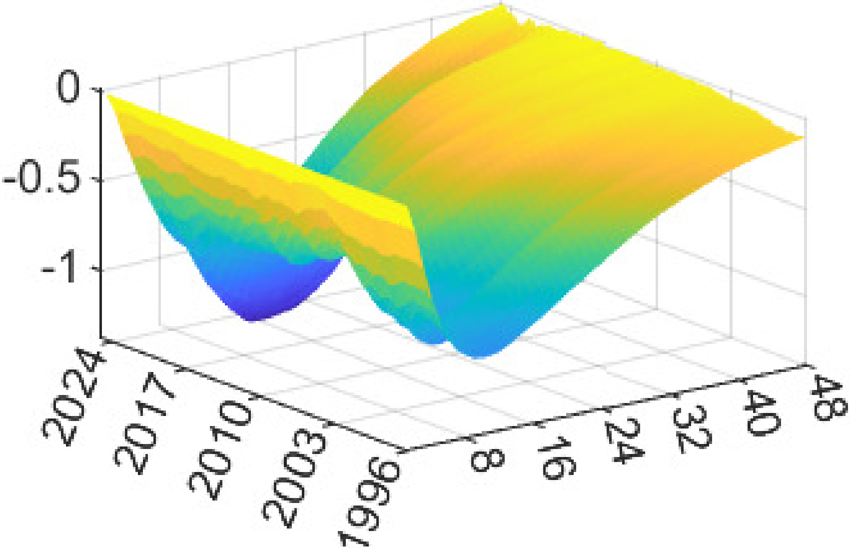

Figure: **M6**: Effect of Monetary Policy Shock on Inflation (1996-2024) - Median value

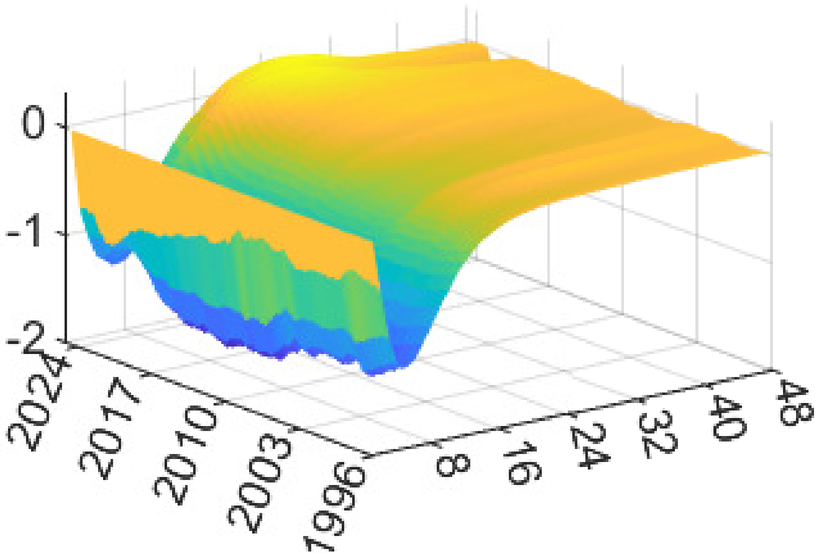

Figure: **M6**: Effect of Monetary Policy Shock on GDP (1996-2024) - Median value

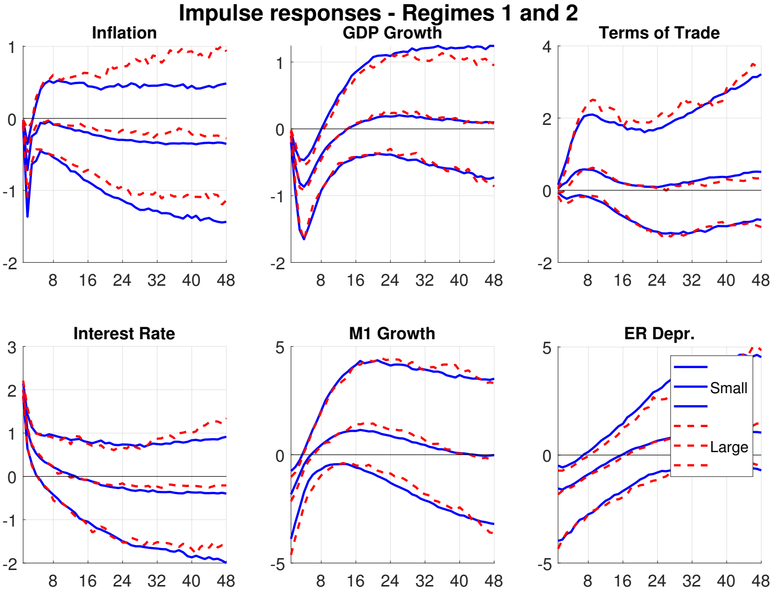

Figure: **M7**: Monetary Policy Shock - Median value and 68% C.I.

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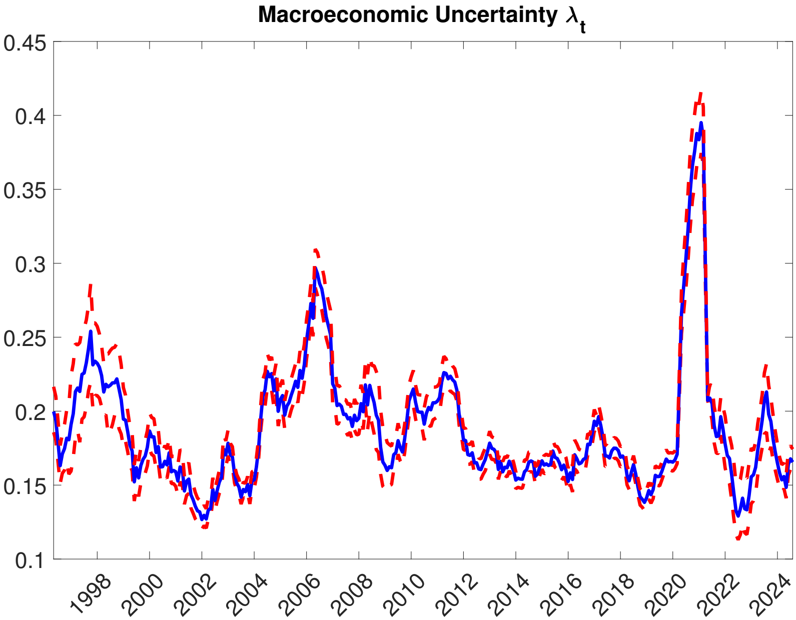

Figure: Macroeconomic Uncertainty Index

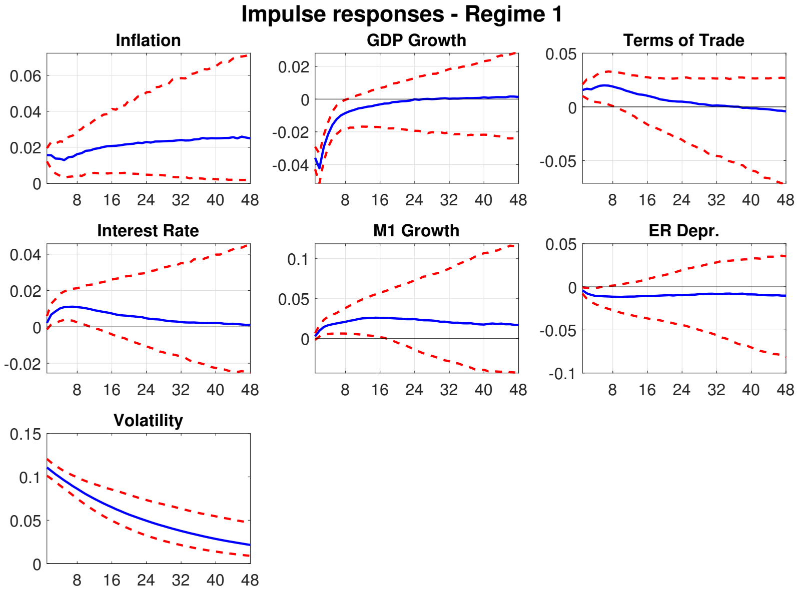

Figure: **M7**: Macroeconomic Uncertainty Shock - Median value and 68% C.I.

Concluding Remarks I

- We have explored the presence of non-linearities in the Peruvian economy.
- Five versions of a Bayesian vector autoregressive (BVAR) model have been estimated. The results obtained under the estimation of these models mentioned allow us to conclude the following:
  - The inclusion of data from the Covid-19 pandemic and later (2020 onwards) can be carried out safely even for a constant coefficients model, since the errors from 2020 are compensated for by those from 2021.
  - However, Stochastic Volatility (especially with volatility feedback) is enough to correct the downturn of the pandemic and other episodes of higher volatility, which implies that we have statistical evidence that says that the rest of the dynamic economic relations had remained stable throughout the sample.

Concluding Remarks II

- The transmission mechanism of monetary policy is stable throughout the 2002-2024 episode, both in the case of a threshold model and in the case of continuously changing parameters, with real effects on activity that reach their peak before the first year, and with an effect on inflation between 12 and 18 months. Moreover, the transmission mechanism is robust across different models.
- The estimated volatility for the models with volatility feedback (M4 and M5) can be interpreted as an aggregate macroeconomic uncertainty index. This index reaches its highest value during the Covid-19 pandemic episode (2020-2021) and, to a lesser extent, during the International Financial Crisis (2008-2009).

Concluding Remarks III

- Shocks in estimated volatility (models M4, M5 and M7) resemble those of a negative demand shock, where both economic activity and inflation go down, and also produces a depreciation of the local currency with respect to the US Dollar. The latter triggers the response of the central bank through the reduction of the policy interest rate plus additional liquidity injection. These effects are more pronounced for the case of a low inflation regime (model M5).

- In light of these results, the research agenda could go towards building a micro-founded dynamic general equilibrium model (DSGE) that takes into account explicitly the role of macroeconomic uncertainty as an important source of fluctuations.
- Although we have verified that the transmission mechanism of monetary policy is stable, nonlinearities are still important. Thus, it remains to be explored in more detail the role of the size of the shocks and the potential asymmetries that can be generated (positive and negative shocks).

Concluding Remarks IV

- The role of the formation of expectations is also extremely important, and therefore it is crucial to determine which signals matter for this, taking into account the presence of non-linearities. Finally, the agenda could also be focused on exploring the transmission mechanism of unconventional monetary policy actions, such as long-term liquidity injection, etc.

References I

Alessandri, P. and Mumtaz, H. (2019). Financial regimes and uncertainty shocks. *Journal of Monetary Economics*, **101**, 31–46.

Amisano, G. and Giannini, C. (1997). *Topics in Structural VAR Econometrics*. Springer, 2nd edn.

Banbura, M. and van Vlodrop, A. (2018). Forecasting with bayesian vector autoregressions with time variation in the mean, tinbergen Institute Discussion Paper, No. TI 2018-025/IV.

Canova, F. and Pérez Forero, F. J. (2015). Estimating overidentified, nonrecursive, time-varying coefficients structural vector autoregressions. *Quantitative Economics*, **6**, 359–384.

Cogley, T. and Sargent, T. J. (2005). Drifts and volatilities: Monetary policies and outcomes in the post WWII u.s. *Review of Economic Dynamics*, **8** (2), 262–302.

Pérez Forero, F. (2021). Predicción de variables macroeconómicas en el perú a través un modelo bvar con media cambiante en el tiempo, working Papers 2021-001, Banco Central de Reserva del Perú.

Primiceri, G. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies*, **72**, 821–852.