Good money and bad money: a nonlinear approach to the relationship with inflation and output.

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February 7, 2025

Abstract

This study investigates the nonlinear relationship between the monetary aggregate M1, inflation, and output in Mexico, an emerging economy, under varying levels of uncertainty. Utilizing a nonlinear local projections approach, we identify distinct responses to monetary shocks across low and high uncertainty regimes, defined by the US equity market volatility and Mexico's government default risk. In low uncertainty scenarios, inflation exhibits a positive response to monetary shocks, while high uncertainty conditions yield negative effects. Output responses are less consistent: in the low risk regime, output shows a modest positive response, whereas in the high risk regime, it initially declines before rebounding. However, no significant effects are observed under high and low volatility conditions. These results underscore the necessity of incorporating nonlinear dynamics into policymakers' models, as traditional linear approaches may obscure certain aspects of monetary policy impacts.

JEL Classification: C32, E41, E42, E51, E52

Keywords: Monetary policy, Monetary Aggregates, Mexico, nonlinear local projections, risk

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1 Introduction

Modeling monetary policy transmission systems has long been a challenge for macroeconomists. In recent years, central banks have relied on nominal interest rates as their primary policy tool, even in frameworks with a dual mandate focusing on price stability and economic growth. However, money targeting can provide a more direct link to economic activity, as it reflects the public's demand for liquidity and consumption needs. Furthermore, monitoring monetary aggregates can enhance the understanding of inflation dynamics and output fluctuations, offering a broader perspective on economic health.

The academic discourse has increasingly favored interest rate targeting, leading to a gradual abandonment of monetary aggregates in policy considerations. This shift can be traced back to influential critiques such as those of Poole (1970) and Woodford (2003), who argued that an interest rate rule could effectively substitute for money demand considerations. However, this perspective has been challenged by recent studies that highlight the role of monetary aggregates in various contexts. Given the evolving economic landscape and the complexities introduced by uncertainty—manifested as equity market volatility or risk of government default—it is appealing to review the dynamics of monetary aggregates from a novel perspective.

The monetary aggregate M1 plays a crucial role in the economy, serving both consumption and precautionary functions. As a narrow measure of money supply, M1 encompasses cash and demand deposits, which are readily available for spending. This immediacy makes M1 particularly relevant for understanding consumer behavior and economic activity. In periods of stability, households and businesses may prioritize consumption, utilizing their liquid assets to drive demand for goods and services. Conversely, during times of uncertainty or economic instability, the precautionary motive for holding money becomes more pronounced. Individuals and institutions may choose to increase their cash holdings as a buffer against potential shocks or adverse events, thereby influencing overall liquidity in the economy.

This dual role of M1 underscores its importance in assessing macroeconomic conditions. The balance between consumption and precautionary savings can significantly impact inflation dynamics and output levels. For instance, an increase in M1 driven by heightened precautionary demand may not lead to immediate inflationary pressures if it does not translate into increased spending. Conversely, if M1 growth is primarily associated with rising consumption, inflationary pressures may emerge more rapidly. Therefore, understanding the interplay between these roles is essential for policymakers aiming to navigate the complexities of monetary policy effectively.

This paper seeks to contribute to this discussion by investigating the nonlinear dynamics of real money shocks on inflation and output in Mexico, an emerging economy. Utilizing a Nonlinear Local Projections (NLPs) approach, we identify distinct responses to real M1 shocks in low and high uncertainty regimes defined by the volatility of the US equity market and Mexico's government default risk. By exploring these dynamics, we aim to provide insights that enhance our understanding of how M1 influences macroeconomic variables under varying conditions of uncertainty.

The empirical relationship between monetary aggregates with output and prices has been widely studied. However, the results have been inconclusive over time, as studies conducted for similar periods and countries have yielded different outcomes. As highlighted by Favara and Giordani (2009) there are studies that aim to recover the predictive capacity of monetary aggregates for output and inflation. While it is not the main objective of this work, studies conducted by Friedman and Kuttner (1992), Estrella and Mishkin (2007), and Binner et al. (2010) found no improvement in predictive accuracy when incorporating monetary aggregates into their models, after including other macroeconomic variables. In contrast, authors such as Stock and Watson (1989), Amato and Swanson (2001), Stavrev and Berger (2012), and more recently Do (2024) do find a predictive relationship between money indicators and output or inflation for different countries and periods.[1]

[1]These results are conditioned by factors such as the data revisions of monetary aggregates and model specifications.

In Mexico, there are three studies that focus primarily on the predictive content of monetary aggregates for inflation. While Díaz (2003) finds a rather modest relationship, concentrated in narrower aggregates like M1, de Luna and García (2001) conclude that monetary aggregates anticipated movements in prices and economic activity during certain periods. However, there are periods when money lost its property as a leading indicator of prices and economic activity. Lastly, in the most recent work, Banxico (2019) employs a Bayesian VAR to determine the relationship between M1 and the output and the interest rate. The findings reveal that a shock to output has a nearly one-to-one effect on M1.[2] In the same study, through a probit model, the probability of an economic slowdown is estimated using information from M1.

Although the discussion regarding the predictive ability of money remains open, in this work we focus entirely on the structural approach to the relationship. In the last 30 years, New Keynesian models have been one of the main tools used by macroeconomists to investigate how shocks affect the transmission channels of monetary policy (Ireland, 2000; Collard and Dellas, 2005). One of the main reasons for omitting a variable that had been historically important to central bank policy can be found in Poole (1970). However, New Keynesian models were criticized by Nelson (2003), who pointed out their omission of money among the variables considered, which was not justified by empirical evidence.

Similarly, in a rather controversial article, Woodford (2008) analyzes the arguments for giving prominent attention to monetary aggregates targeting in the conduct of monetary policy, and concludes it is not useful for monetary policy implementation. The origin and scope of these arguments can be found in Woodford (2003), where it is explicitly stated that the equilibrium paths of inflation and output can be understood without reference to the implicit trajectory of money demand, as long as there is an interest rate rule in place. Despite this, in recent years, Belongia and Ireland (2022) contributed by presenting an innovative New Keynesian model to illustrate the effect of replacing the Federal Reserve's interest rate rule with a money rule. They concluded that adjusting the money growth, instead of the interest

[2] Additionally, a shock to the interest rate produces a negative response on M1, with an effect close to one.

rate, could have led to an earlier recovery from the Global Financial Crisis. In a similar study, using empirical methods, Gerlach and Svensson (2003) propose a variation of the monetary growth indicators of the European Central Bank. They find that including a measure called the real money gap improves the prediction of inflation when combined with the output gap.

The pioneers in testing New Keynesian agent-based models that overlooked the role of monetary aggregates were Favara and Giordani (2009), who used a Vector Autoregressive model (VAR) approach to seek the empirical validity of these models. In that study, they found that the results of these theoretical models do not hold empirically. In particular, shocks to nominal monetary aggregates have a persistent effect on both inflation and output. Moreover, when analyzing the variance decomposition, the monetary aggregate accounts for a large percentage of the variance. Holtemöller (2002) conducts an extensive and thorough analysis of the use of VAR models for Germany and the Euro area. The study finds that using cointegrated models produces more sensible impulse responses to the general transmission of monetary policy than those relying solely in Cholesky decomposition. Additionally, the study finds a positive relationship between monetary aggregate shocks and both prices and output.

More recently, using a Time-Varying Parameter VAR (TVP-VAR), Berger et al. (2023) estimate dynamic impulse responses to study the relationship between money growth and inflation for Europe and the United States. They find a nonlinear relationship, which ranges from a positive to a negative response to shocks in M1, suggesting that this instability is due to its connection with the regime of inflation. In the latest analysis, Horan (2024) employs three different approaches to analyze the relationship between monetary aggregates and economic activity. First, the author evaluates the correlation of cyclical trends extracted using the Hamilton filter. Second, Granger causality tests are applied. Finally, a VAR model is estimated, where the Impulse Response Functions (IRFs) reveal a positive effect on both economic activity and prices. The first two approaches yield modest results, indicating that monetary aggregates, particularly the broader ones, serve as leading indicators for output and prices. The author also highlights that broader aggregates are the most useful for this purpose.

A nonlinear relation has been also studied by Cukierman (2017), who compares the impacts of increases in the monetary base had on inflation in two events: post-World War I Germany and the aftermath of the Lehman Brothers collapse in the United States. The author highlights that, while both economies experienced an increase of more than 400% in their monetary base, this only translated into high and persistent inflation in Germany, whereas in the United States, the impact was minimal during those years, not exceeding a level of 4% inflation annually. The author's main conclusion is that the difference between the experiences of both countries is due to how the monetary base expansion was used. He notes that it was used to finance government spending in Germany, whereas in the United States, it was the result of meeting liquidity demands by financial institutions, which did not translate into consumption, and therefore, neither into higher prices.

In light of this finding, one might wonder whether the impact of money on inflation and output is a temporary structural change in nature, or rather it depends on a variable that dictates whether money will be used for consumption or precaution. Following this argument, it is possible to think the drivers of liquid money demand are diverse: precaution and liquidity needs by households and institutions in response to events generating uncertainty, risk, or volatility; or increased consumption, which in turn depends on the economy's productivity and interest rate.

2 Model and Data

To analyze this potentially nonlinear relationship, we employ a model that allows for two distinct regimes. This enable us to distinguish the nature of the relationship in each state of the economy. We adopt the local projections (LPs) approach proposed by Jordà (2005) in their seminal paper, but with a focus on the nonlinearities that these models can accommodate (Ahmed and Cassou, 2016).

It is pertinent to explain the reason we make use of local projections instead of a VAR, as

is commonly done in the macroeconometric literature. While VAR-based impulse responses and local projections are asymptotically equivalent under relatively non-restrictive assumptions, as demonstrated by Plagborg-Møller and Wolf (2021), local projections offer several advantages when estimating dynamic relationships in response to macroeconomic shocks. As extensively pointed out in Jordà and Taylor (2024), the main advantage is their simplicity. Being a univariate method, local projections are less constrained than a VAR in terms of their ability to handle relatively short time series. Additionally, their computation for nonlinear relationships is much simpler and more interpretable than in a VAR. Computing impulse response functions in a state-dependent VAR framework requires Monte Carlo simulations whereas the LPs "directly estimate the average response across all possible trajectories that the economy may follow in the future, including possible future shifts in the state, given today's state and conditional on controls" (Jordà and Taylor, 2024). It has also been demonstrated in Montiel Olea et al. (2024) that LP's are more robust to misspecifications than VARs.

For our study, we built a system with the following four endogenous variables: economic output (i.e., IGAE, a monthly economic activity indicator for Mexico), month-over-month inflation, the interbank equilibrium interest rate for 28 days (TIIE 28), and the amount of real money in the economy (M1). We analyze the period from January 2005 to March 2024. All variables are seasonally adjusted, except for the interbank equilibrium interest rate. Although stationarity is not required by LPs, we performed certain transformations to the variables to achieve it. Thus, we took the difference of the logarithm of economic output and M1, whilst we took the difference of the interest rate. Month-over-month inflation did not require any transformation. We present the battery of stationarity tests we performed on the transformed variables in the Appendix.[3] As in the VAR framework, LPs require an identification strategy. For this purpose, we used the Cholesky decomposition track with the following ordering: output, inflation, interest rate, and M1.

[3]We tested for stationarity in the transformed variables using the Phillips-Perron test and the Augmented Dickey-Fuller test. The results strongly support the stationarity of the four series. The results are shown in tables 1 and 2.

We consider output to be the most exogenous because it is partially dependent on external factors to the system, such as government spending and the US demand for Mexican exports. Then we place monthly inflation, followed by the interest rate, as the latter typically responds to the former in the same period. The monetary aggregate is ordered at the end because it directly responds to the interest rate. The literature presents various studies that place monetary aggregates at the end of the ordering due to their high degree of endogeneity. For small economies, the work by Carrillo and Elizondo (2015) on Mexico stands out. Although the primary focus of the study is not on the role of monetary aggregates, their inclusion in the ordering is clearly defined and aligns with our previously described arguments.

Another useful case is the study by Belongia and Ireland (2016), which adopts an ordering that places monetary aggregates after inflation, output, and the interest rate. Once again, the high endogeneity of this variable justifies its position at the end. It is worth noting that the study aims to analyze the impact of a monetary policy shock on inflation and output when money is explicitly included in the system. Finally, a study previously discussed in the literature review follows a similar approach to ours by analyzing monetary aggregate shocks, but using broader aggregates. This study examines the impact on output and prices through a VAR system, where the monetary aggregate is ordered after prices and output but before the interest rate. In our robustness section, we will use that ordering, placing the aggregates before the interest rate, as a robustness check Horan (2024).

We use the narrow monetary aggregate M1 because it directly reflects public's demand for liquidity for its two main uses: consumption and precaution. Thus, M1 provides a direct view of the relationship between money and economic activity, unlike broader monetary aggregates, such as M2 and M3, which include components related to the public's demand for longer term assets. Therefore, broader aggregates may lead to contradictory results when analyzing their link with inflation and output. For instance, M3 includes long-term government bonds, which are not held for consumptiuon purposes as are cash and coins. Building on this, it is important to note that studies like Cukierman (2017) highlight the consensus that M1 growth is the most significant variable when it comes to inflation. For Mexico, there is

evidence of the advantages of using narrower aggregates due to their strong connection with key macroeconomic variables (Díaz, 2003).

To gather more evidence in support of the relationship between the variables, we performed a series of Granger causality tests. This is useful to assess whether the information contained in M1 contributes to predicting either output or inflation. We performed the test sequentially, adding 1 lag at a time, with a maximum of 10 lags. Results are shown in Table 3, which shows Granger causality from M1 to the output in a consistent fashion over the 10 lags. This finding coincides with studies carried out by Banxico (2019). However, in the case of inflation, results are not significant at the 90% confidence level when including only 1 lag and neither when including up to lags 3, 4, and 10. Although these results suggest a weak relationship between M1 and inflation, we still need to test our hypothesis regarding nonlinear effects using an adequate framework.

The nonlinear local projections framework allow us to study the hypothesis that the effects of money on output and inflation are distinct under different levels of uncertainty. Although uncertainty is not directly observed, there exist financial securities used for risk management and hedging whose market price is a proxy for the level of uncertainty investors are facing. Thus, to define the regimes of low and high uncertainty within our framework, we rely on the historical market prices of two financial securities: the VIX, a measure of future volatility in US equity markets, and Mexico's 5-year credit default swap (CDS), a measure of Mexico's default risk.

The VIX, or the Chicago's Board Options Exchange's Volatility Index, gauges investors' expectations regarding 30-day ahead volatility in US equity markets. We use the VIX because there is evidence that uncertainty shocks that manifest as volatility in US financial markets affect Mexico's domestic variables (Carrillo et al., 2020). One key advantage of the VIX is its exogeneity, since nonlinear local projections can generate biased IRFs if the state variable receives feedback from the endogenous variables of the system when shocked, as noted by Gonçalves et al. (2024). However, Mexico is an emerging economy that does not have an

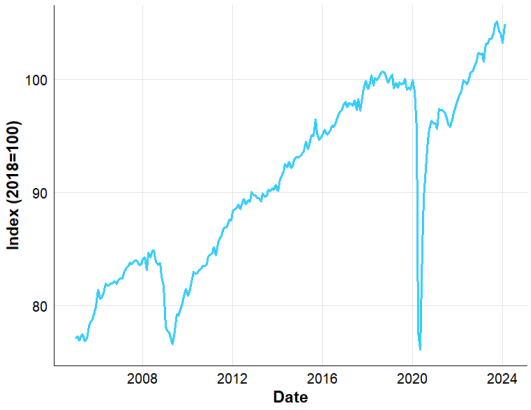


Figure 1: Mexico's output

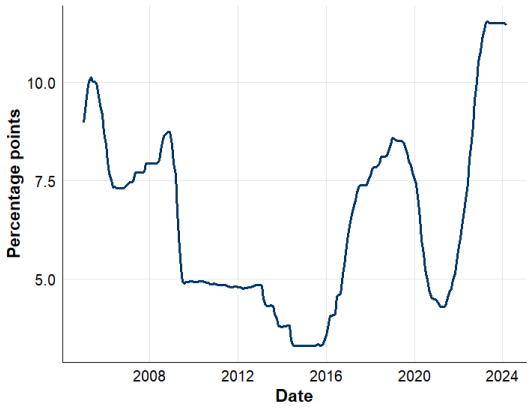


Figure 2: Mexico's interest rate

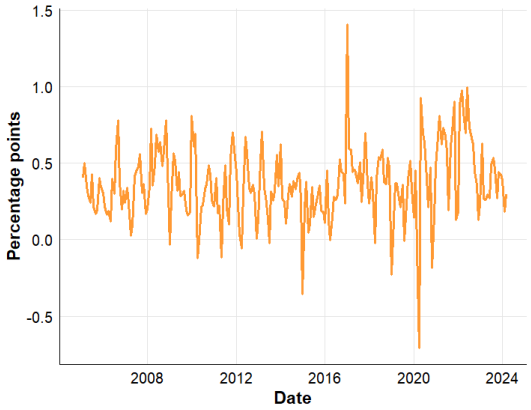


Figure 3: Mexico's monthly inflation

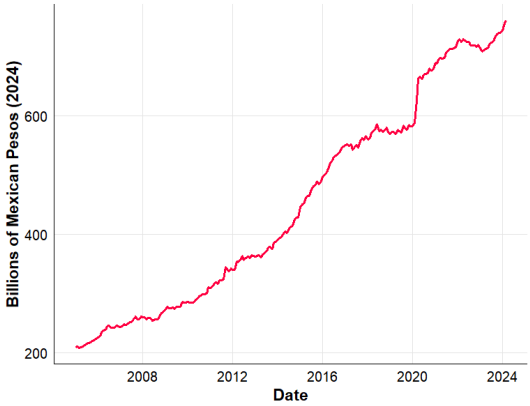


Figure 4: Mexico's real M1

Figure 5: Endogeneous variables of the system.

impact on US equity markets. Therefore, we can reasonably consider the VIX exogenous to our system's variables. Thus, our local projection estimates are not subject to said bias concerns.

Mexico's 5-year CDS reflects the certainty the market has in the country's ability to pay its debt back in the medium term. We use this variable to capture a credit risk factor that can drive the demand for more secure and/or liquid assets under uncertainty conditions. Unlike the VIX, Mexico's CDS could be pointed out as potentially endogeneous with respect to the set of domestic variables included in our analysis. However, we argue the CDS is more affected by events that influence the country's ability to repay in the medium term rather

than the short-term dynamics of the domestic variables considered. For instance, oil price shocks play a major role in sovereign risk of oil exporting countries (Pavlova et al., 2018). Political uncertainty in the form of elections, reforms, and violent conflicts also contribute to sovereign credit risk (Pan et al., 2024). Therefore, we rule out biased IRFs concerns, just like in the case of the VIX.

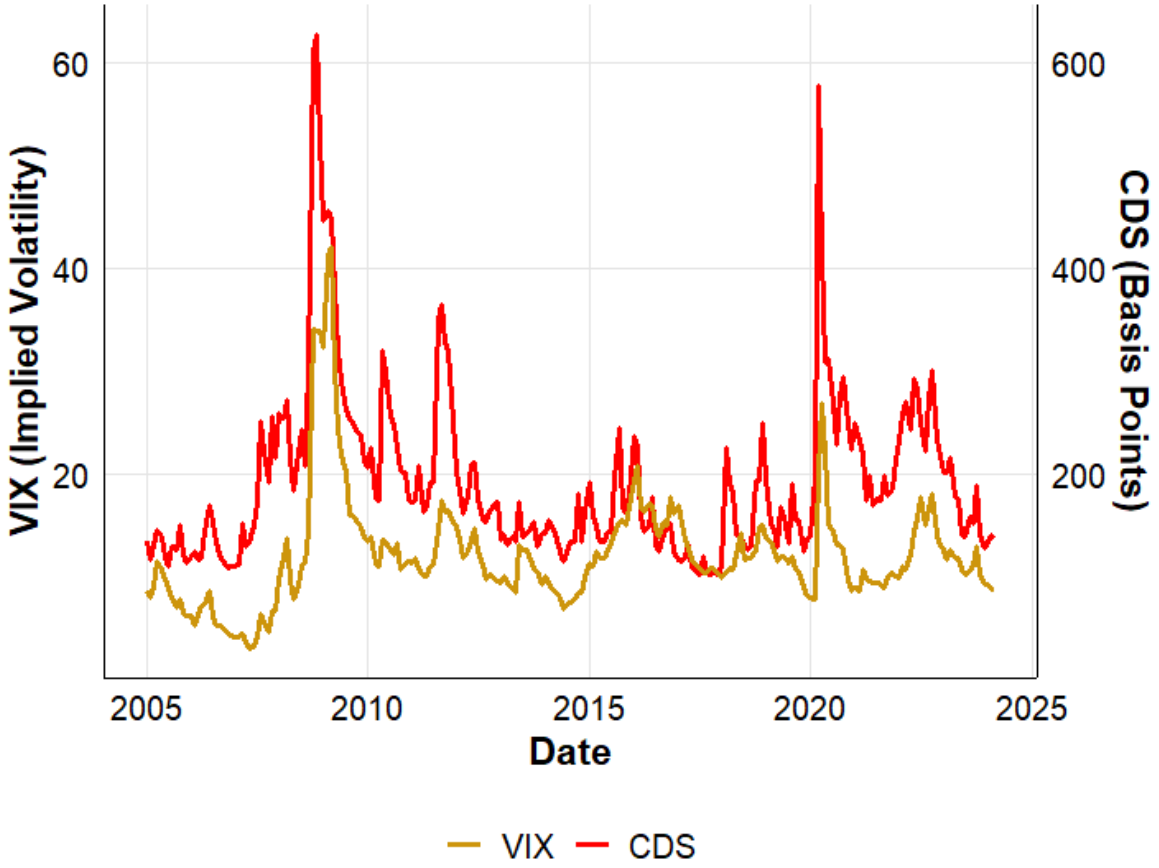


Figure 6: Regime variables: VIX and Mexico's CDS.

To compute our set of nonlinear local projections under two regimes of uncertainty (i.e. low and high uncertainty), we follow the approach initially proposed by Ahmed and Cassou (2016) for a binary regime, with the necessary modifications made by Adämmer (2019) to allow for a continuous regime. Although both approaches allow us to estimate the two sets of effects under the two regimes, we consider the latter to have two advantages.[4] The first

[4]We still followed the binary regime approach as a robustness check.

one is that the full sample is leveraged for the estimation of both effects. The second one is that, due to the transformation of the state variable through a sigmoid function, the estimated effects exhibit a smooth transition behavior between regimes.

In mathematical terms, we employ the following model for each horizon $h \in [1, ..., H]$ and regime $i \in \{High, Low\}$:

$$\begin{aligned} Y_{t+h} = \alpha^h + B^h_{1,High}(Y_{t-1})(1 - f(R_{t-1})) + \sum_{p=2}^{P} B^h_{p,High}(Y_{t-p})(1 - f(R_{t-1}))+ \\ B^h_{1,Low}(Y_{t-1})(f(R_{t-1})) + \sum_{p=2}^{P} B^h_{p,Low}(Y_{t-p})(f(R_{t-1})) + \Pi^h Z_{t-1} + u^h_{t+h} \end{aligned} \tag{1}$$

where α^h is a vector of constants; Y_t is the vector of endogenous variables and the set of matrices $B^h_{p,i}$ their estimated effects for lag p and regime i; Z_{t-1} is the lagged vector of exogenous variables/controls and the matrix Π^h their estimated effects; u_t is the autocorrelated error vector; R_{t-1} is the lagged regime variable; and $f(\bullet)$ is the transition function defined below. P is chosen by the Bayesian Information Criterion with the constraint $P \leq 10$. The collection of the ordinary least squares (OLS) regressions defined in Equation (1) are called nonlinear local projections. Effects estimated by nonlinear local projections are linked to the IRFs via the following equation:

$$IR(h, i) = B^h_{1,i} d \tag{2}$$

where d is the Cholesky decomposition of the covariance matrix of the residuals (following the ordering described earlier) of a VAR for Y_t of order P'. The order of the VAR, P', is chosen by the Bayesian Information Criterion with the constraint $P' \leq 10$. Additionally, the matrices $B^0_{1,i}$ are set equal to the identity matrix.

To test our hypothesis, we are particularly interested in the two sets of estimated effects of money on inflation and output under the two regimes, and their corresponding IRFs. To

estimate the effects, we rely on the R package published by Adämmer (2019). To carry out the estimation, the package requires H, the maximum horizon for the LPs, and to choose whether the standard errors of the estimated effects are adjusted for serial correlation and heteroskedasticity.

It is worth noting Equation 1 introduces the nonlinearity into the local projections by transforming the lagged regime variable, R_{t-1}, with the transition function $f(\bullet)$. Then, the endogenous variables are multiplied by the transition function to achieve a smooth transition behavior in the matrices $B_{1,i}^{h}$. Auerbach and Gorodnichenko (2012) proposed de-trending and then standarizing the regime variable before plugging it into the transition function to avoid scale issues.[5] The transition function $f(\bullet)$ is defined as:

$$F(R_t) = \frac{e^{-\gamma(R_t)}}{1 + e^{-\gamma(R_t)}}$$

where the parameter $\gamma > 0$ controls the degree of curvature of the function. For our baseline estimations we set $\gamma = 6$.

Our specification of local projections in Equation (1) includes a block of exogenous variables/controls, accounting for global and US variables relevant to the Mexican economy. This exogenous block is part of estimated VAR required to obtain the structural shock matrix d. We include the US industrial production to account for the demand for Mexico's exports. We also include the US shadow federal funds rate by Wu and Xia (2016) to account for the effects of US monetary policy on the domestic economy. The shadow rate is commonly included in studies on Mexico (Carrillo et al. (2020), Hernández et al. (2024), Alba et al. (2024) and Cantú et al. (2022)), as it better reflects unconventional monetary policy in the US. In the case where the VIX is used as the regime variable, we include the price of oil (WTI) as well. For the case in which the CDS is used as the regime variable, we did not include the price of oil because it is correlated with sovereign credit risk in oil exporting economies (Pavlova

[5]The regime variable is de-trended using the method by Hodrick and Prescott (1997) with parameter $\lambda = 129600$, which was originally proposed in Ravn and Uhlig (2002) for monthly data.

et al., 2018; Chuffart and Hooper, 2019).

3 Results

3.1 Regime probabilities

Unlike the binary regime approach, the smooth transition defined in Equation (1) does not impose a hard separation between the states of the economy. Instead, the transition function $f(\bullet)$ maps the lagged regime variable R_{t-1} to the $[0, 1]$ interval, giving the probability of being in a certain regime or the other.[6] Therefore, Equation (1) can be interpreted as a decomposition of the observed effects into a linear combination of the estimated effects in the high- and low-uncertainty regimes.

Figures 7 and 8 show the probability of being in the high volatility and high risk regime, respectively. We compared these probabilities with the corresponding regime variable that originated them. Note the VIX and the CDS are filtered using the Hodrick-Prescott method and then standarized to avoid the scale to influence the probabilities. It is interesting that the periods during which the probability of being in the high risk regime is close to 1 are more prolonged compared to those estimated by the volatility regime.

3.2 Impulse response functions of inflation to an M1 shock

Figure 9 illustrates how the nonlinearity in the local projections induces differentiated behaviors in the IRFs across states, either using volatility (VIX) or risk (CDS) as regime variable. In both cases, inflation responds positively to an M1 shock in the low state. This suggests that the increased demand for liquid assets under low uncertainty is more likely to be directed

[6] Strict interpretation is probability of being in a certain regime given the information set at the previous period. This in turn allows to interpret the resulting state-dependent IRFs as conditional in the state of the economy at the previous period.

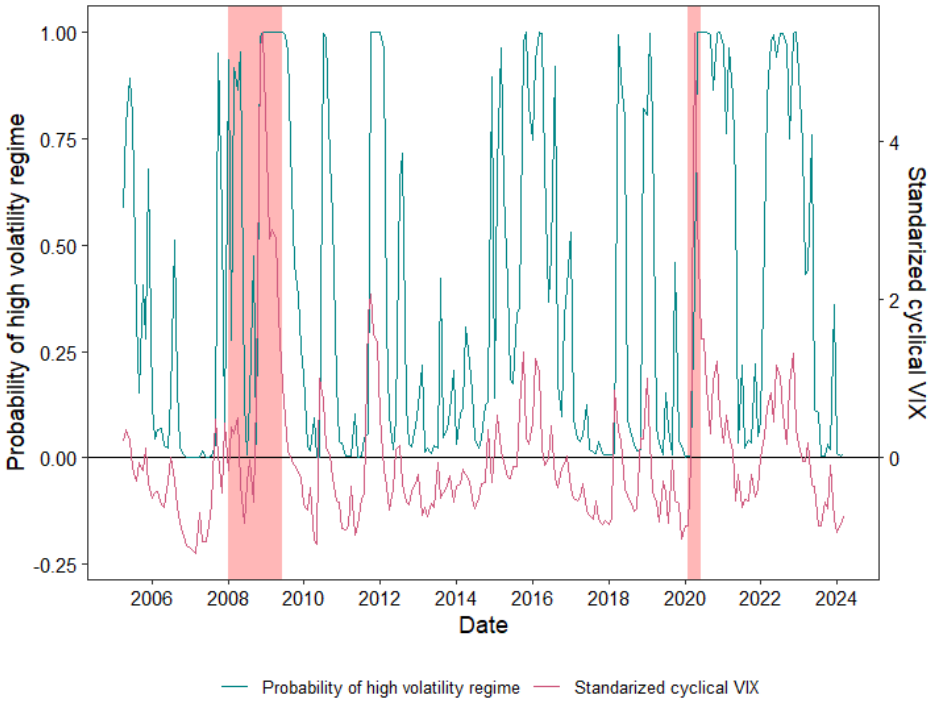


Figure 7: In green, we depict the probability of being in the high-volatility regime, while in purple, we present the standarized cyclical component of the VIX estimated using the Hodrick-Prescott Filter. The shaded red areas correspond to recession periods in the United States.

toward consumption, thereby driving inflation up in the short term.[7]. In the high state, the immediate response of inflation is negative. This points out a relatively underexplored phenomenon in monetary aggregates. The negative response may be attributed to a combination of risk-averse behavior, where households and businesses opt for highly liquid financial assets, and a precautionary demand for cash. Events such as the Great Financial Crisis and the COVID-19 pandemic illustrate this.

One of the key differences between the low volatility and the low risk regimes is that the latter shows a rebound in inflation after 12 months. This can be explained by the fact that the CDS regime better captures the risk appetite/risk aversion dichotomy among Mexican households and businesses. In contrast, the VIX serves more as a global uncertainty indicator. However,

[7]Since we are using real M1 instead of nominal, these results rule out situations when households demand more money to account for higher prices.

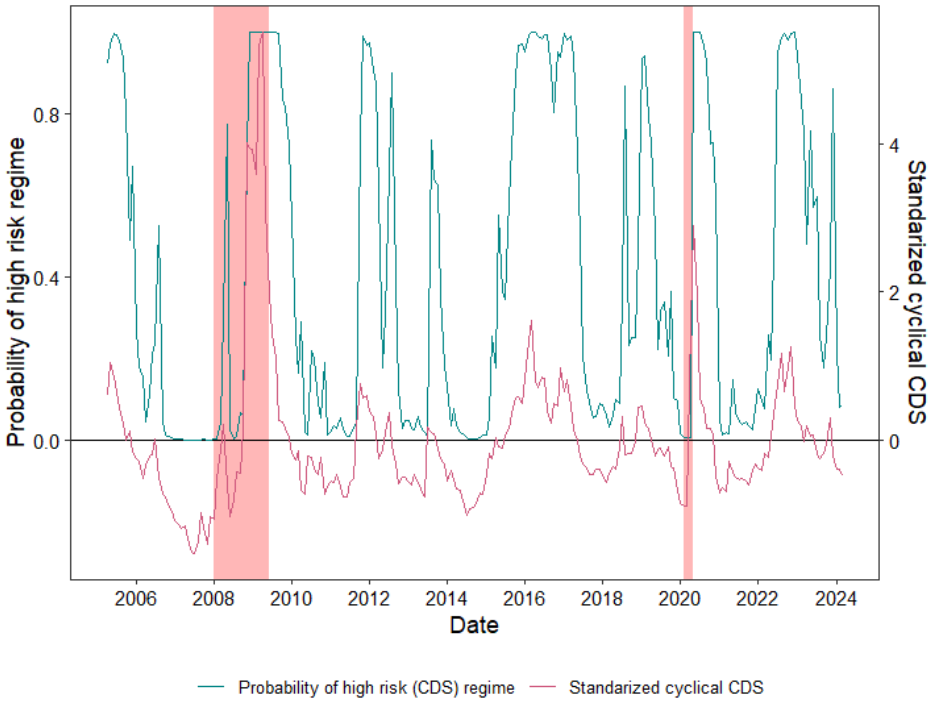
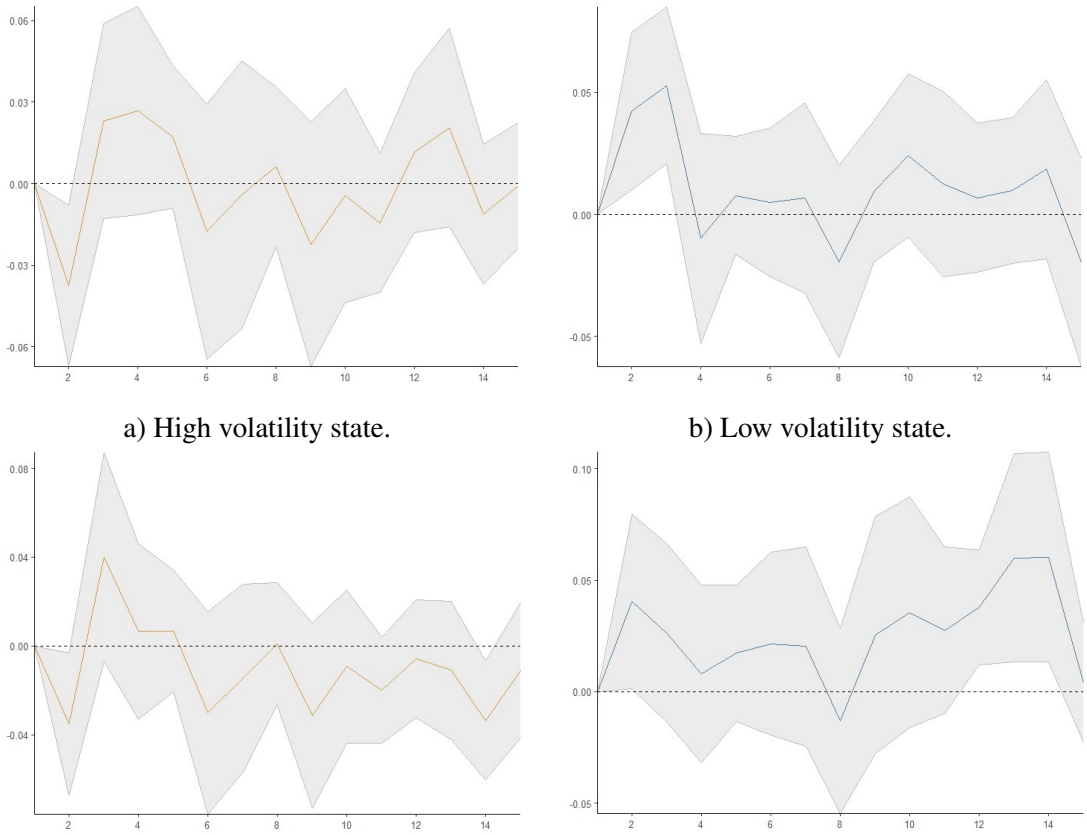


Figure 8: In green, we depict the probability of being in the high-risk regime, while in purple, we present the standarized cyclical component of the CDS estimated using the Hodrick-Prescott Filter. The shaded red areas correspond to recession periods in the United States.

the CDS is more sensitive to idiosyncratic factors in Mexico.

3.3 Impulse response functions of output to an M1 shock

For the case of output, we find distinct results between the volatility and the risk regimes. As shown in Figure 10, for the nonlinearity defined by the VIX, we find no statistically-significant responses of the monthly growth of output to a shock in real M1. For the CDS-based regime, we do find statistically-significant effects. When the Mexican sovereign default risk is low, we observe a positive response in the initial periods. In the other state, we initially observe a negative response that slightly rebounds after eleven periods. A possible interpretation is that, the CDS regime compared to the VIX regime, as in the case with inflation, might better capture risk aversion behavior in response to idiosyncratic factors in Mexico. Therefore, in the state where the Mexican sovereign default risk is high, an increase in M1



a) High volatility state.

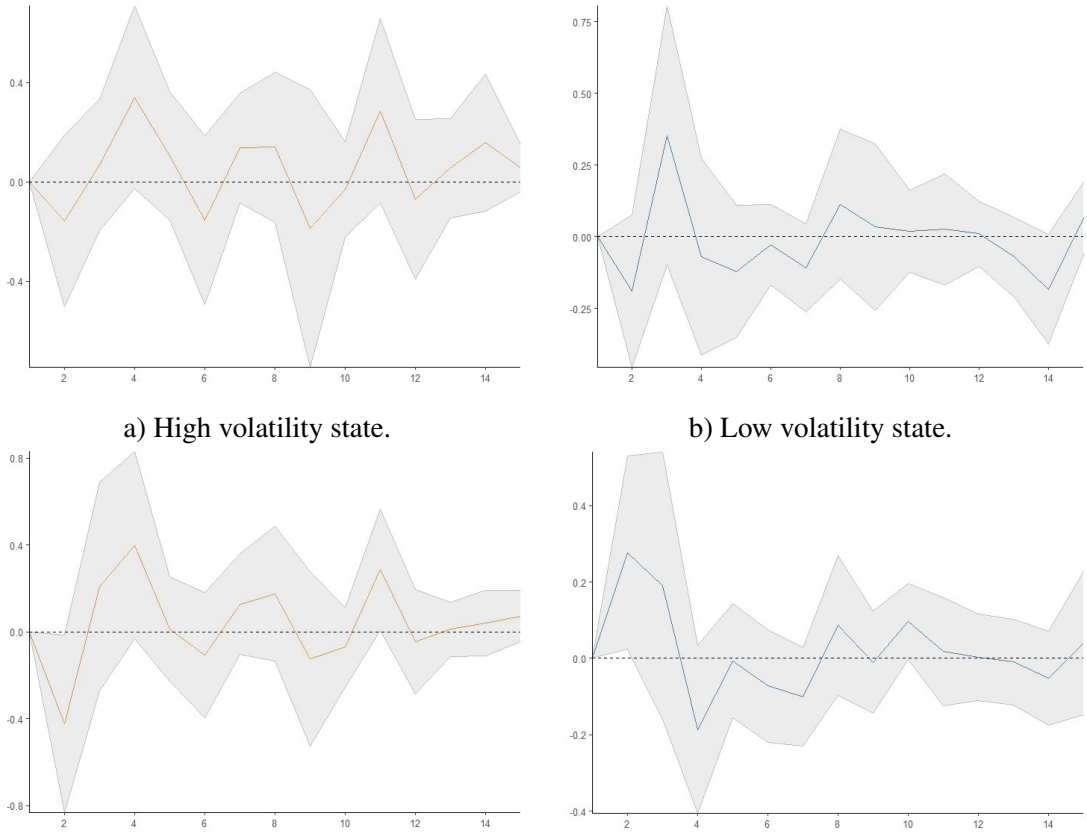
b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 9: IRFs of a one standard deviation M1 shock to monthly inflation. The vertical axis represents the monthly inflation and the horizontal axis the periods after the shock. Confidence intervals set at 90%.

might reflect heightened risk aversion behavior that is related to a decrease in consumption and hence output.



a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 10: IRFs of a one standard deviation M1 shock to output. The vertical axis represents percentage change and the horizontal axis the periods after the shock.
Confidence intervals set at 90%.

4 Robustness exercises

We started our robustness exercises by varying the value of γ. In our baseline estimation, we arbitrarily set $\gamma = 6$ because it is used in the estimations carried out by Hernández et al. (2024) in a similar framework and dataset to ours. It is important to note that a value of γ close to zero leads to smoother transitions between regimes, while higher values result in a regime change resembling a binary transition. In Figures 11 and 12 we see the results are almost identical with $\gamma = 7$. Something similar happens when $\gamma = 5$, as shown in Figures 13 and 14.

Furthermore, we changed the information criterion by which the lag lengths, P and P', are

selected to estimate the local projections. We found similar results when using the corrected Akaike Information Criterion by Hurvich and Tsai (1989), as shown in Figures 15 and 16.

As is common in the literature employing VARs, robustness checks involve modifying the variable ordering by which the Cholesky decomposition is done. Naturally, these orderings must be reasonable or have precedent in similar studies. Nonetheless, IRFs estimated through local projections tend to be more robust to misspecifications than those produced by VARs (Montiel Olea et al., 2024). In Figures 17 and 18, we show the results of placing the interest rate after M1 (i.e., output, inflation, M1, interest rate), as in Horan (2024), one of the most recent studies that analyzes the same topic in the United States. Additionally, we modified the ordering so inflation reacts to the interest rate (i.e., output, interest rate, inflation, M1). The results are shown in Figures 19 and 20. In both cases, we found results very similar to those of our baseline estimation, which do not alter our conclusions.

As a final transparency analysis, we followed a binary regime approach. As previously described, this method splits the sample into two and estimates the effects in each regime separately. To define the regimes, we did not use the cyclical component of the VIX and the CDS. Instead, we simply defined the high and low regimes as above and below the median of each variable, respectively. Our results for inflation remained consistent: under high volatility states, the response is negative, while under low volatility states, the impact of M1 on inflation is positive. However, the results for output are not conclusive in all states (Figures 21 and 22).

It is important to note the limitations of the binary regime approach. Since a smooth transition is not included, noise is introduced into the estimates by the observations near the classification threshold. In addition, the classification threshold is solely based on the median of the regime variables. Therefore, we prefer to rely on our baseline estimation and the rest of the robustness exercises.

5 Conclusions

This study focuses on analyzing the response of inflation and output to a shock in the monetary aggregate M1 in Mexico, using a nonlinear local projections approach. Nonlinearities are introduced into the variables' dynamics by modeling smooth transition effects between two regimes. The two regimes aim to reflect conditions of low and high uncertainty in the economy. The regimes are defined in two different ways: by the implied volatility in US equity markets and by the price of hedging against a Mexican government default.

The primary objective of this work is to analyze, through the application of a nonlinear approach, the relationship between money—specifically the monetary aggregate M1—and inflation and output, from an unexplored perspective. Despite the extensive literature on this topic, nonlinear analyses remain relatively scarce. Such an approach allows for a deeper exploration of the roles of precaution and liquidity preference when assessing whether money demand influences inflation and economic growth.

As observed in the Impulse Response Functions derived from the nonlinear local projections, a one standard-deviation shock to M1 in the low volatility regime resulted in an immediate increase in monthly inflation of up to 0.5%, which gradually dissipated over time. Similarly, in the low risk regime, the effect was comparable but also resurged after 12 months. In contrast, under both high volatility and high risk regimes, the immediate impact was a decline of the same magnitude, albeit shorter in duration, as the effect faded after the second period. A one standard-deviation shock to M1 had no significant effect on output in either the high and low volatility regimes. However, the effect in the low risk regime was of around 0.25% two periods after the shock, vanishing afterwards. Lastly, the effect in the high risk regime was negative in the two first periods, reaching -0.4% in the second period after the shock, then rebounded eleven periods after the shock to 0.3%.

Although the robustness exercises showed the results regarding the nonlinear effects are somewhat solid, they may not generalize to other emerging economies. Mexico is particularly

susceptible to uncertainty shocks that manifest as volatility in US financial markets. Future research should extend this approach to a broader set of economies to determine whether the uncertainty-dependent responses can be generalized.

Considering nonlinear effects represent significant implications for the study of moneyless models and for empirical research on the relationship between monetary aggregates and inflation and output. From a public policy perspective, the key takeaway is that incorporating monetary aggregates into nonlinear models and monitoring their variations may contribute to understanding and forecasting inflation and economic growth.

References

Adämmer, Philipp (2019), "lpirfs: An r package to estimate impulse response functions by local projections." *The R Journal (2019)*, 11, 421–438.

Ahmed, M. Iqbal and Steven P. Cassou (2016), "Does consumer confidence affect durable goods spending during bad and good economic times equally?" *Journal of Macroeconomics*, 50, 86–97, URL https://www.sciencedirect.com/science/article/pii/S0164070416300490.

Alba, Carlos, Gabriel Cuadra, and Raul Ibarra (2024), "The effects of central bank extraordinary measures on financial conditions: Evidence from mexico." *Applied Economics*, 56, 4064–4085.

Amato, Jeffery D and Norman R Swanson (2001), "The real-time predictive content of money for output." *Journal of Monetary Economics*, 48, 3–24.

Auerbach, Alan J and Yuriy Gorodnichenko (2012), "Measuring the output responses to fiscal policy." *American Economic Journal: Economic Policy*, 4, 1–27.

Banxico (2019), "M1 y su potencial de predicción de la actividad económica." *Extracto del Informe Trimestral Julio - Septiembre 2019.*, 45–48.

Belongia, Michael T and Peter N Ireland (2016), "Money and output: Friedman and schwartz revisited." *Journal of Money, Credit and Banking*, 48, 1223–1266.

Belongia, Michael T and Peter N Ireland (2022), "A reconsideration of money growth rules." *Journal of Economic Dynamics and Control*, 135, 104312.

Berger, Helge, Sune Karlsson, and Pär Österholm (2023), "A note of caution on the relation between money growth and inflation." *Scottish Journal of Political Economy*, 70, 479–496.

Binner, Jane M, Peter Tino, Jonathan Tepper, Richard Anderson, Barry Jones, and Graham Kendall (2010), "Does money matter in inflation forecasting?" *Physica A: Statistical Mechanics and its Applications*, 389, 4793–4808.

Cantú, Carlos, Roberto Lobato, Calixto López, and Fabrizio López-Gallo (2022), "A loan-level analysis of financial resilience in mexico." *Journal of Banking & Finance*, 135, 105951.

Carrillo, Julio A and Rocio Elizondo (2015), "How robust are svars at measuring monetary policy in small open economies?" Technical report, Banco de Mexico Working Papers.

Carrillo, Julio A, Rocio Elizondo, and Luis G Hernández-Román (2020), "Inquiry on the transmission of us aggregate shocks to mexico: A svar approach." *Journal of International Money and Finance*, 104, 102148.

Chuffart, Thomas and Emma Hooper (2019), "An investigation of oil prices impact on sovereign credit default swaps in russia and venezuela." *Energy Economics*, 80, 904–916.

Collard, Fabrice and Harris Dellas (2005), "Poole in the new keynesian model." *European Economic Review*, 49, 887–907.

Cukierman, Alex (2017), "Money growth and inflation: Policy lessons from a comparison of the us since 2008 with hyperinflation germany in the 1920s." *Economics Letters*, 154, 109–112.

de Luna, Alfonso Guerra and Alberto Torres García (2001), "Agregados monetarios en méxico:¿ de vuelta a los clásicos?" *Banco de México. Documento de Investigación*, 1–17.

Díaz, Daniel G Garcós (2003), "Agregados monetarios, inflación y actividad económica en méxico." *Estudios Económicos*, 37–78.

Do, Nguyen Duc (2024), "Money/asset ratio as a predictor of inflation." *The Quarterly Review of Economics and Finance*, 97, 101896.

Estrella, Arturo and Frederic S Mishkin (2007), "Is there a role for monetary aggregates in the conduct of monetary policy?"

Favara, Giovanni and Paolo Giordani (2009), "Reconsidering the role of money for output, prices and interest rates." *Journal of Monetary Economics*, 56, 419–430.

Friedman, Benjamin M and Kenneth N Kuttner (1992), "Money, income, prices, and interest rates." *The American Economic Review*, 472–492.

Gerlach, Stefan and Lars EO Svensson (2003), "Money and inflation in the euro area: a case for monetary indicators?" *Journal of Monetary Economics*, 50, 1649–1672.

Gonçalves, Sílvia, Ana María Herrera, Lutz Kilian, and Elena Pesavento (2024), "State-dependent local projections." *Journal of Econometrics*, 105702.

Hernández, Juan R, Daniel Ventosa-Santaulària, and J Eduardo Valencia (2024), "Global supply chain inflationary pressures and monetary policy in mexico." *Emerging Markets Review*, 58, 101089.

Hodrick, Robert J and Edward C Prescott (1997), "Postwar us business cycles: an empirical investigation." *Journal of Money, credit, and Banking*, 1–16.

Holtemöller, Oliver (2002), "Structural vector autoregressive models and monetary policy analysis." SFB 373 Discussion Papers 2002,7, Humboldt University of Berlin, Interdisciplinary Research Project 373: Quantification and Simulation of Economic Processes, URL `https://ideas.repec.org/p/zbw/sfb373/20027.html`.

Horan, Patrick J (2024), "Money, output, and prices: 1967-2022." *The Quarterly Review of Economics and Finance*, 101870.

Hurvich, Clifford M and Chih-Ling Tsai (1989), "Regression and time series model selection in small samples." *Biometrika*, 76, 297–307.

Ireland, Peter N (2000), "Interest rates, inflation, and federal reserve policy since 1980." *Journal of Money, Credit and Banking*, 417–434.

Jordà, Òscar (2005), "Estimation and inference of impulse responses by local projections." *American economic review*, 95, 161–182.

Jordà, Òscar and Alan M Taylor (2024), "Local projections." Working Paper 32822, National Bureau of Economic Research, URL `http://www.nber.org/papers/w32822`.

Kwiatkowski, Denis, Peter CB Phillips, Peter Schmidt, and Yongcheol Shin (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?" *Journal of econometrics*, 54, 159–178.

Montiel Olea, José Luis, Mikkel Plagborg-Møller, Eric Qian, and Christian K Wolf (2024), "Double robustness of local projections and some unpleasant varithmetic." Working Paper 32495, National Bureau of Economic Research, URL `http://www.nber.org/papers/w32495`.

Nelson, Edward (2003), "The future of monetary aggregates in monetary policy analysis." *Journal of Monetary Economics*, 50, 1029–1059.

Pan, Wei-Fong, Xinjie Wang, Yaqing Xiao, Weike Xu, and Jinfan Zhang (2024), "The effect of economic and political uncertainty on sovereign cds spreads." *International Review of Economics & Finance*, 89, 143–155.

Pavlova, Ivelina, Maria E De Boyrie, and Ali M Parhizgari (2018), "A dynamic spillover analysis of crude oil effects on the sovereign credit risk of exporting countries." *The Quarterly Review of Economics and Finance*, 68, 10–22.

Phillips, PCB (1988), "Testing for a unit root in time series regression." *Biometrika*.

Plagborg-Møller, Mikkel and Christian K Wolf (2021), "Local projections and vars estimate the same impulse responses." *Econometrica*, 89, 955–980.

Poole, William (1970), "Optimal choice of monetary policy instruments in a simple stochastic macro model." *The Quarterly Journal of Economics*, 84, 197–216.

Ravn, Morten O and Harald Uhlig (2002), "On adjusting the hodrick-prescott filter for the frequency of observations." *Review of economics and statistics*, 84, 371–376.

Stavrev, Emil and Helge Berger (2012), "The information content of money in forecasting euro area inflation." *Applied Economics*, 44, 4055–4072.

Stock, James H and Mark W Watson (1989), "Interpreting the evidence on money-income causality." *Journal of Econometrics*, 40, 161–181.

Woodford, Michael (2003), *Interest and prices*. Princeton University Press.

Woodford, Michael (2008), "How important is money in the conduct of monetary policy?" *Journal of Money, credit and Banking*, 40, 1561–1598.

Wu, Jing Cynthia and Fan Dora Xia (2016), "Measuring the macroeconomic impact of monetary policy at the zero lower bound." *Journal of Money, Credit and Banking*, 48, 253–291.

A Diagnostic statistics

Variable	Phillips Perron Statistic	P-value
Output (y)	-103.48	0.01
Inflation (π)	-161.85	0.01
Interest Rate (i)	-58.63	0.01
M1 (m)	-256.07	0.01

Table 1: Phillips-Perron Test results for the endogenous variables (Phillips, 1988).

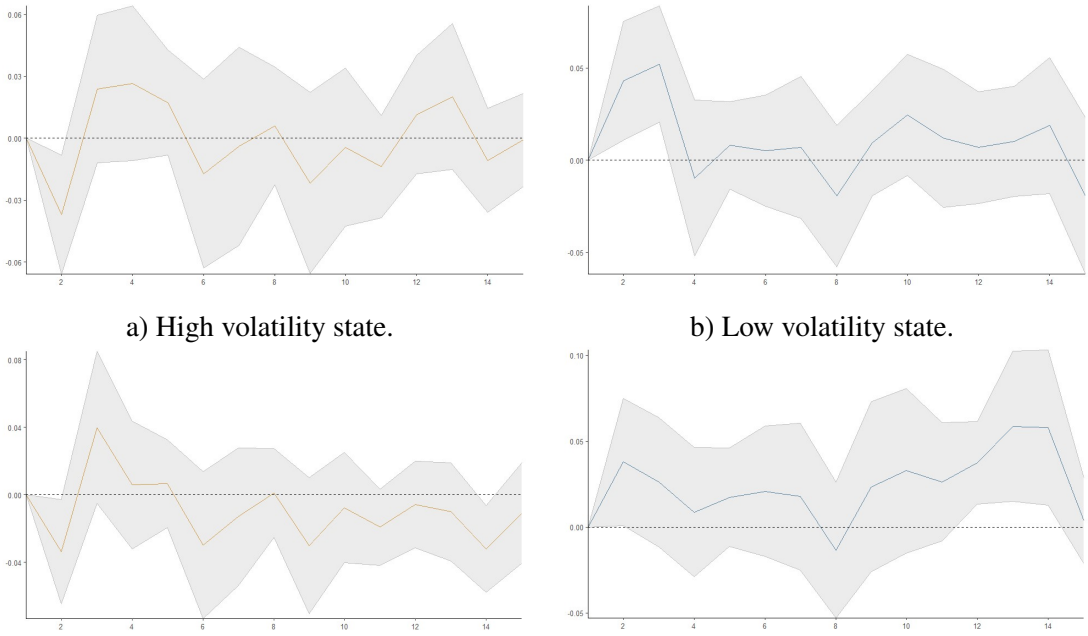
Variable	KPSS Statistic (tau)	KPSS Statistic (mu)
Output (y)	0.0431	0.0532
Inflation (π)	0.0988	0.1445
Interest Rate (i)	0.0414	0.0317
M1 (m)	0.0773	0.0891

Table 2: KPSS Test results for the endogenous variables. The statistics are reported for both the deterministic options τ and μ. The critical values for at the 10% confidence level are 0.347 and 0.119, respectively (Kwiatkowski et al., 1992).

Lag	π	y
1	0.68	0.00
2	0.08	0.00
3	0.12	0.00
4	0.12	0.00
5	0.06	0.00
6	0.09	0.00
7	0.07	0.00
8	0.09	0.00
9	0.09	0.00
10	0.13	0.00

Table 3: Granger Causality Test results. The H_0 is M1 not granger causing the variable (P-values)

B IRFs of robustness exercises



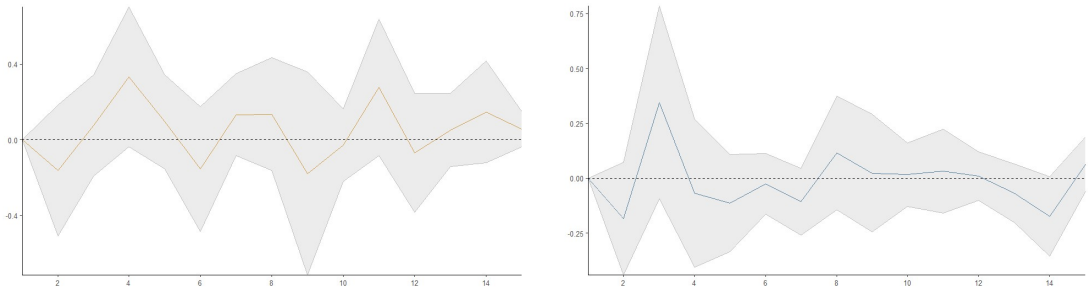
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

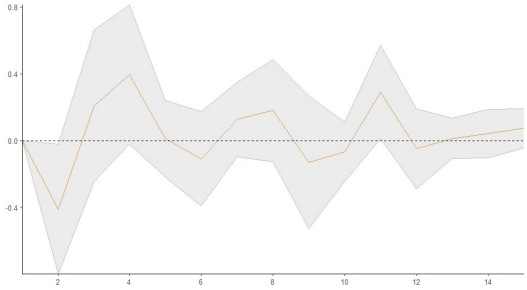
d) Low Mexican CDS state.

Figure 11: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.

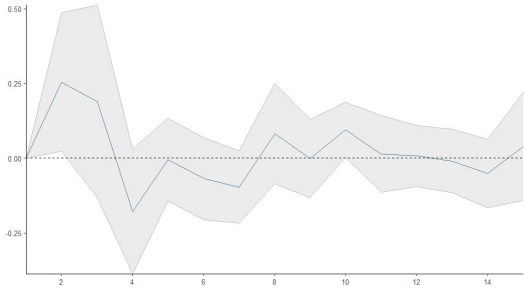


a) High volatility state.

b) Low volatility state.

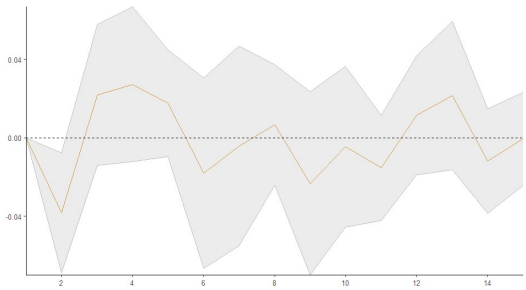


c) High Mexican CDS state.

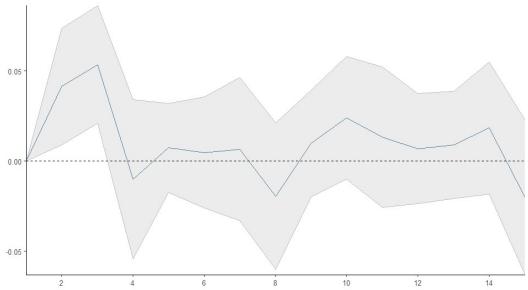


d) Low Mexican CDS state.

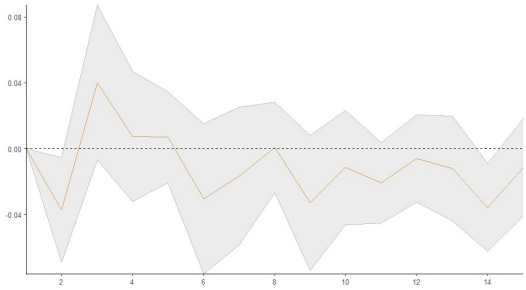
Figure 12: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.



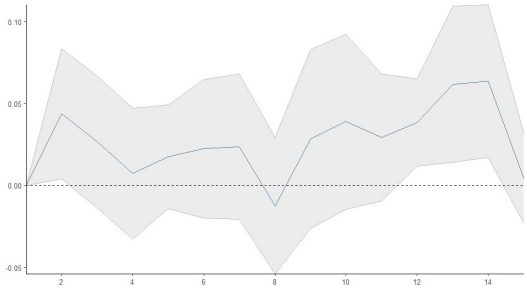
a) High volatility state.



b) Low volatility state.

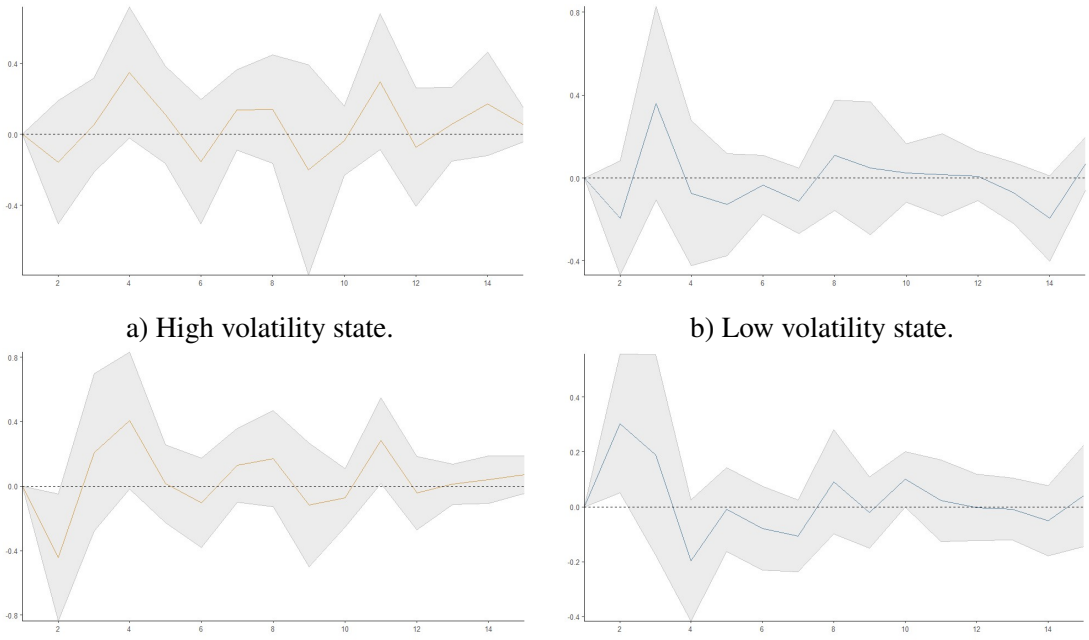


c) High Mexican CDS state.



d) Low Mexican CDS state.

Figure 13: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.



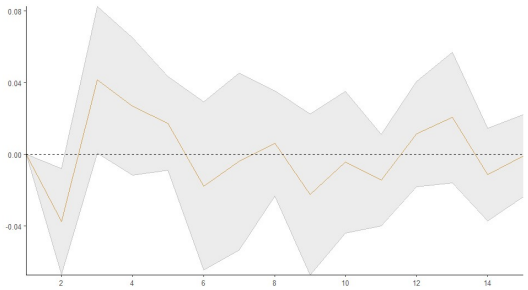
a) High volatility state.

b) Low volatility state.

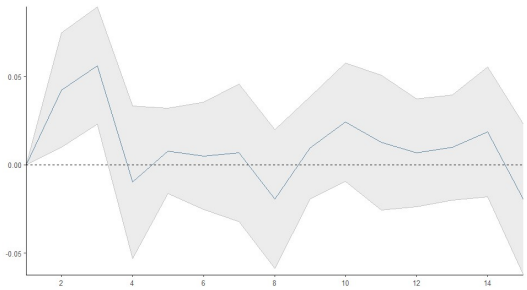
c) High Mexican CDS state.

d) Low Mexican CDS state.

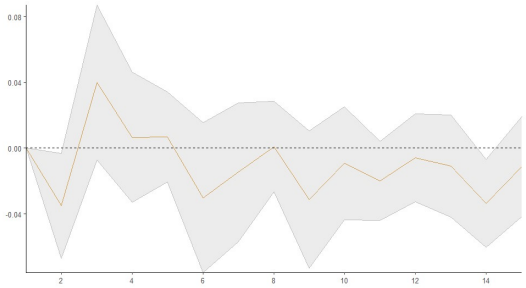
Figure 14: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.



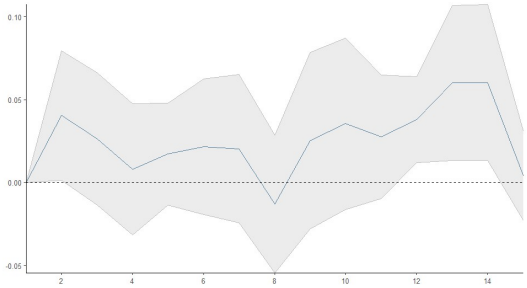
a) High volatility state.



b) Low volatility state.

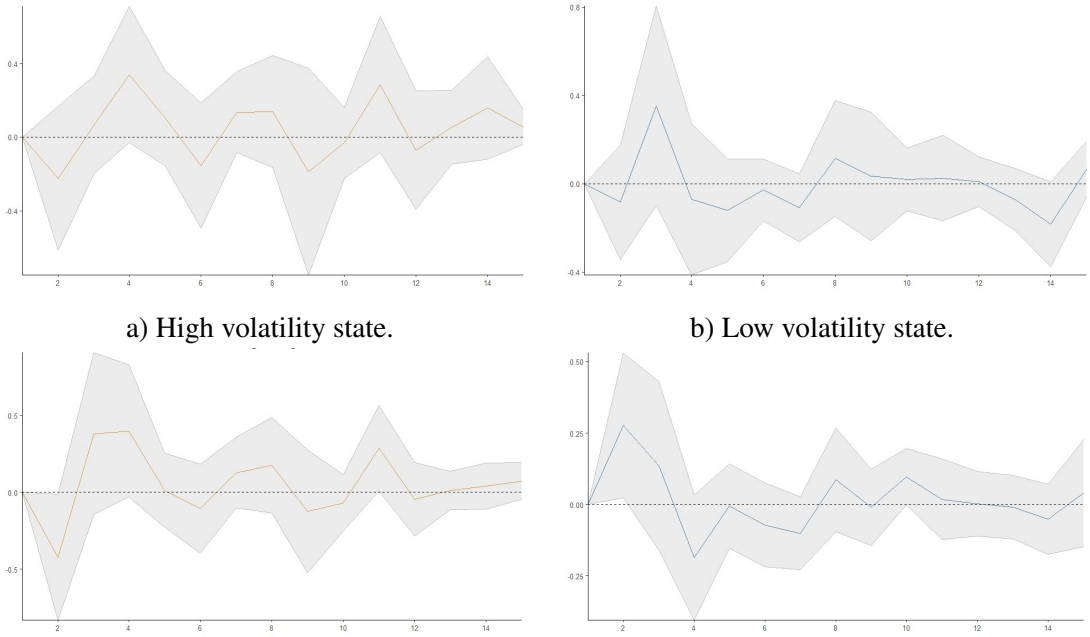


c) High Mexican CDS state.



d) Low Mexican CDS state.

Figure 15: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.



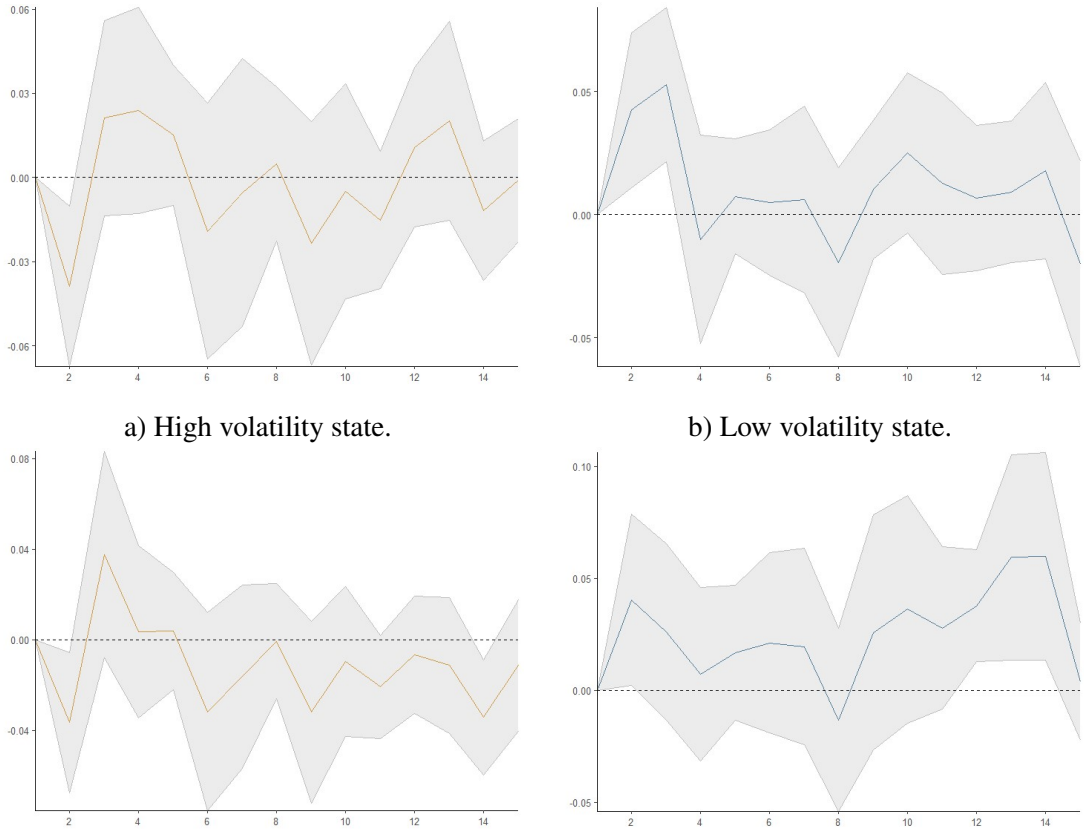
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 16: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.



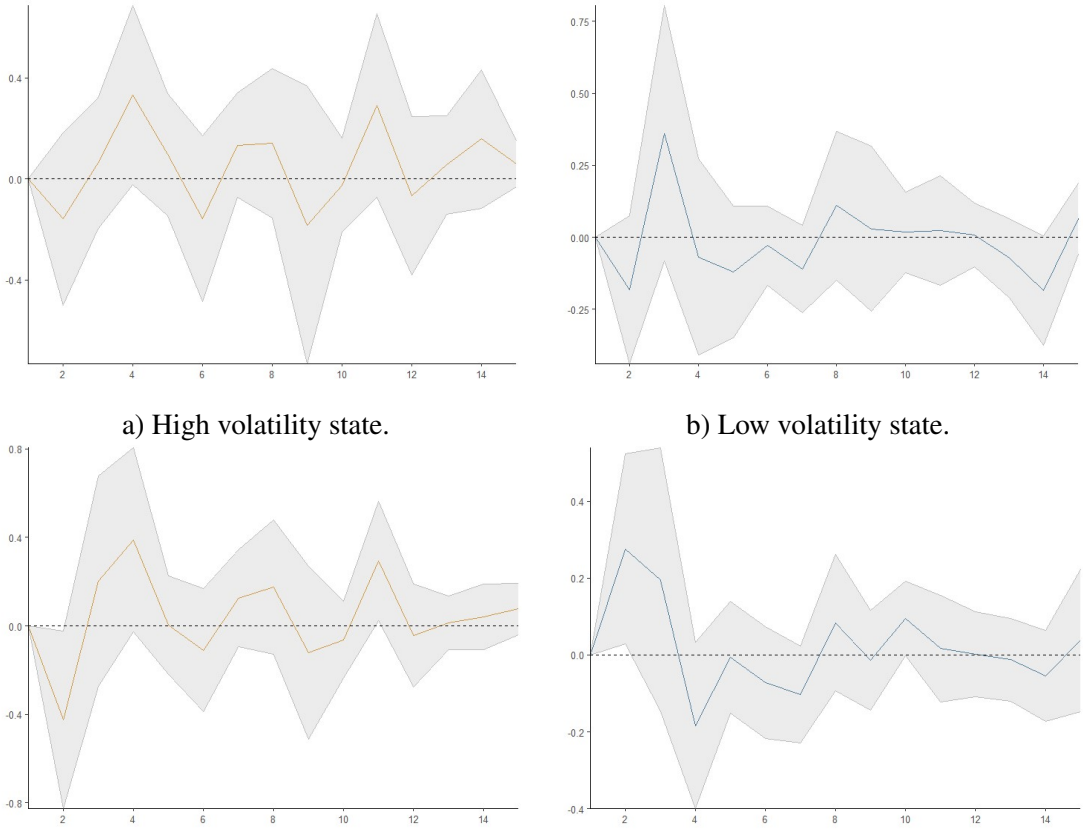
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 17: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.



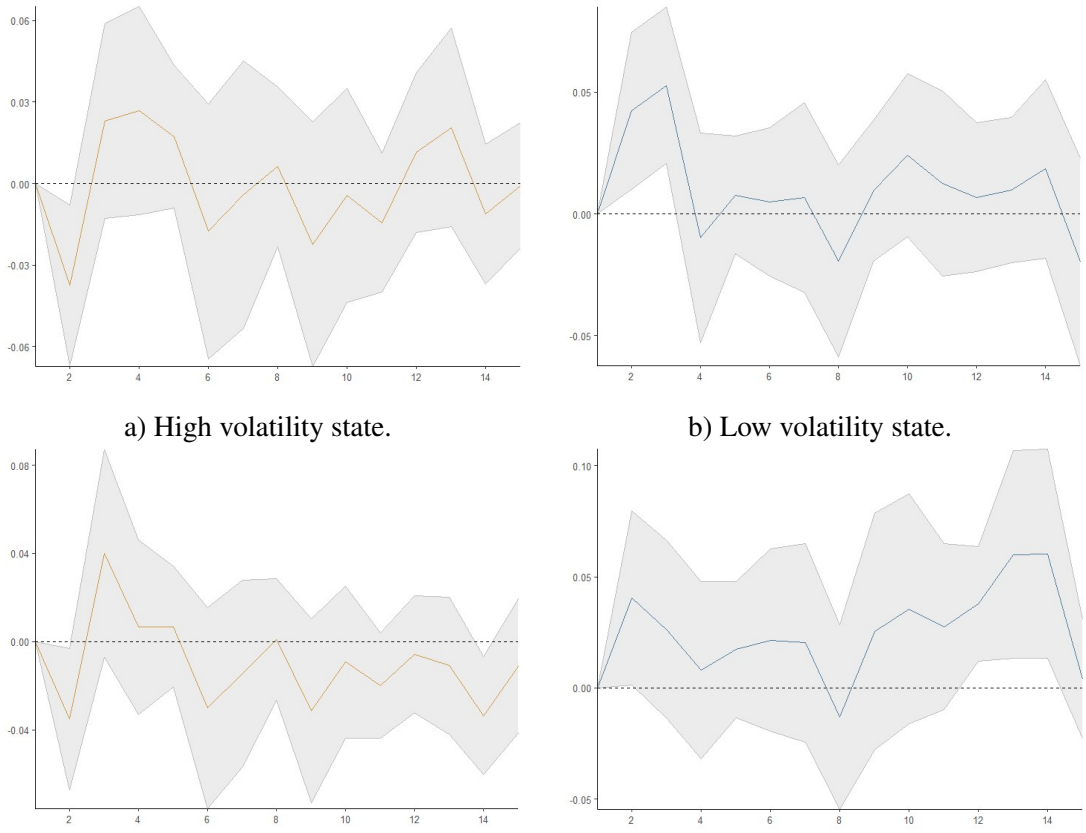
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 18: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.



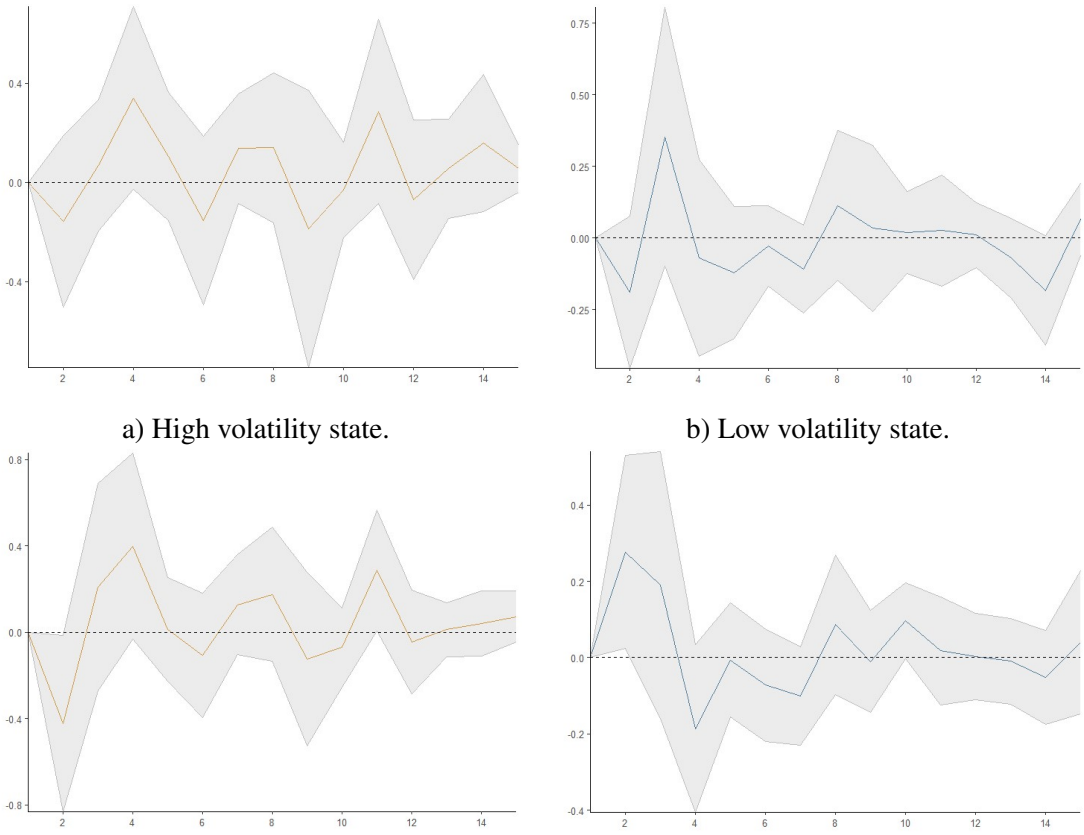
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 19: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.



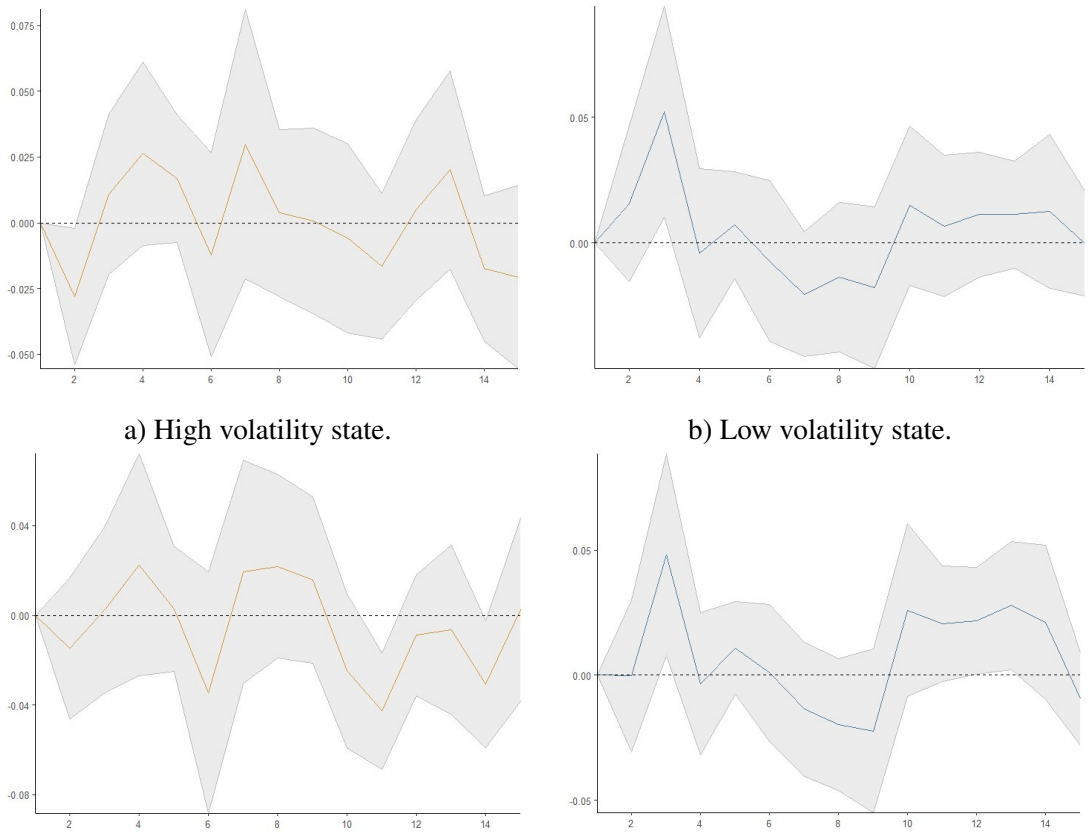
a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 20: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.



a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 21: IRFs of a one standard deviation shock of M1 to monthly inflation. Confidence intervals set at 90%.



a) High volatility state.

b) Low volatility state.

c) High Mexican CDS state.

d) Low Mexican CDS state.

Figure 22: IRFs of a one standard deviation shock of M1 to output. Confidence intervals set at 90%.