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Macroeconomic Stabilization and Monetary Policy in Small Open Economies

Autor: Santiago Camara

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Abstract

In this paper I analyze the role of monetary policy in nominal stabilization in small open economies. In particular, I focus on studying the underlying forces that explained the nominal stabilization several emerging countries exhibited in the second half of the 1990s and the early 2000s. In order to do so, I first estimate several empirical models using both rolling sample windows and also allowing for time-varying parameters. Secondly, I interpret the empirical findings estimating a New Keynesian DSGE model with drifting coefficients and stochastic volatilities.

*This master thesis is dedicated to the memory of Enrique "Kawa" Kawamura. I am deeply indebted to him both professionally and personally. He was both a mentor and a role model. Anything I have achieved in my life, and anything I will ever achieve will be partly because of his teachings.I would like to thank Daniel Heymann, Guido Lorenzoni and Lawrence Christiano, and the participants of the Argentinean Central Bank seminar participants for insightful comments and guidance. I would also like to thank my parents, Adriana and Luis, and my sister Milagros. I am grateful for Jose Luis Flor Toro and Yong Cai's comments and advice. Finally, but definitely not least, I would like to thank María Samara for her words of support.

1 Introduction

Macroeconomic instability was one of the key distinguishing characteristic of many Latin American countries during the second half of the twentieth century and the first half of the 2000s. These countries exhibited both extreme nominal and real volatility, and experienced both economic and financial crises.

Although other regions also experienced macroeconomic volatility, nominal instability was a recurrent phenomenon of Latin American economies, particularly between the late 1970s and mid 1990s. High and persistent inflation became a chronic disease of these economies as indexation mechanisms surged as coping mechanism for economic agents. Although inflation is an economic phenomenon with multiple causes, that emerges as the interaction of monetary and real factors, monetary factors are generally dominant.

The underlying cause for the persistence of high inflation has been subject to debate. While accepting the long term relationship between money growth and inflation the underlying causes for monetary expansions are manifold. Much of this literature emphasizes the role of the recurrent monetization of fiscal deficits. The limits of monetary and fiscal policies become blurry and money supply growth becomes passive to the government's financing needs. Heymann et al. [1995] show how episodes of high inflation are associated with periods of high fiscal deficit. The monetary authorities becomes subjugated to the needs of the treasury. A concrete example of this presented in Heymann et al. [1991] monetary expansions due to distributive conflicts between different factions over fiscal transfers.

Another strand of literature has emphasized the role of expectations as a determinant of inflation inertia. Taylor [1980] and Fuhrer and Moore [1995] show that inflation persistence will emerge in a framework with an overlapping structure of long term wage contracts where there is a lack of state contingent assets. The importance between how firms, households and governments form expectations and the resulting behavior of inflation is described by Sargent [1982]. The author stresses how a shock to expectations, perhaps by the implementation of both fiscal and monetary reforms, can lead to a fast stabilization of nominal variables.

The rich theoretical literature has been met with an equally rich empirical literature. Lucas [1980] and McCandless et al. [1995] show that in the long run there is a strong and positive correlation between money growth and inflation, while money is neutral with respect to GDP growth. However, these papers usually focus on developed countries. A counterexample is, Burdisso et al. [2013] and Basco and Katz [2014] show that permanent increases in the money supply have more than proportional effects on prices and negative permanent impact on GDP.

In recent years the literature has focused on the short run effects of monetary policy. Grauwe and Polan [2005] use a panel of 160 countries over 30 years and concludes that the degree of co-movement between money growth and inflation depends on the average rate of inflation. Countries that have experienced high inflation episodes have a stronger correlation between money growth and inflation than countries that have low inflation rates on average. Sargent and Surico [2011] present evidence that in developed economies where central banks actively seek to control inflation and meet targets, money growth is correlated with positive real GDP growth. The authors conclude that this finding is due to sound and credible monetary institutions.

It is clear that regimes of high inflation have negative effects on the normal functioning of economies. Planning horizons shrink and relative prices become more volatility which hinder investment, productivity and long run growth. In consequence, policymakers in Latin America implemented several reforms aiming to reduce inflation. Calvo and Végh [1999] present evidence on the repeated efforts of stabilization plans by policy makers in these economies. As the authors stress, more often that not, stabilization plans have failed, usually ending in balance of payment crises.

Developed countries conquered inflation in the 1980s and most emerging countries finally succeeded curving nominal instability by the first half of the 2000s. The macroeconomic literature has made several attempts at analyzing the underlying drivers of this phenomenon for developed countries after the episodes of high inflation in the late 1970s. Cogley et al. [2010] use Bayesian methods to estimate two models of post WWII US inflation rates with drifting stochastic volatilities and drifting coefficients. The authors find a reduction in the variance of the coefficients that control the degree of activism was crucial to the fall of inflation under the chairmanships of Volker and Greenspane. At the same time, the fall in mean inflation was accompanied with a fall in the persistence of inflation and a lower correlation of inflation with the natural rate of unemployment.

Recent literature has focused on the stabilization of open and emerging countries. In this setting, exchange rate pass-through is of crucial importance. While Cámara [2016] found that the Currency Board in Argentina was key to lower nominal volatility, but increased real and nominal volatility and weak monetary policy activism where key in the revival of inflation in the late 2000s. In terms of efficacy of monetary policy, Ca'Zorzi et al. [2007] have found that a low, well-established inflation regime is key to achieve real depreciations with low pass-through.

This paper aims to shed more light on the underlying drivers of nominal stability in Latin American countries in recent years and at the same time analyze why Argentina keeps on battling inflation. The rest of the paper is organized as follows. Section 2 presents a descriptive analysis of macroeconomic data and some motivational facts. Section 3 presents two sets of econometric exercises: first, standard Bayesian SVARs using rolling sample windows; second State Space models with permanent and transitory shocks. Section 4 presents the estimation of a New Keynesian DSGE model for a SOE with drifting parameters. Section 5 discusses the results of the econometric and optimizing models. Section 6 concludes by presenting final remarks and future research agenda.

2 Preliminaries and Motivational Facts

Latin American economies fought both real and nominal instability in the last 70 years. Figure 1 presents cross country evidence for the period 1960-2017[1]. For each of the countries in the sample I computed both yearly GDP growth rates and yearly GDP deflator inflation rate. Next, I computed the standard deviation of each series across time for the whole sample. Each point in the figure is a country, where Latin American countries are represented in yellow.

In an open economy setting the role of monetary policy becomes more intricate than in a close economy. Aside from the fact of how an increase in the nominal interest rate impacts on inflation and output, we can also ask how an increase in the nominal interest rate impact both the real exchange rate. Furthermore, given that open economies face shocks coming from the rest of the world, such as interest rate shocks, foreign demand

[1] Source of data for this figure is the Penn World Table National Accounts Data v9.1

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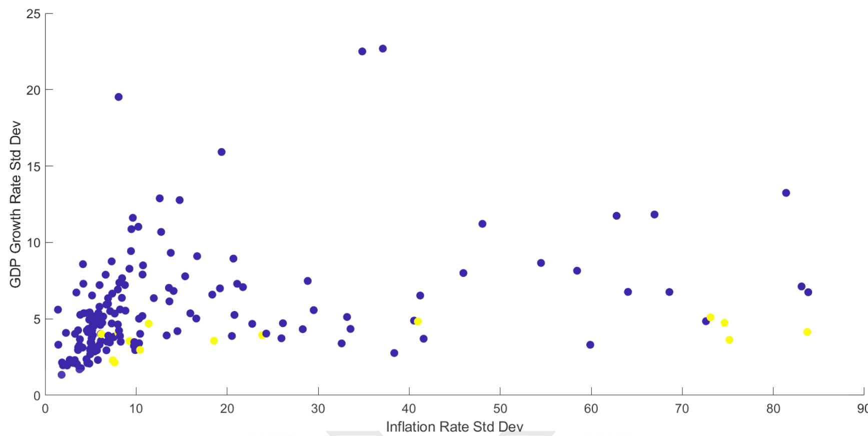
Figure 1: Nominal and Real Volatility 1960-2017



shocks, cost-push shocks, we can also ask how monetary policy reacts to these shocks and the impact on the domestic economy.

Before introducing econometric exercises into the analysis, I present motivating evidence on the long and short run relationships between inflation, nominal devaluation and different nominal interest rates. Macroeconomic theory suggests that in the long run there is a strong relationship between inflation rates and the nominal interest rate. This long run relationship is usually called the Fisher effect. The Fisher equations states:

$$i_t = R_t + \mathbb{E}_t \pi_{t+1} \tag{1}$$

where i_t denotes the nominal interest rate, R_t denotes the nominal interest rate, π_t denotes the inflation rate, and $\mathbb{E}_t$ denotes the expectation conditional on information available in period t.

Surveys over macroeconomic expectations is usually scarce, specially in emerging economies. Assuming that on average expected inflation equals actual inflation, we can state the following relationship between the variables in equation 1

$$i = R + \pi \tag{2}$$

where the variables without time-subscript refer to long-run averages. Figure 2 shows the averages of the inflation and the nominal interest rate. Each scatter plot in the graph represents one country. Because of scarcity of data, I construct averages for 45 countries

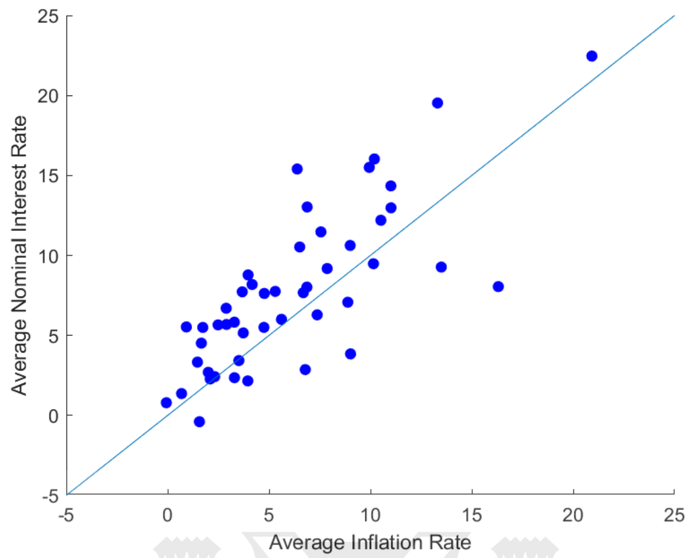


Figure 2: Average Inflation and Nominal Interest Rates: Cross-Country Evidence

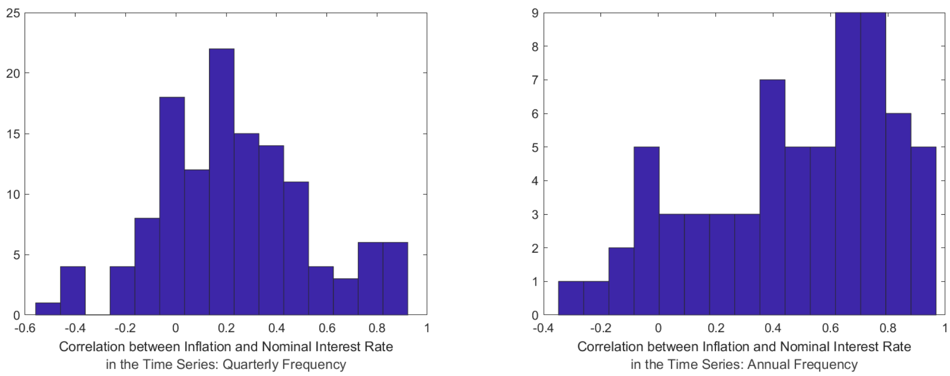
with more than 20 years of data. I introduce the 45 degree line for reference Although the typical sample is 1980-2017, there are several countries that only have data for the last 20 years. As in each dot represents one country, and the averages are taken over the longest available non-interrupted sample. The graph shows that increases in the nominal interest rate are strongly associated with one-for-one increases in the inflation rate. In other words, the graph presents evidence supporting the Fisher effect in the long run.

However, although the evidence suggests the validity of the Fisher effect in the long run, it implies nothing for the short run relationship between the variables. Figures 3a and 3b present evidence of the short run relationship between Inflation and the Nominal Interest Rate. On both figures, the exercise is to study the correlation between inflation and the nominal interest rate across time for different countries. In order to do so, I constructed time series of inflation and nominal interest rates and computed the time series correlation for each country, and then plotted the histogram of these correlations for different countries[2] On figure 3a, I present evidence on the time series correlation between the variables at the quarterly frequency between inflation and the lending nominal interest rate for 128 countries

[2]For the left panel using quarterly frequency data, the typical sample is 1985-2017. I use CPI inflation and the Nominal Lending Interest Rate. The source of the data is the IMF's IFS. For the right panel using annual frequency data, the typical sample is 1989-2016, and the data and the source is the same as in 2

Figure 3: Inflation and Nominal Depreciation: Cross-Country and Time Series Evidence

(a) Correlation at the Quarterly Frequency (b) Correlation at the Annual Frequency



for the period 1981-2017. We observe that the mass is concentrated between 0 and 0.3, while there is some mass at both negative and right tails. On figure 3b I present evidence on the time series correlation between the variables at the annual frequency. The graph shows that the for most countries in my sample, the time series correlation at the annual level is centered around 0.7. Although this finding is in favor of the Fisher effect from a time perspective, it still shows certain heterogeneity across countries, with a significant mass of the distribution with correlation values lower than 0.4. Hence, the data seems to show that there is significant evidence in favor of the Fisher effect in the long run, i.e., a strong positive statistical association between inflation and nominal interest rates. Nevertheless, the evidence of a long-run relationship between the variables does not imply any particular behavior for the short-run relation between variables. Although the data seems to show that in the time series the relationship between the variables becomes stronger as we focus on lower frequencies, we can not say anything else.

Next, given that these paper focus on open economies, we study the behavior of the nominal exchange rate, its relationship between inflation and the theoretical implications of the Fisher effect in an open economy. In an open economy setting, the uncovered interest rate parity condition (UIP from now on) states that nominal interest rate differentials are equal to the expected nominal depreciation rate

$$i_t - i_t^* = \mathbb{E}\{\Delta S_t\} \tag{3}$$

where i_t^* is the foreign nominal interest rate and S_t is the amount of local currency needed to buy one unit of the foreign currency, and Δ represents the growth rate operator in percentage points. We can manipulate the UIP condition using the Fisher equation 1 for both the domestic and foreign country

$$i_t + \mathbb{E}\{\Delta S_t\} = i_t^*$$

$$R_t + \mathbb{E}_t\{\pi_t\} + \mathbb{E}\{\Delta S_t\} = R_t^* + \mathbb{E}_t\{\pi_t^*\}$$

$$R_t + \pi + \Delta S = R^* + \pi^* \tag{4}$$

where, from the first equation to the second I used the Fisher equation 1, and from the second equation to the third I assumed expected variables are equal to the average on the long run. Equation 4 states that if the domestic economy has a higher nominal interest rate than the foreign economy (due to differences in the real interest rate or the inflation rate), then the interest rate differential should be covered by a nominal depreciation of the domestic currency. If we further assume that real interest rates in the long run are equal across countries, i.e. $R = R^*$, we have

$$\pi + \Delta S = \pi^* \tag{5}$$

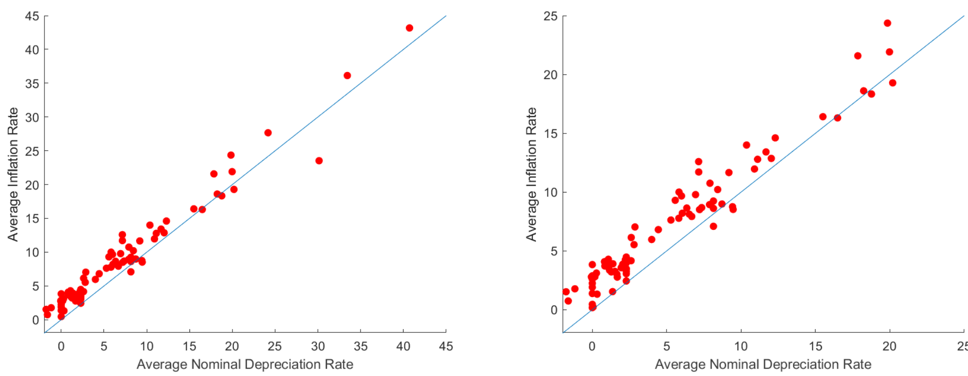
Figures 4a and 4b presents evidence on the long run relationship between the inflation rate and the nominal depreciation rate. Each dot in the graph corresponds to the average of these rates for one country. The left panel presents data across 91 countries for the period 1981-2017, while in the right panel I cut the sample, only presenting evidence for the 85 countries in my sample that have less than 25% of average inflation for the period defined above. For reference I introduce the 45 degree line. Both panels suggest a clear positive relationship between the average inflation rates and the nominal depreciation rates in the long run, as the correlation between the variables is close to one[3].

However, this does not seem to be the case in the short run. Figure 5 presents a evidence of the relationship between the quarterly inflation rate and the nominal depreciation rate in the short run. For each country I computed the correlation across time

[3]Each dot represents the average of inflation and nominal depreciation. For each country the average rates are calculated for the period 1981Q1 - 2017 Q4. The solid line is the 45 degree line. Source of the data: IMF-IFS. Inflation rate is computed using the CPI Index, while the nominal depreciation is calculated using the Nominal Exchange Rate calculated as the average of the period.

Figure 4: Average Inflation and Nominal Depreciation: Cross-Country Evidence

(a) Complete Sample (b) Reduced Sample



between inflation and the nominal depreciation rate. Finally, I group the countries into 15 different bins and plot a histogram. It is noteworthy the heterogeneity in the short run correlations across countries. Most countries exhibit a low correlation (0-0.3) between the variables at the quarterly level. Nevertheless, a substantial mass of countries exhibit correlation higher than 0.5 and some even close to one. Not surprisingly, the countries on the right tail are countries that experienced substantial nominal instability (Brazil, Bolivia, Israel, Peru, Poland).

3 The Empirical Models

In this section I present several econometric models to estimate the relationship between nominal and real variables, identify monetary policy shocks and their impact on the macroeconomy.

In the first subsection, I apply several structural VAR methodologies to identify monetary policy shocks. On the second subsection, I apply the framework developed by Uribe [2018] which introduces permanent and transitory monetary shocks to identify monetary policy shocks. The sample of countries is Argentina, Brazil, Chile, Mexico and South Korea. As data availability for nominal and real variables is not the same (nominal variables such as CPI, Nominal Exchange Rates, monetary variables) are reported at higher frequencies and usually count with longer time series. In consequence, some of the econometric

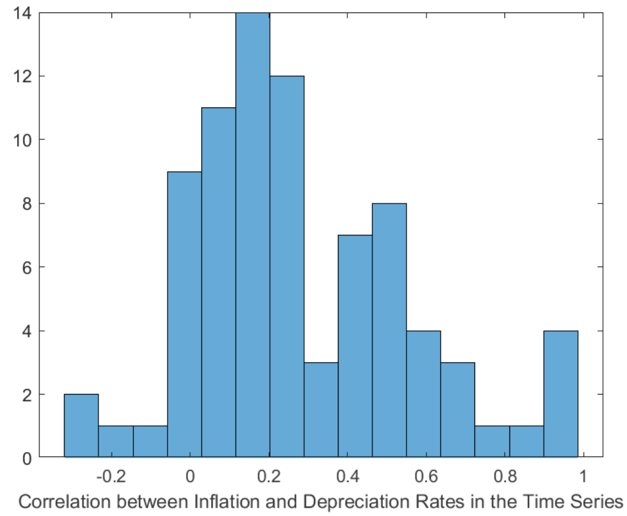


Figure 5: Inflation and Nominal Depreciation: Cross-Country and Time Series Evidence

exercises will focus only on nominal variables, while other, more large scale models, will take into account both type of variables.

The goal of this paper is to find key empirical regularities across countries. I leave to appendix A.1 the data description for each country. Also, given that this paper introduces no innovation in terms of the empirical models estimated, I leave the description of the models and the estimation procedures to the appendix subsection A.3

3.1 Structural VAR Analysis

In this subsection I will carry out several SVAR econometric exercises using several model specifications. Given the substantial regime changes and policy changes across time in this economy, I employ Primiceri [2005] time varying parameter structural VAR models. This methodology allows both for drifts in the auto-regressive coefficients and in the stochastic volatilities[4].

First, I use two model specifications at the monthly frequency to study exchange rate pass through

[4]To keep results comparable across countries and across time periods within different time periods, the shocks are normalized to one.

1. Bivariate model using the Nominal Exchange Rate and the CPI[5]. In order to achieve identification, I assume a recursive identification. I assume that a monthly nominal depreciation shock does not impact the CPI inflation rate[6].

2. Bivariate model using the Nominal Exchange Rate and the Real Exchange Rate. In order to achieve identification, I use Blanchard and Quah [1988] long run restrictions methodology. I assume that nominal depreciation shocks have no impact on real depreciations in the long run

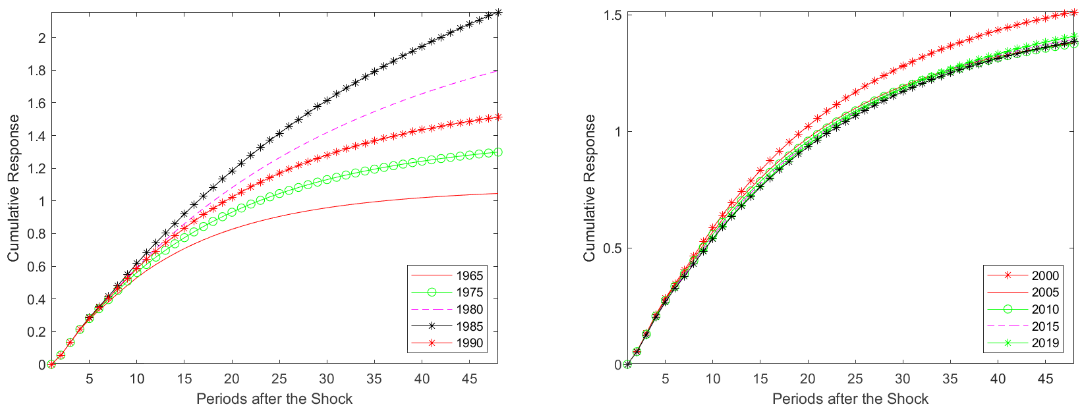
Figures 6a to 9 present the cumulative impulse response functions of CPI inflation to a 1% nominal depreciation shock under the recursive identification scheme. This econometric exercise allows us to also study the dynamics of the volatility of each equation of the model. If the identification scheme is correct, we can study both the systematic part of the model, the auto-regressive coefficients of the model, and the non-systematic part of the model, the volatility of the equations. In this section, I will study the systematic response of the economy and leave the report of the stochastic volatilities to the appendix A.3.1.

For Argentina, figures 6a and 6b show a substantial time-varying effect of a nominal depreciation shock to CPI inflation across time periods. On the left panel, we can observe that from 1965-1985 the accumulated effect of a nominal depreciation shock to inflation increases through time. To gauge the magnitude of this difference, the impact at 1985 is twice as big as the impact on 1965 at the 2 year horizon and at the 4 year horizon. Interestingly, the time varying difference quiets down after the hyperinflation period as can be seen in the right panel. Using a recursive identification scheme, there is little time difference in the IRF between 2000 and 2019.

The dynamics for Brazil, in figure 7 shows the opposite results that for Argentina. We can observe that between 1995 and 2015, the systematic structure of the model implies a much lower impact of a nominal depreciation shock on CPI inflation. The impact in 2015 is four times lower than in 1995. However, closer to the end of the sample, we observe that the cumulative impact increases, although it is still half as large as in 1995.

[5]Technically, the model has three variables as a Foreign Price Index is also used. However, I take this variable as exogenous

[6]This assumption it is not free of controversy. This identification strategy implies that a nominal depreciation shock implies a real depreciation 1-to-1 on impact



(a) 1965-1990 (b) 2000-2019

Figure 6: TVP IRF on Inflation: Argentina

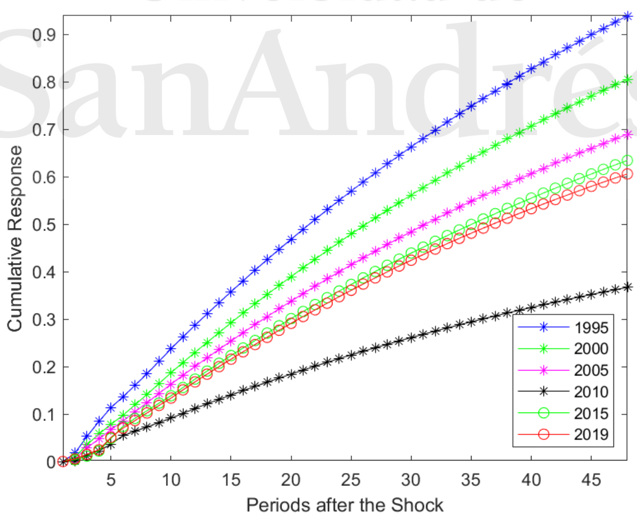
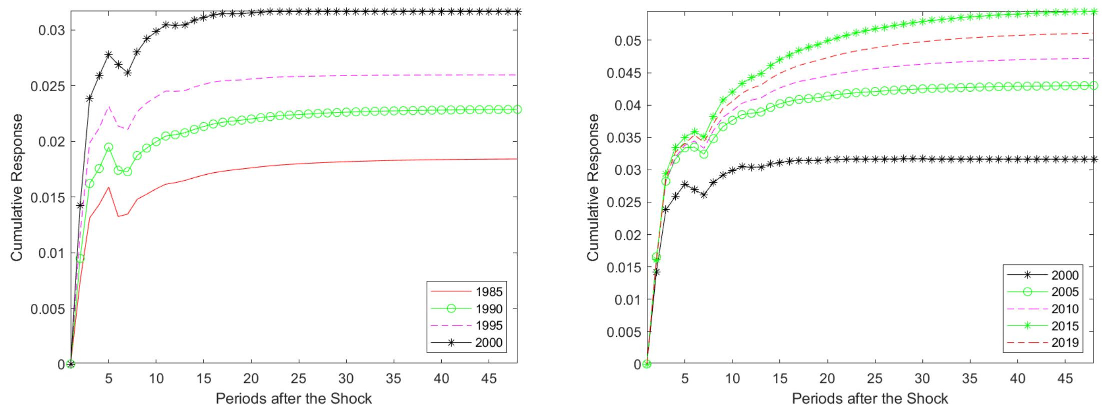


Figure 7: TVP IRF on Inflation: Brazil



(a) 1985-2000

(b) 2000-2019

Figure 8: TVP IRF on Inflation: Chile

The data for Chile, showed in 8a and 8b, presents somewhat puzzling results. For the whole sample, the impact of a nominal depreciation shock on CPI inflation is low and fast. The cumulative impact seems to flatten out after 10 months or less. Compared to other countries, the impact on inflation is one order of magnitude lower. Furthermore, the impact of the shock becomes increasing through time, which goes against economic intuition given the nominal stabilization the country went through in the last decades. This could be due to identification scheme and is addressed below.

Mexico and South Korea, given their far less nominal instability than the countries studied above, show less pronounced time variant effect on the IRFs. As can be seen in figures 9, 10a and 10b, with time, the impact of a nominal depreciation shock on the CPI inflation decreased. This decrease was between 10% and 20%. Again, this difference in IRFs is lower than for more nominally unstable economies such as Argentina or Brazil.

Next, we turn to the second time-varying SVAR analysis. Under this methodology, using the nominal and real exchange rates, the identification scheme imposes that in the long run nominal depreciations have no impact on the real depreciation rate.

Figures 11 to 13b present time-varying cumulative IRFs of nominal depreciation shocks to the real depreciation rate. Under this identification scheme the results are more volatile across time periods. However, across countries, the results are in line with the previous exercise.

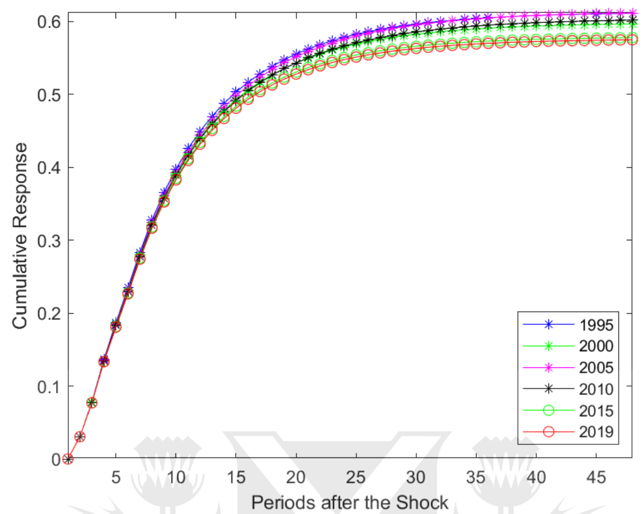
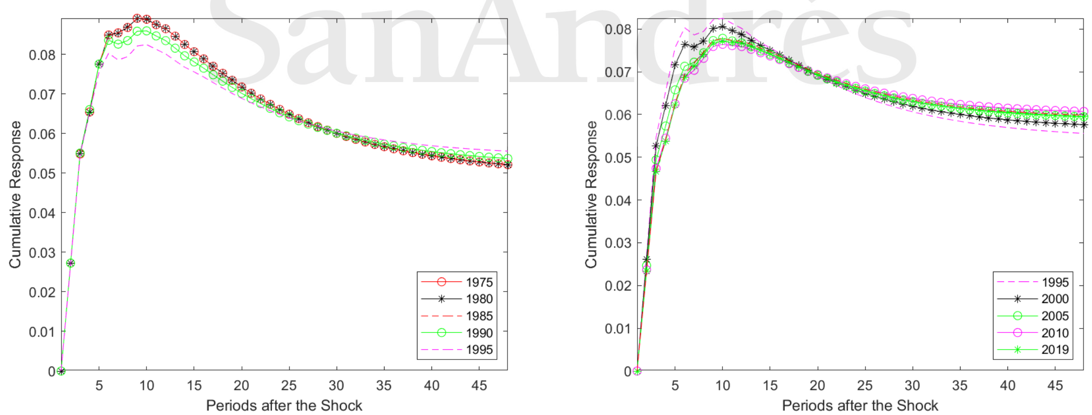


Figure 9: TVP IRF on Inflation: Mexico



(a) 1975-1995

(b) 1995-2019

Figure 10: TVP IRF on Inflation: South Korea

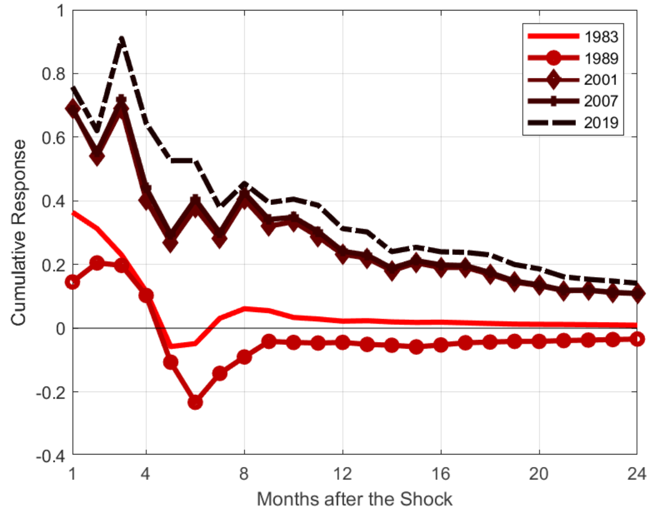
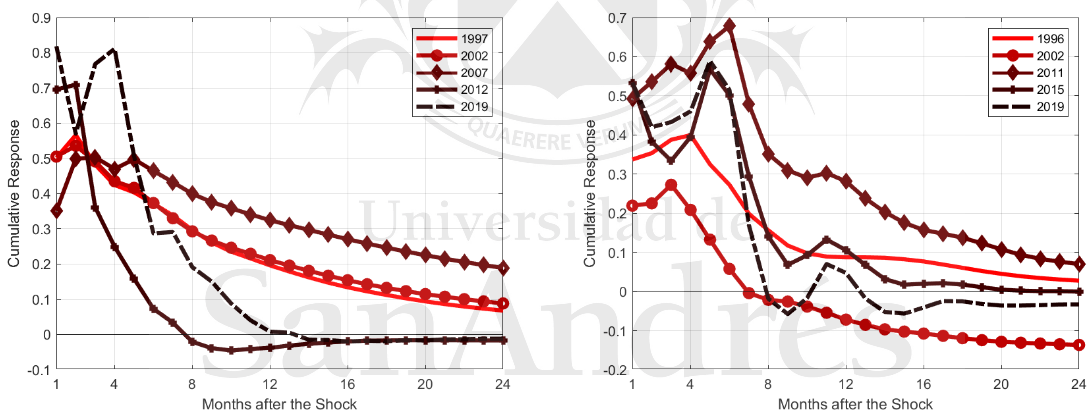


Figure 11: TVP IRF on Inflation with Long Run Restrictions: Argentina

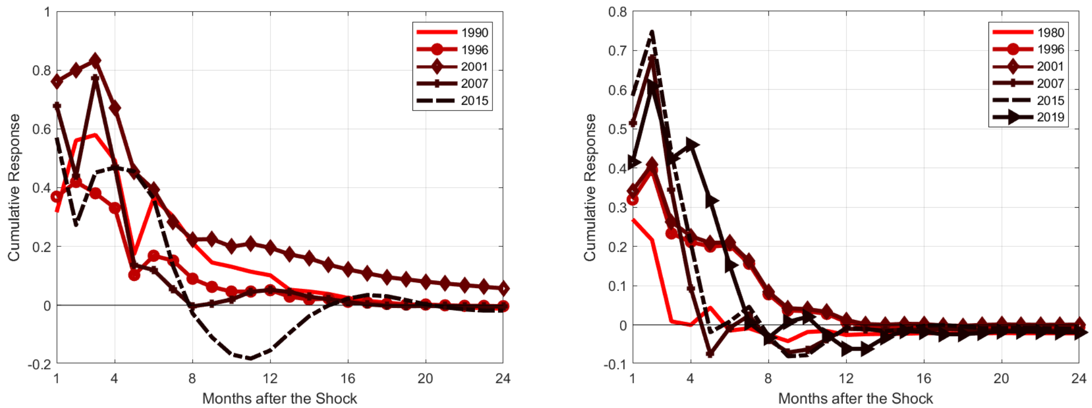


(a) Brazil (b) Chile

Figure 12: TVP IRF on Inflation with Long Run Restrictions: Brazil & Chile

For Argentina, the IRFs for 1983 and 1989, periods of high inflation the impact of nominal depreciations shocks on real depreciations is low on impact (0.2 to 0.4) and die out after 4 or 5 months. On the other hand, for the three periods after the fall of the currency board, the effect on impact is between two and four times greater (0.7 to 0.8). Furthermore, one year after the shock, the real exchange rate is still 0.3% greater than zero.

The results for the rest of the countries in the sample are similar to the ones



(a) Mexico (b) South Korea

Figure 13: TVP IRF on Inflation with Long Run Restrictions: Mexico & South Korea

found for Argentina. In more recent years, depreciation shocks in Brazil lead to a greater impact on the real exchange rate, but they tend to be more short lived. The data for Chile and Mexico seem to show that as the nominal stabilization process was consolidated, nominal depreciation shocks lead to lower pass-through. However, it seems that after the Great Recession, the effects are somewhat lower. Finally, South Korea exhibits great time variance across time. Although the impact of nominal depreciations seems to be short-lived for all periods, the magnitude of the response both on impact and after a quarter is much greater for more recent periods.

3.2 State Space Model Analysis

The next empirical exercise is an application of Uribe [2018] state space model. The five macroeconomic indicators are the logarithm of real output, denoted y_t, the inflation rate, denoted by π_t and expressed in percent per year, and the nominal interest rate, denoted i_t and also expressed in percent per year, ϵ_t is the nominal depreciation rate, expressed in percent per year, and i^*_t, the foreign interest rate, expressed in percent per year. It is assumed that the five variables driven by five exogenous shocks: a non-stationary monetary shock X^m_t, a stationary monetary shock, denoted z^m_t, a non-stationary non-monetary shock, denoted X^n_t, a stationary non-monetary shock, denoted z^n_t, and a foreign non-stationary monetary shock X^{m*}_t. The variables in the model are related according to the following state space system:

$$\begin{bmatrix} y_t \\ \pi_t \\ i_t \\ \epsilon_t \\ i_t^* \end{bmatrix} \equiv \begin{bmatrix} \text{log of real output} \\ \text{inflation} \\ \text{interest rate} \\ \text{depreciation rate} \\ \text{foreign interest rate} \end{bmatrix}; \qquad \begin{bmatrix} \hat{y}_t \\ \hat{\pi}_t \\ \hat{i}_t \\ \hat{\epsilon}_t \\ \hat{i}_t^* \end{bmatrix} \equiv \begin{bmatrix} y_t - X_t \\ \pi_t - X_t^m \\ i_t - X_t^m \\ \epsilon_t - X_t^m + X_t^{m^*} \\ i_t^* - X_t^{m^*} \end{bmatrix}$$

The model has an auto-regressive form

$$\begin{bmatrix} \hat{y}_t \\ \hat{\pi}_t \\ \hat{i}_t \\ \hat{\epsilon}_t \\ \hat{i}_t^* \end{bmatrix} = B(L) \begin{bmatrix} \hat{y}_{t-1} \\ \hat{\pi}_{t-1} \\ \hat{i}_{t-1} \\ \hat{\epsilon}_{t-1} \\ \hat{i^*_{t-1}} \end{bmatrix} + C \begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t \\ z_t \\ \Delta X_t^{m^*} \end{bmatrix}; \qquad \begin{bmatrix} \Delta X_t^m \\ z_t^m \\ \Delta X_t \\ z_t \\ \Delta X_t^{m^*} \end{bmatrix} = \rho \begin{bmatrix} \Delta X_{t-1}^m \\ z_{t-1}^m \\ \Delta X_{t-1} \\ z_{t-1} \\ \Delta X_{t-1}^{m^*} \end{bmatrix} + \psi \begin{bmatrix} \nu_t^1 \\ \nu_t^2 \\ \nu_t^3 \\ \nu_t^4 \\ \nu_t^5 \end{bmatrix}$$

Next, THE observable equations that relate the system described above with the data are given by:

$$\begin{aligned} \Delta y_t &= \hat{y}_t - \hat{y}_{t-1} + \Delta X_t \\ r_t &= \hat{i}_t - \hat{\pi}_t \\ \Delta i_t &= \hat{i}_t - \hat{i}_{t-1} + \Delta X_t^m \\ \Delta \epsilon_t &= \hat{\epsilon}_t - \hat{\epsilon}_{t-1} + \Delta X_t^m - \Delta X_t^{m^*} \\ \Delta i_t^* &= \hat{i^*}_t - \hat{i^*}_{t-1} + \Delta X_t^{m^*} \end{aligned}$$

Next, we turn to the assumptions that allow us to identify the structural shocks in this model. In this exercise we are going to follow the same assumptions as Schmitt-Grohé and Uribe [2018]. We are going to assume that output is cointegrated with the non-stationary non-monetary process X_t^n. Domestic Inflation and the Nominal Interest Rate are cointegrated with X_t^m, and the Foreign Nominal Interest Rate is cointegrated with

X_t^{m*}[7]. Note, this set of assumptions implies that the real depreciation rate is stationary. Furthermore, we are going to make two sign-restriction assumptions. The first assumption is that a transitory increase in the interest rate ($\uparrow z_t^m$) has a non-positive impact on inflation. The second assumption is that a transitory increase in the interest rate ($\uparrow z_t^m$) has a non-positive impact on output. In other words, we assume that

$$C_{1,2} \leq 0, \quad C_{2,2} \leq 0$$

In order to be agnostic about the impact of permanent shocks, we assume that $C_{2,1}, C_{3,1}, C_{5,5}$ to have a prior mean set at -1. This implies that a priori, there is an equal probability of these shocks to have a positive or negative effect. Finally, we set $C_{3,2} = C_{1,4} = 1$ as a normalization. The next table presents the prior distribution of all coefficients estimated in the model.

Table 1: Prior Distributions

Parameter	Distribution	Mean	Std. Dev.
Main Diagonal elements of B_1	Normal	0.95	0.5
All other elements of B_i,$i = 1, \ldots, L$	Normal	0	0.25
C_{21}, C_{31}, C_{55}	Normal	-1	1
$-C_{12}, -C_{22}$	Gamma	1	1
All other estimated elements of C	Normal	0	1
ψ_{ii} for $i = 1, \ldots, 5$	Gamma	1	1
ρ_{ii} for $i = 1, \ldots, 5$	Beta	0.3	0.2
ρ_{44}	Beta	0.7	0.2
$R_{ii}, i = 1, \ldots 5$	Uniform $\left[0, \frac{\text{var}(o_t)}{10}\right]$	$\frac{\text{var}(o_t)}{10\text{x}2}$	$\frac{\text{var}(o_t)}{10\text{x}\sqrt{4}}$
Elements of A	Normal	$mean\,(o_t)$	$\sqrt{\frac{\text{var}(o_t)}{T}}$

Due to data availability problems I estimate this empirical model using data only for Argentina and Mexico. The lack of data at the quarterly frequency for Brazil, Chile and South Korea make the estimation of a large scale Bayesian model inaccurate and the results are too sensitive to priori distribution selection. Figures 14 to 18 present the results of the estimation for both Argentina and Mexico.

[7]Note that this assumptions imply that the variables are non-stationary. In particular, the assumption implies the variables follow a unit root process. In the Appendix A.1 test this hypothesis using the Augmented Dickey Fuller test.

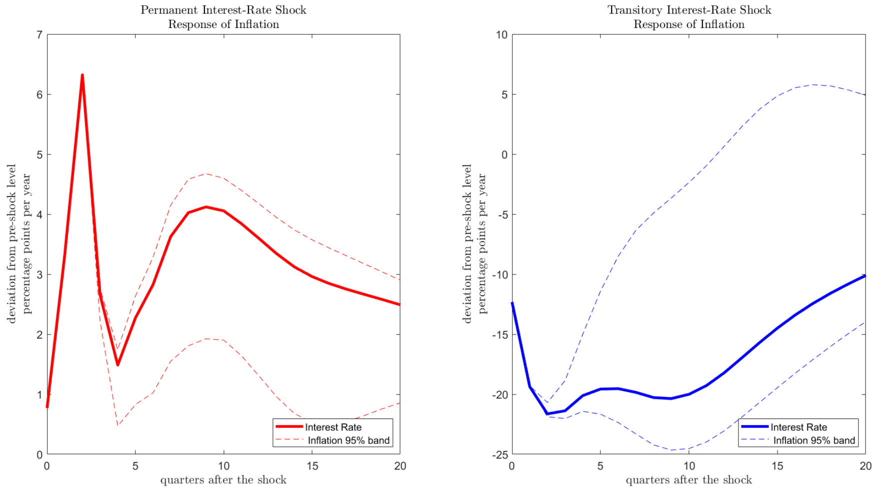


Figure 14: Impulse Response Function of Monetary Shocks: Argentina

Figures 14 and 15 show that permanent monetary shocks lead to a fast and big response of inflation, while transitory shocks lead to a drop in inflation on impact that continues persistently after.

Figure 16a and 16b show that permanent monetary shocks lead to a depreciation of the currency on impact but a mild impact on the real exchange rate. In other words, permanent monetary shocks does not affect substantially the relative prices in this economy. On the other hand, the figures show that transitory shocks lead to persistent real appreciations.

Finally, 16, 17 and 18 plot the estimated non observed monetary permanent component. Interestingly, we can observe from 16 and 17 that across the whole sample period, there is a high correlation or co-movement between the monetary permanent shock and inflation. Although, this co-movement weakens in the 1990s and in the first years after the 2001 crisis, the co-movement becomes stronger once inflation increases after the Great Recession. The data shows that for Mexico, permanent monetary shocks largely explain inflation during the country's nominally unstable period. However, since the Tequila Crisis and the adoption of an inflation targeting regime, the permanent monetary component became muted.

Hence, it seems that Argentina, still nominally unstable, exhibits relatively high

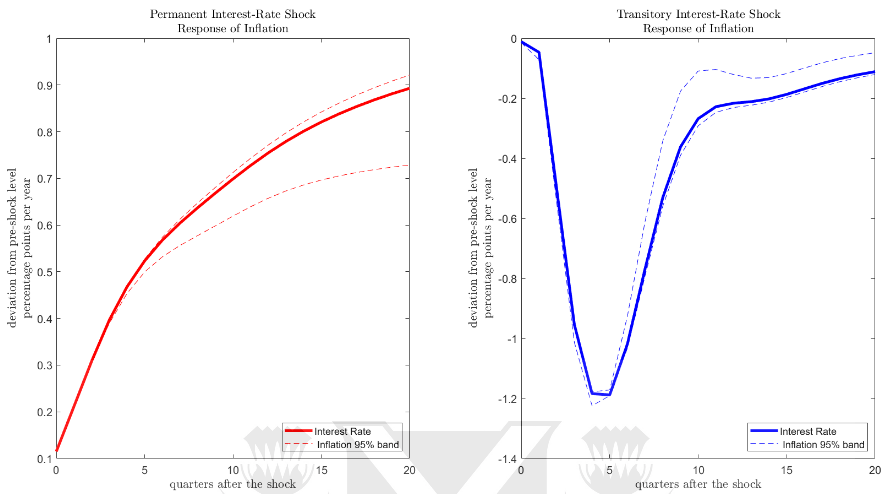
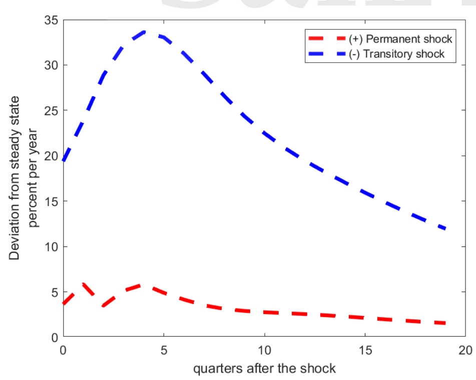
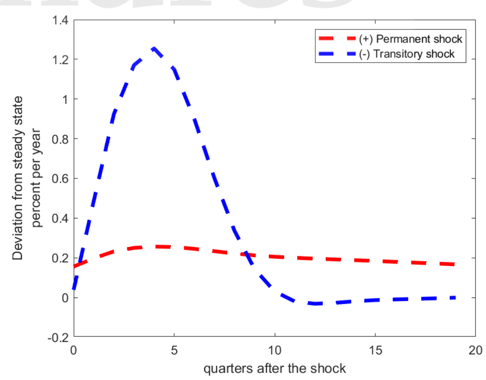


Figure 15: Impulse Response Function of Monetary Shocks: Mexico



(a) Argentina



(b) Mexico

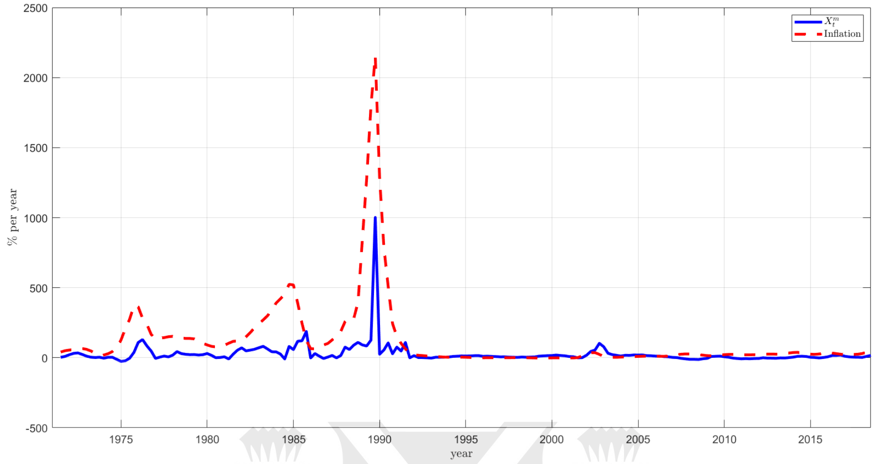


Figure 16: Permanent Monetary Component: Argentina

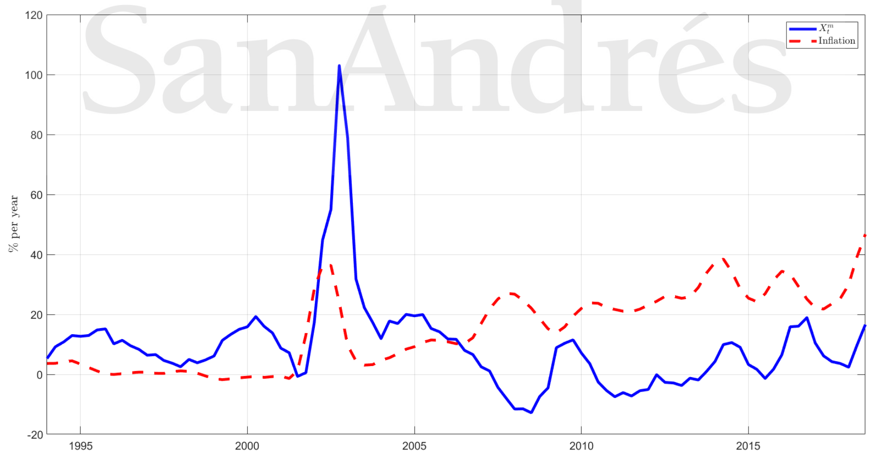


Figure 17: Permanent Monetary Component: Argentina 1995-2019

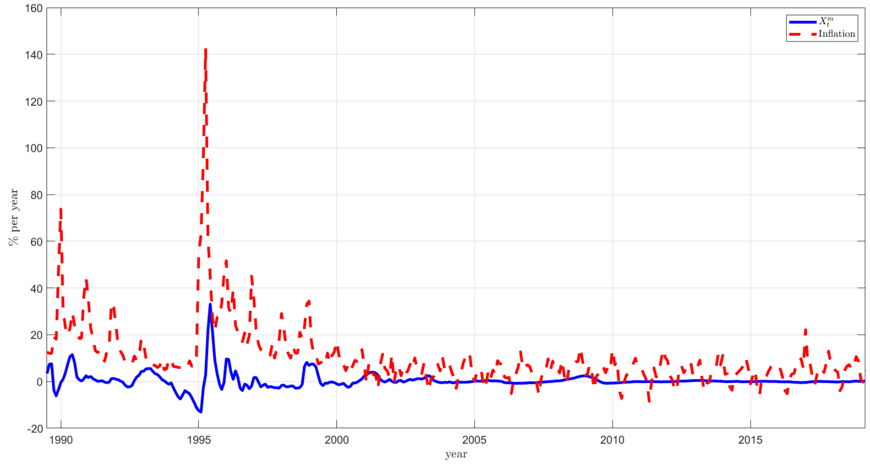


Figure 18: Permanent Monetary Component: Mexico

inflation explained mainly by recurrent permanent monetary shocks, while Mexico, who once experienced high inflation and has now achieved stabilization, exhibit relatively low inflation, explained by factors other than permanent shocks. In order to support this hypothesis, 2 and 3 present a Variance Decomposition analysis for both countries. This analysis also show that permanent monetary shocks explain largely the variance of inflation in Argentina, while stationary monetary shocks explain most of the variance of inflation in Mexico.

	GDP Growth Rate	Inflation	Interest Rate	Depreciation
X^m	17.32	92.64	13.10	11.08
z^m	19.12	0.1710	11.99	1.17
X^n	35.77	1.4045	0.45	1.53
z^n	0.079	0.001	0.017	0.001
X^{m*}	27.71	5.78	74.44	86.20

Table 2: State Space Model Variance Decomposition: Argentina

To summarize the results of this section, it seems that the non-structural empirical exercise seem to suggest the importance of both time-varying in the systemic and non-systemic part of the economy and also the importance of permanent monetary shocks. The next section, introduces an analytic framework to study the importance of these underlying

	GDP Growth Rate	Inflation	Interest Rate	Depreciation
X^m	0.12	7.96	2.78	11.98
z^m	0.21	70.45	10.93	3.32
X^n	92.42	0.045	0.08	0.22
z^n	7.23	21.52	86.13	76.31
X^{m*}	0.03	0.028	0.07	8.17

Table 3: State Space Model Variance Decomposition: Mexico

sources of nominal volatility.

4 A More Structural Analysis

In this section, we present a structural explanation of the empirical facts and regularities presented above. We estimate a simple New-Keynesian model, without capital nor labor market frictions. This model allows us to address the causes of the declines in volatility, persistence and predictability of inflation.

4.1 Model Description and Estimation

The analytical framework is that of a small open economy with a Home country and the rest of the world is summarized as a Foreign economy. In this subsection I present a summarized description of the model estimated in this paper. I leave a full description for the Appendix A.4.

Households maximize lifetime utility over consumption streams, hours worked and holdings of real balances:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, h_t, \frac{M_t}{P_t}\right) \tag{6}$$

where c_t is the consumption aggregator, h_t is hours worked, and M_t/P_t are holdings of real balances. Households maximize utility subject to the following budget constraint

$$P_t c_t + S_t D^*_{t-1} R^*_{t-1} + D_{t-1} R_{t-1} + M_t + T_t \leq W_t h_t + D_t + S_t D^*_t + M_{t-1} + \omega_t \tag{7}$$

where P_t is the aggregate price index, S_t is the spot nominal exchange rate, D^*_{t-1} are holdings of bonds in foreign currency, R^*_{t-1} is the interest rate on bonds in foreign currency fixed in period $t-1$, D_{t-1} are holdings of bonds in domestic currency, R_{t-1} is the interest rate on bonds in domestic currency fixed in period $t-1$, M_t are holdings of nominal balances, W_t are nominal wages and Ω_t are any profits coming from the ownership of the firms in this economy.

Consumption is an aggregator of intermediate goods produced both in the Home economy, C_t^H, and the Foreign economy, C_t^F:

$$c_t = \left[\omega^{\frac{1}{\eta}} \left(c_t^H\right)^{1-\frac{1}{\eta}} + (1-\omega)^{\frac{1}{\eta}} \left(c_t^F\right)^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{8}$$

In the Home economy, there is a continuum of intermediate goods indexed with j, each produced only with labor:

$$y_{jt}^H = z_t h_{jt} \tag{9}$$

where z_t is a productivity process common to the whole economy, and h_{jt} are hours worked in the production of variety j. Demand for each variety j is given by

$$y_{jt}^H = \left(\frac{P_{jt}^H}{P_t^H}\right)^{\epsilon} y_t^H \tag{10}$$

where ϵ is the elasticity of substitution across varieties.

I assume intermediate good producers face a Calvo pricing friction. With probability θ^H the firm is able to re-optimize their price. Given the history of nominal instability in the countries analyzed, I assume that if firms are not able to re-optimize their prices, they are able to fully index their prices to past inflation (i.e. $P_{jt}^H = \pi_{t-1} P_{jt-1}^H$). The Lagrangian of the firm's problem is

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} r_{t,t+s} P_{t+s}^H \left[\left(\frac{P_{j,t+s}^H}{P_{t+s}^H}\right)^{1-\epsilon} y_t^H - \frac{W_{t+s}}{P_{t+s}^H} h_{j,t+s} + \dots \right.\right.$$
$$\left.\left. + mc_{j,t+s}^H \left(z_{t+s} h_{j,t+s} \left(\frac{P_{j,t+s}^H}{P_{t+s}^H}\right)^{-\epsilon} y_t^H \right) \right] \right\}, \tag{11}$$

Next, we turn to variables of the Rest of the World or the Foreign economy. The world interest rate is given by:

$$R_t^* = R_t^W \exp\left[\phi\left(d_t^* - d_t\right)\right] \exp\left(\psi_t\right) \tag{12}$$

where $d_t^* \equiv D_t^*/P_t^*$ is the real value of debt in foreign currency. The world demand for home goods is

$$c_t^{H*} = \left(\frac{P_t^H}{S_t P_t^*}\right)^{-\eta^*} y_t^* \tag{13}$$

Monetary policy is assumed to follow a Taylor Rule of the form

$$\frac{R_t}{R} = \left(\frac{R_t}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi_t^T}\right)^{\alpha_\pi} \left(\frac{Y_t^H}{Y_{t-1}^H}\right)^{\alpha_y} \left(\frac{\pi_t^s}{\pi_{t-1}^s}\right)^{\alpha_{\pi^s}}\right] \exp(\epsilon_t^M) \tag{14}$$

where π_t is the consumer aggregator inflation rate, π_t^T is the inflation target in period t, and π_t^s is the nominal depreciation rate. Note, that I allow for time varying inflation target. Changes in the inflation target will represent permanent inflationary shocks. I allow for the inflation target to change through time, following an $AR(1)$ process:

$$\pi_t^T = \rho_0 + \rho_{\pi^T} \pi_{t-1}^T + \epsilon_t^T \tag{15}$$

Finally, it is noteworthy to present some market clearing conditions. Production of Home goods must be equal to Home consumption of Home goods and Foreign consumption of Home goods:

$$y_t^H = c_t^H + c_t^{H*} \tag{16}$$

We can write the economy wide budget constraint as

$$S_t D_{t-1}^* R_{t-1}^* - S_t D_t = P_t^H + C_t^{H*} - P_t^F C_t^F \tag{17}$$

where the left hand side represents changes in foreign bond holdings at the aggregate level and the right hand side presents the trade balance.

The economy has six exogenous driving forces: z_t, a stationary productivity process, R_t^W, a world interest rate shock, ψ_t, a risk premium shock, π_t^* is a foreign inflation shock, y_t^* is a foreign output shock, and ϵ_t^m is a domestic monetary policy shock. Each exogenous process is modeled as an $AR(1)$ process and their volatility is modeled as $AR(1)$ in logs. I follow Justiniano and Primiceri [2008] methodology to estimate time varying variance of the exogenous driving forces of the model.

4.2 Nominal Stabilization and Monetary Policy

I estimate the model described above using Bayesian techniques for both Argentina. I implement the MCMC methods using 10 chains for 10.000 replications each, dropping the first 20% replications as burn ins and ensure convergence. Table 4 presents the prior and posterior distributions for the main parameters estimated: the $AR(1)$ coefficients for the inflation target ρ_{π^T} and the stationary monetary policy shock ρ_{ϵ^m}, the inflation coefficient on the Monetary Policy Taylor rule ϕ^{π}, the level of the standard deviation of the inflation target and stationary shock $\sigma_s^{\pi^T} s$ and $\sigma_s^{\epsilon^m} s$, and the standard deviations for the volatility of these nominal shocks, s^{π^T} and s^{ϵ^m}.

Parameter	Prior Distribution			Posterior Distribution		
	Dist	Mean	Std	Mean	10%	90%
ρ_{π^T}	Beta	0.4	0.2	0.518	0.201	0.749
ρ_{ϵ^m}	Beta	0.6	0.2	0.223	0.05	0.44
ϕ^{π}	Normal	1.3	0.25	1.11	1.050	1.272
$\sigma_{ss}^{\pi^T}$	Inverse-Gamma	2	2	3.809	3.002	4.133
$\sigma_{ss}^{\epsilon^m}$	Inverse-Gamma	2	2	0.528	0.299	0.784
s^{π^T}	Inverse-Gamma	0.01	0.01ˆ2	0.167	0.144	0.192
s^{ϵ^m}	Inverse-Gamma	0.01	0.01ˆ2	0.045	0.022	0.079

Table 4: Bayesian Estimation: Argentina

The model estimation results go in line with the results found for the empirical models found above. For Argentina, permanent monetary shocks have bigger volatility and stationary monetary shocks, almost 8 times at the posterior mean. Furthermore, if we allow for time-varying volatilities, the standard deviations of the $AR(1)$ process for the volatilities are bigger for permanent shocks than for transitory shocks. Also, permanent monetary shocks are more persistent than transitory shocks and that monetary policy only reacts modestly towards inflation.

5 Conclusion

This paper analyzes the underlying sources of nominal stabilization in small open economies. In particular, this paper uses both empirical and structural frameworks to study how monetary policy shocks affect both nominal and real variables. Using data for five countries, I conducted TVP-SVAR analysis. Using data for Argentina and Mexico, I conducted a novel study of monetary policy in small open economies using a state space model that allows for both permanent and transitory shocks. Finally, using data for Argentina I tried to explain the reasons for the failure of nominal stabilization through an NK-DSGE model with stochastic volatilities.

The results show that the ability of monetary policy to affect inflation, output and real depreciations varied remarkably across time. As countries achieved nominal stabilization they were able to conduct real depreciations and decouple nominal and real exchange rates. Furthermore, both the state space model and the DSGE model seem to suggest that the lack of nominal stabilization in Argentina is due to the persistence of permanent monetary shocks. On the contrary, it seems that a key underlying driver of nominal stability in Mexico was how the permanent monetary component was muted down.

Looking forward, there are several robustness checks and extensions both necessary and of interest. First, the DSGE analysis should be extended to more countries. Second, the DSGE model implemented is small, or at best, medium scale. Hence, a larger scale model with more shocks and features should be studied. This could allow for a bigger role of financial and labor frictions, and or the role of government debt and default.

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A Appendix

A.1 Data Description

A.1.1 Data Description: Argentina

A.2 Testing for Stationary Time Series

In this appendix subsection I present evidence that support my claims over the the presence of trends in the variables used in the different models in Section 3

A.2.1 Testing for Stationary Time Series: Argentina

The following table 5 presents the p-value of the Augmented Dickey Fuller test for unit roots in time series for Argentinean Data

Variable	Implied p-value				
	ADF	+Drift	+4 Lags	+ 8 Lags	+12 Lags
CPI Inflation	0.0000	0.0000	0.0000	0.0001	0.0005
Nom. Int. Rate	0.0000	0.0000	0.2400	1.000	0.9885
NEER Dep Rate	0.0000	0.0000	0.0000	0.0001	0.0004
US FF Nom. Int. Rate	0.4552	0.0499	0.0143	0.0384	0.0704
GDP Growth Rate	0.0000	0.0000	0.0000	0.0010	0.0384

Table 5: Stationary Test for Argentina: Quarterly Data

A.2.2 Testing for Stationary Time Series: Mexico

The following table 6 presents the p-value of the Augmented Dickey Fuller test for unit roots in time series for Mexico Data

Variable	Implied p-value				
	ADF	+Drift	+4 Lags	+ 8 Lags	+12 Lags
CPI Inflation	0.0046	0.0002	0.0011	0.0079	0.0406
Nom. Int. Rate	0.0358	0.0016	0.0297	0.0764	0.0599
NEER Dep Rate	0.0000	0.0000	0.0000	0.0005	0.0044
US FF Nom. Int. Rate	0.4552	0.0499	0.0143	0.0384	0.0704
GDP Growth Rate	0.0000	0.0000	0.0000	0.0000	0.0002

Table 6: Stationary Test for Mexico: Monthly Data

A.3 TVP SVAR

This appendix presents the details of the paper introduced in the sub-section (3.1). Consider the model

$$y_t = c_t + B_{1,t}y_{t-1} + \ldots + B_{k,t}y_{t-k} + u_t \qquad t = 1, \ldots, T$$

where y_t is an n x 1 vector of observed endogenous variables; c_t is an n x 1 vector of time varying coefficients that multiply constant terms; $B_{i,t}$ for $i = 1, \ldots k$ are n x n matrices of time-varying coefficients; u_t are heteroscedastic unobservable shocks with variance covariance matrix Ω_t. Without loss of generality, consider the triangular reduction of Ω_t, defined by

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

where A_t is the lower triangular matrix

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha_{nn-1,t} & 1 \end{bmatrix}$$

and Σ_t is the diagonal matrix

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix}$$

It follows that

$$y_t = c_t + B_{1,t} y_{t-1} + \ldots + B_{k,t} y_{t-k} + A_t^{-1} \Sigma_t \epsilon_t \tag{18}$$
$$V(\epsilon_t) = I_n$$

Stacking in a vector B_t all the RHS coefficients, (18) can be written as

$$y_t = X_t' B_t + A_t^{-1} \Sigma_t \epsilon_t$$
$$X_t' = I_n \otimes \left[1, y_{t-1}', \ldots, y_{t-k}'\right]$$

Next, we turn to the specification of the time variation of the parameters in the model. Let α_t be the vector of non-zero and non-one elements of the matrix A_t and σ_t be the vector of the diagonal elements of the matrix Σ_t. The dynamics of the model's time varying parameters is specified as follows:

$$B_t = B_{t-1} + \nu_t$$
$$\alpha_t = \alpha_{t-1} + \zeta_t$$
$$\log \sigma_t = \log \sigma_{t-1} + \eta_t$$

All the innovations in the model are assumed to be jointly normally distributed with the following assumptions on the variance covariance matrix:

$$V = VAR\left(\begin{bmatrix} \epsilon_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix}$$

For further details on the model and the estimation procedure see Primiceri [2005].

A.3.1 TVP-SVAR: Stochastic Volatility Analysis

In this subsection, I present the stochastic volatilities estimated in the first econometric exercise of section 3.1.

A.4 SOE-NK DSGE Model

In this Appendix I describe the equilibrium conditions of the model studied in section 4.

A.4.1 Household Equilibrium Conditions

Let $\beta^t \lambda_t / P_t$ be the Lagrange multiplier of the Household's utility maximization problem. Then, the equilibrium conditions are

$$\begin{aligned} \lambda_t &= U'_{c,t} \\ w_t \lambda_t &= U'_{h,t} \\ \lambda_t &= \beta R_t \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \\ \lambda_t &= \beta R^*_t \mathbb{E}_t \left(\frac{\pi^s_{t+1} \lambda_{t+1}}{\pi_{t+1}} \right) \\ \frac{U'_{\frac{M}{P}}}{\lambda_t} &= 1 - R_t^{-1} \end{aligned} \tag{19}$$

where $w_t = W_t / P_t$. The stochastic discount factor for claims n domestic currency is

$$r_{t,t+s} = \beta^s \frac{\lambda_{t+s}}{\lambda_t} \frac{P_t}{P_{t+s}} \tag{20}$$

A.4.2 Firm's Equilibrium Conditions

Final consumption good production function and optimality conditions

$$\begin{aligned} c_t &= \left[\omega^{\frac{1}{\eta}} \left(c^H_t \right)^{1-\frac{1}{\eta}} + (1-\omega)^{\frac{1}{\eta}} \left(c^F_t \right)^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \\ c^F_t &= (1-\omega) \left(p^F_t \right)^{-\eta} c_t \\ c^H_t &= \omega \left(p^H_t \right)^{-\eta} c_t \end{aligned} \tag{21}$$

where $p^F_t \equiv P^F_t / P_t$ and $p^H_t \equiv P^H_t / P_t$. The optimality conditionf for labor demand is

$$p^H_t mc^H_t z_t = w_t \tag{22}$$

The for pricing optimality conditions, given 11, is

$$1 = \theta \left(\frac{\pi^H_t}{\pi_t} \right)^{\eta-1} + (1-\theta) \left(\tilde{p}^H_t \right)^{1-\eta} \tag{23}$$

where $\tilde{p}^H_t \equiv \tilde{P}^H_t / P_t$ and $\pi^H_t \equiv P^H_t / P^H_{t-1}$

A.4.3 Rest of the World Equilibrium Conditions

$$R_t^* = R_t^W \exp\left[\phi\left(d_t^* - d_t\right)\right] \exp\left(\psi_t\right) \tag{24}$$

where $d_t \equiv D_t^*/P_t^*$. The local price of foreign goods $\left(P_t^F\right)$ satisfies the law of one price $P_t^F = S_t P_t^*$. If we define the real exchange rate as $rer_t = S_t P_t^*/P_t$ then,

$$rer_t = p_t^F \tag{25}$$

The world demand for home goods is

$$c_t^{H*} = \left(\frac{P_t^H}{S_t P_t^*}\right)^{-\eta^*} y_t^* = \left(\frac{p_t^H}{rer_t}\right)^{-\eta^*} y_t^* \tag{26}$$

A.4.4 Aggregation and Market Clearing

Market clearing conditions:

$$\begin{aligned} y_t^H &= c_t^H + c_t^{H*} \\ y_t^H &= z_t h_t \end{aligned} \tag{27}$$

Also, the following conditions must be satisfied that relate some rates of inflation with relative prices

$$\begin{aligned} \frac{p_t^H}{p_{t-1}^H} &= \frac{\pi_t^H}{\pi_t} \\ \frac{rer_t}{rer_{t-1}} &= \frac{\pi_t^s \pi_t^*}{\pi_t} \end{aligned} \tag{28}$$

where $\pi_t^* \equiv P_t^*/P_{t-1}^*$