Prices Stability and Macroeconomic Volatility Spillovers in Latin America *

Camilo Granados †

University of Texas at Dallas

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Abstract

In order to determine the presence of volatility spillovers among macroeconomic variables a Vector Autorregresive (VAR) model with multivariate heteroskedasticity effects is carried out for five countries in Latin America. The variables considered are real activity, price level, interest rate, and exchange rate. The results indicate that there are few within country volatility spillovers. Those that are significant are usually sizable and point to the relevance of international shocks in spreading volatility to other countries rather than local effects. Finally, we obtain that the volatility of inflation is not generally affected by the uncertainty shocks in the exchange rate, this result is noticeable as the price instability effects of the exchange rate fluctuations is usually the justification behind exchange rate intervention programs in these economies.

Key words: Macroeconomic volatility, volatility spillovers, price stability, Multivariate GARCH, Variance Causality.

JEL Codes: E31, E52, F42, Q17, Q43.

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†School of Economic, Political and Policy Sciences, University of Texas at Dallas. Richardson, TX 75080, USA. Email: camilo.granados@utdallas.edu

1 Introduction

Economic policy objectives include managing both the level and volatility of macroeconomic variables. In the last decades many countries implemented the inflation targeting regime to aim moderate and stable prices. Similarly, stability of the product and exchange rates, among other fundamentals, can be deemed as desirable.

On the other hand, central banks have engaged in direct intervention to the currency market. Arguably, because a lower volatility of exchange rate implies a more stable inflation, which is aligned with the inflation targeting objectives. But at the same time, theoretical benchmarks as Galí and Monacelli (2005) associate the most stable exchange rate regime with higher volatility in the rest of fundamentals and lower welfare losses.

Overall, in countries with limited passthrough from exchange rate to prices, is still not clear at what extent such link between the volatilities is significant and what direction follows.

To shed the light of data evidence, we empirically explore such associations in volatilities by applying causality tests in variance to a system of four macro variables (GDM, nominal interest rate, CPI and exchange rate) for five countries in Latin America. The methodology is based on a VAR model with heterosckedastic errors that are modelled using a stochastic volatiliy model (SVM). Additionally, from the reduced estimation we also compute impulse response functions.

We aim to facilitate answering questions as: Does the exchange rate volatility affect the inflation and output volatility?, How sensible is the stability of the macroeconomic variables to the variability of the interest rate?. At least, based on literature supporting either view, we argue that both the specific structure of each country as well as the particular assumptions of the model used can lead to different answers in each case, which makes relevant a multi country exersice relying on the data evidence, like the one carried out in this document.

Related literature. This paper is related to the literature focusing on the relationship between economic fundamentals driven by higher order moment effects, and in particular second order effects that capture volatility spillovers working through uncertainty shocks. In conventional pre-Global Financial Crisis (GFC) approaches, the second order moments where overseen and abstracted from modeling analyses. However, the relevance of these effects became more evident after the crisis episode, and has been thereby incorporated to theoretical and empirical macroeconomic frameworks, for example, in a seminal contribution Fernandez-Villaverde et al. (2011) use a DSGE setup to show that volatility dynamics can generate spillovers to the real variables in the economy.

In contrast, volatily has usually been a subject of study in finance and later in econometrics with the contributions of Engle (1982) and Bollerslev (1986). The application of this literature and subsequent developments have been majoritarily applied to financial returns modelling. The initial methodologies were meant to correct for a time varying variance so that inference based on estimates of the second moments could be correctly approximated. Posterior metholologies, allow for multivariate frameworks so that evaluating the extent in which the volatility is affected but the degree of uncertainty other variables becomes feasible.

In any case, typically, the volatility spillovers studies were still focused on variance transmission between financial variables. For example Diebold and Yilmaz (2009) and Ng (2000). These models are estimated by using multivariate GARCH setups, later in the methodology it will be mentioned how such approach limits the number of variables they can include. Similarly, in a multicountry setup, Engle et al. (2012, REStats) study the volatility to volatility effects across asian countries stock indexes.

Simultaneously, on the theoretical side, studies like Uribe and Yue (2006), find that external interest rate shocks amplifies the volatility of macroeconomic fundamentals in EMEs. Then, based on these results, the effects are not only financial but also economic in general. In that line, several studies started testing spillovers from financial variables to macroeconomic fundamentals.

Some examples are Apostolou and Beirne (2017) that study the macroeconomic volatility spillover effects from movements in the conditional variances of the FED and ECB balance sheets.

Finally, within country studies have also been implemented; Fountas et al. (2006) and Karanasos and Zeng (2013) check for volatility spillovers between prices and output in UK. Belgacem et al. (2015) check for volatility spillovers of macroeconomic anouncements in the stock and commodity prices, and Hegerty (2016) that uses a VAR-GARCH approach with macro variables and commodity prices to check for volatility spillovers in nine countries.

Our documents builds on such approaches by simplifying the technique to approach the multivariate spillovers. That is done by departing from GARCH modelling and adopting an Stochastic Volatility Model (SVM). Such approach breaks limitation in the number of variables or lag structure that we can use as well in the computational problems associated with parameter restrictions and positive definiteness of the variance matrix in GARCH models.

The paper is organized as follows, after this introduction, the methodology implemented is explained in the second section, then the results are shown in the third section, and in the fifth one we conclude.

2 Methodology

Algorithm 1 Estimation (VAR-SVM)

1: VAR estimation on X_t then obtain errors.
2: With the errors e_t estimate a Stochastic Volatility Model (SVM)
3: Obtain the conditional variances and perform Causality tests among them using a VAR.

The summarized methodology is described in the algorithm 1. For the current exercise we follow a monetary VAR structure (Christiano et al. (1996b), Christiano et al. (1996a) and Bernanke and Mihov (1995)) :

$$X_t = \begin{bmatrix} y_t \\ p_t \\ i_t \\ er_t \end{bmatrix}, \qquad \Phi(L)X_t = \mathbf{e_t}, \qquad e_t \sim N(0, \Sigma_{t|t-1}) \tag{1}$$

Where y_t is the GDP, p_t is the CPI, i_t is the nominal interest rate and er_t is the exchange rate.

We depart from a non correlated process (e_t), that still could display non linear dependence, reflected in a time varying conditional variance:

$$\begin{aligned} y_t &= \mu_t + e_t & \qquad e_t &\sim N(0, \sigma^2_{t|t-1}) \\ e_t &= \sigma_{t|t-1}\varepsilon_t & \qquad \varepsilon_t &\sim i.i.d.(0,1) \end{aligned}$$

where ε_t is the standarized error term. This is modeled in a GARCH as:

$$\sigma^2_{t|t-1} = \gamma_0 + \gamma_1 e^2_{t-1} + \cdots + \gamma_q e^2_{t-q} + \beta_1 \sigma^2_{t-1} + \cdots + \beta_m \sigma^2_{t-m}$$

With conditional variance given by: $\sigma^2_u = \frac{\gamma_0}{1-\gamma_1+\cdots+\gamma_q+\beta_1+\cdots+\beta_m}$ and $\gamma_1 + \cdots + \gamma_q + \beta_1 +$

$\cdots + \beta_m < 1$

A multivariate framework applies the same approach but to a vector of errors with the advantage of being able to check for volatility spillovers between variables,

$$\begin{aligned} \mathbf{y_t} &= \boldsymbol{\mu}_t + \boldsymbol{e}_t \\ \boldsymbol{e}_t &= \mathbf{H_t}^{1/2}\mathbf{z_t} \qquad\qquad E(\mathbf{z_t}) = 0, \quad var(\mathbf{z_t}) = \mathbf{I}_N \end{aligned}$$

with conditional variance given by:

$$\begin{aligned} var(\mathbf{y_t}|\Psi_{t-1}) = var_{t-1}(\mathbf{y_t}) = var_{t-1}(e_t) &= \mathbf{H_t^{1/2}} var_{t-1}(\mathbf{z_t}) \left(\mathbf{H_t^{1/2}}\right)' \\ &= \mathbf{H_t} \end{aligned}$$

The difference between several types of GARCH is based in the way to model $\mathbf{H_t}$. This is usually complicated, being one of the most challenging problems to obtain an invertible and positive semi-definite matrix at every t. Possible modelling approaches are:

1. Direct: $\mathbf{H_t}$: Generalization of the univariate GARCH equation (VEC y BEKK).
2. Factor models: variance of $\mathbf{e}_t$ is generated by unobserved heteroskedastic factors that are independent (O-GARCH, GO-GARCH).
3. Separated modelling of conditional variances and correlations (CCC, DCC)

The direct approach generalizes the results from the usual model but implies the estimation of a large number of parameters and a well defined (invertible) variance matrix for all periods. The second are parsimonious approaches but less helpful for studying volatility spillovers since factors are extracted from the volatilities and the third one represent a more simplified version, also less computational costly than the rest but not necessarily as general as the SVM neither as convenient for estimation.

Given how complicated may be to model H_t, we shift to a SVM in which positive definitiness is also achieved with the added benefit involving a simpler estimation:

$$\begin{aligned} e_t &= \sigma_t \epsilon_t, \qquad \epsilon_t \sim N(0,1) \\ e_t^2 &= \sigma_t^2 \epsilon_t^2 \\ \ln e_t^2 &= \ln \sigma_t^2 + \ln \epsilon_t^2 \end{aligned}$$

with: $\ln \sigma_t^2 = \phi \ln \sigma_{t-1}^2 + v_t, \qquad v_t \sim N(0, \sigma_v^2)$

here we departed from the residuals of the model and decompose it in its parts.

Let $z_t = \ln e_t^2$, $x_t = \ln \sigma_t^2$. Then the SVM can be expressed as a Unobserved components model:

$$\begin{aligned} z_t &= \alpha + x_t + u_t, \qquad \ln \epsilon_t^2 - \alpha \sim \log \chi^2_{(df)} \\ x_t &= \phi x_{t-1} + v_t \end{aligned}$$

A reduced form model for z_t is an ARMA(1,1):

$$z_t = \tilde{\alpha} + \phi z_{t-1} + w_t - \theta w_{t-1}, \qquad w_t \sim N(0, \sigma_w^2)$$

However, we can approximate the Moving Average part by estimating a higher order AR process, that will be more useful when dealing with a multivariate framework:

$$\underbrace{z_t}_{\ln e_t^2} = \tilde{\alpha} + \underbrace{\sum_{i=1}^{p} \phi_i z_{t-1}}_{\ln \sigma_t^2} + w_t \tag{2}$$

This model still implies estimating many parameters and by including more lags indentification issues may arise.

For the multivariate case Departing from: $\mathbf{e_t} = \text{Chol}(\Sigma_t)\boldsymbol{\epsilon}_t$

The corresponding multivariate the reduced form model is a VARMA(1,1):

$$\mathbf{z_t} = \tilde{\boldsymbol{\alpha}} + \Phi \mathbf{Z_{t-1}} + \mathbf{w_t} - \Theta \mathbf{w_{t-1}}, \qquad \mathbf{w_t} \sim N(0, \Sigma_w^2)$$

the higher order autorregresive approximation is a VAR(P),

$$\mathbf{z_t} = \tilde{\boldsymbol{\alpha}} + \sum_{i=1}^{p} \Phi_i \mathbf{z_{t-1}} + \mathbf{w_t} \tag{3}$$

with $\mathbf{z_t} = [\ln e_{1t}^2 \;\; \ln e_{2t}^2 \;\; \ldots \ln e_{kt}^2]'$

The equation (3) will be expression we use to check for volatility spillovers through Granger Causality tests and impulse response functions.

In that spirit, the Granger causality can be denoted in terms of conditional expectations.

x_t Granger causes z_t if:

$$E(z_{t+1}|z_t, z_{t-1}, \dots) \neq E(z_{t+1}|z_t, z_{t-1}, \dots, x_t, x_{t-1}, \dots)$$

This definition can be extended to higher order moments:

$$E(z^r_{t+1}|z_t, z_{t-1}, \dots) \neq E(z^r_{t+1}|z_t, z_{t-1}, \dots, x_t, x_{t-1}, \dots)$$

$r = 2$ would correspond to the variance causality case. The conditional variance of z_t is predicted by using the information provided by x_t.

2.1 Data

The table 1 summarizes the data used and their sources. It should be noticed that the model is montly while the GDP is quarterly. Here instead of using directly activity variables as the Industrial Production Index (IPI), we carry out a time series decomposition following the method of Santos Silva and Cardoso (2001) to obtain a montly GDP using the IPI as input.

Table 1: Data used and sources

Country	Period	Variable	Description	Fuente
Colombia	1982M01 - 2013M12	**y**	GDP	DANE
		p	CPI	DANE
		i	3-months deposits interest rate	Banco de la República
		er	Exchange rate COP/USD	Banco de la República
Chile	1991M01 - 2013M12	**y**	GDP	SOSOFA
		p	CPI	Banco Central de Chile
		i	3-months deposits interest rate	Banco Central de Chile
		er	Exchange rate CLP/USD	Banco Central de Chile
Brasil	1999M01 - 2013M12	**y**	GDP	Banco Central de Brasil
		p	CPI	IBGE
		i	SELIC rate	Bloomberg
		er	Exchange rate BRL/USD	Bloomberg
Perú	1995M01 - 2013M12	**y**	GDP	INEI
		p	CPI	INEI
		i	3-months deposits Interest rate	Banco Central de Reserva del Perú
		er	Exchange rate PEN/USD	Bloomberg
México	1998M01 - 2013M12	**y**	GDP	INEGI
		p	CPI	Banco Central de México
		i	3-months deposits Interest rate	Banco Central de México
		er	Exchange rate MXN/USD	Bloomberg

The exercise is focused on inflation targeting countries with floating exchange rate. However, the sample in each case may cover more than one exchange regime. To control for that we include exchange rate regime dummies in each case and according to table 2.

Table 2: Exchange Rate Regimes in these countries

País	Regimes	Description and period	Source
Colombia	4	1) Crawling-peg: 1967.06 -1991.06 2) Trade certificates: 1991.06 - 1994.02 3) Currency Bands: 1994.02 - 1999.09 4) Floating: 1999.10 - currently	Villar and Rincón (2001)
Chile	4	1) Fixed Exchange Rate: 1970 - 1982.09 2) Crawling-peg: 1982.09 - 1984.07 3) Currency Bands:1984.09 - 1999.09 4) Floating: 1999.10 - currently	Jalil et al. (2006)
Brasil	3	1) Fixed Exchange Rate: 1980 - 1994.10 2) Semi-fixedExchange Rate: 1994.11 -1998.12 3) Floating: 1999.01 - currently	Reisen and Grandes (2005)
Peru	2	1) Controlled Exchange Regime: 1980 - 1990.07 2) Managed Floating:1990.08 - currently	Chang and Lupu, [2011]
Mexico	5	1) Controlled Floating: 1976.09 - 1982.08 2) Controlle Exchange rate: 1982.08 - 1985.07 3) Regulated Floating: 1985.09 - 1991.10 4) Currency Bands: 1991.11 - 1994.12 5) Floating: 1994.12 - currently	Bank of Mexico [2009]

3 Results

The main body of the document contains tests for all countries but only the graphs for Colombia for presentation simplicity. The remaining graphical results, are in the appendix B.

To begin with we model the mean of the system of variables. This is done in all cases with a VAR in levels which remains valid although the variables have unit root according to Hamilton [1994], p. 651. The lags are chosen according to the BIC information criterion. We obtain non correlated errors in each case and perform tests of heteroskedasticity, whose results are shown in table 3. In all cases we find evidence of heteroskedasticity in more than one variable, except in Mexico. That is consistent with the multivariate GARCH effects tests that is rejected in all cases but Mexico. The multivariate GARCH effects rejection represents the first sign of volatility spillovers in the data.

Table 3: GARCH effects test

Country	Variable	LM(1)	LM(2)	LM(4)	multivariate GARCH effects
COL	**y**	0.000	0.000	0.000	
	p	0.166	0.002	0.009	Statistic=682.3 gl=500
	i	0.231	0.171	0.127	p.value=0.000
	er	0.000	0.000	0.000	
CH	**y**	0.000	0.000	0.000	
	p	0.421	0.657	0.828	Statistic=735.5 gl=500
	i	0.000	0.000	0.000	p.value=0.000
	er	0.118	0.288	0.557	
BR	**y**	0.003	0.011	0.004	
	p	0.913	0.267	0.278	Statistic=640.9 gl=500
	i	0.959	0.108	0.298	p.value=0.000
	er	0.096	0.239	0.430	
PE	**y**	0.000	0.000	0.000	
	p	0.869	0.763	0.977	Statistic=664.24 gl=500
	i	0.264	0.269	0.291	p.value=0.000
	er	0.001	0.000	0.000	
MX	**y**	0.466	0.717	0.488	
	p	0.798	0.820	0.394	Statistic=537.34 gl=500
	i	0.001	0.001	0.000	p.value=0.1203
	er	0.942	0.576	0.757	

The multivariate test is based on Doornik and Hendry (1997), as shown in Lutkepohl (2005).

However, as mentioned before, mostly want to use the GARCH tests to check for heteroskedasticity and the SVM model to check for the volatility spillovers. The causality tests are carried out based on equation (3) and the results shown in table 4. Our findings suggest that in the case of Colombia we find spillovers originating from the interest rate and weakly from the output (at the 10% of significance). However we find some short run, i.e., instantaneous spillovers from the other variables. Peru is a similar case, there we find output and interest rate volatility spillovers and short term effects in prices and interest rate too. For the rest of the countries we find spillovers originating from the output only or no spillovers at all for Mexico.

Table 4: Causality tests in variance

Country	Variable	Granger	Instantaneous
COL	y	0.097	0.012
	p	0.505	0.008
	i	0.000	0.353
	er	0.291	0.065
CH	y	0.291	0.082
	p	0.844	0.691
	i	0.328	0.204
	er	0.785	0.801
BR	y	0.037	0.515
	p	0.426	0.414
	i	0.235	0.738
	er	0.486	0.600
PE	y	0.037	0.678
	p	0.505	0.046
	i	0.003	0.049
	er	0.041	0.726
MX	y	0.506	0.952
	p	0.908	0.927
	i	0.166	0.964
	er	0.109	0.941

H0: the variable does not cause the rest of the system

The causality tests give a broad measure of volatility spillovers but does not indicate the dynamics that they follow. For that we can check the impulse response functions (IRF). For colombia the IRF is reported in graph 1. The results show some short term effects of output volatility in prices and the interest rate. More noticeable, the interest rate has a permanent significant volatility spillover on the exchange rate. The effect is positive, suggesting that more volatility in the interest rate is followed by an increase in the volatility of the exchange rate.

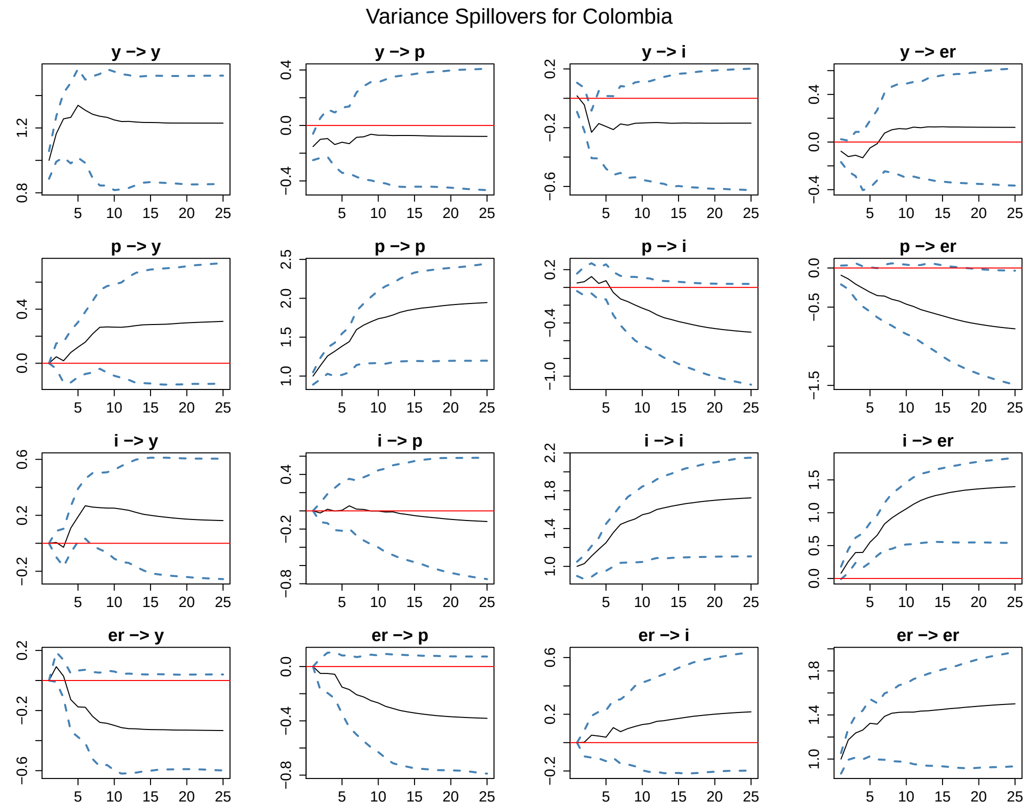

Figure 1: Volatility Spillovers for Colombia (cumulative IRF)

For the rest of the countries, the IRF are reported in the graphs 7-10 in the appendix B. The results are similar, for the most part the presence of volatility spillovers is not general. At the same time, there are several significant effects at all lags that involve output volatility spillovers to the interest rate in the case of chile or to the exchange rate for Brazil.

Finally there are also some short term effects that are reflected more variedly and originate from the exchange rate and interest rates. Then, it seems that the most important volatility links in these economies usually involve the variables that are included in the UIP and have some financial feature.

In the short run these variables are the one originating the spillovers but such effect fades away quickly whereas the real variables exert a lasting effect in the volatility of both interest rate and exchange rate. Mexico as an exception is a country where no significant long run spillovers are found, and only a short term response from the output to the exchange rate is seen.

The results suggest that the spillovers among local variables are non significant, leaving most of the volatilty amplifying role to variables that are more linked with the international markets and shocks. This is an interest feature consistent with literature findings that emphasize in the importance of international volatility shocks in the economy (for example Uribe and Yue (2006), and Kaminsky et al. (2003)).

4 Extensions and future research

Part of the results and literature point to the higher relative importance of the volatility spillovers of the international shocks. In addition, the current results and evidence help decide whether or not each country experiences important internal spillovers.

From the results, we can now apply, for each case, an apropriate methodology to estimate a country-wise macroeconomic volatility indicator, i.e., when we don't find internal spillovers as in Mexico we can take a summarized indicator of the individual volatilities like the first principal component of the conditional variances. Conversely, for the significant spillover case we would prefer to consider the dynamics of the whole conditional covariance matrix of the system, for which we would have to estimate it and obtain an indicator from it that summarizes the whole variance (including off-diagonal elements), for example the determinant of the matrix.

Once the country indicators are constructed we can apply the same exercise as in the previous section and check for the existence of international regional volatility spillovers, which themselves represent an interest question and a contribution to the literature since for now the cross-country applications are based mostly in stock market aggregates and other financial variables, rather than macroeconomic fundamentals.

On the other hand, this model can be amplified to account for a better modelling of the mean, i.e., we can include the money stock in each case and use an SVAR model to identify a monetary policy shock as in Kim (2003). This approach is appealing since the additional cost of modifying the model is not high, also it can be further modified to include even more variables as commodity prices indexes or financial markets aggregate indicators.

All of these modifications are a possible route for further developments of this exercise.

5 Conclusions

This document provides an empirical check for the presence of within country macroeconomic volatility spillovers for five economies in Latin-America. We consider this a relevant exercise motivated in the mixed evidence suggesting the presence of such effects in inflation targeting countries with floating exchange regimes.

Globally, the tests indicate the presence of spillovers and the causality test suggest it comes either from the interest rates or output and mostly affecting the interest rate and exchange rate. There are several other effects in the short run coming from variables as the prices.

When we look at the dynamic effect, reflected in the IRF, we check that the interest rate are exchange rate are subject to volatility spillovers coming from the output and also exert effects on each other at different terms, depending on the country. We find remarkable that most of the effects involve either the interest rate or the exchange rate.

In summary the results point to the existence of time varying volatilities but lack of crossed effects in most of the cases except those including variables such as the interest rate and the exchange rate. In our view, this represents an interest result that suggests the higher relative importance of international volatility spillovers rather than internal. This is backed by theory as well as in Uribe and Yue (2006) and Kaminsky et al. (2003).

In such sense, a future research effort in the direction of checking for international volatility links could be worth pursuing.

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A Log Returns of the models

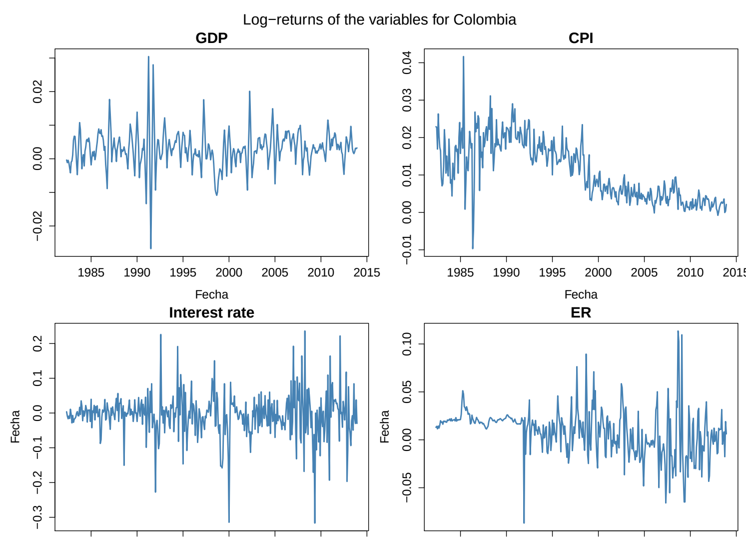

Figure 2: Returns of the variables for Colombia.

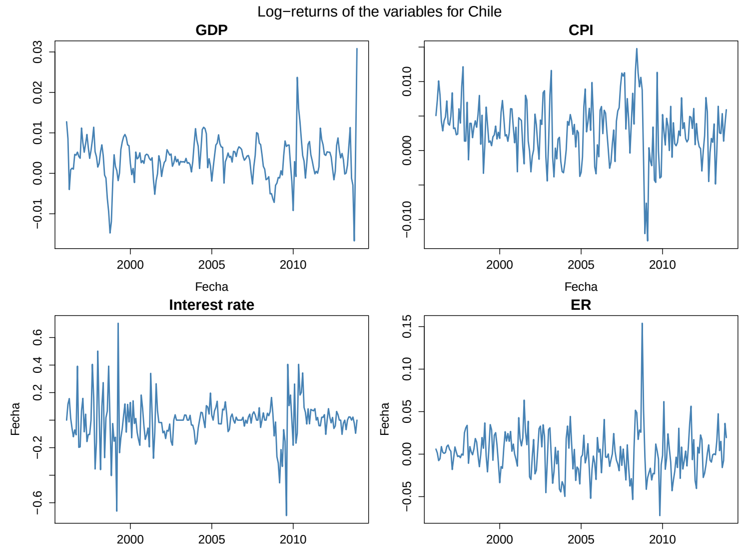

Figure 3: Returns of the variables for Chile.

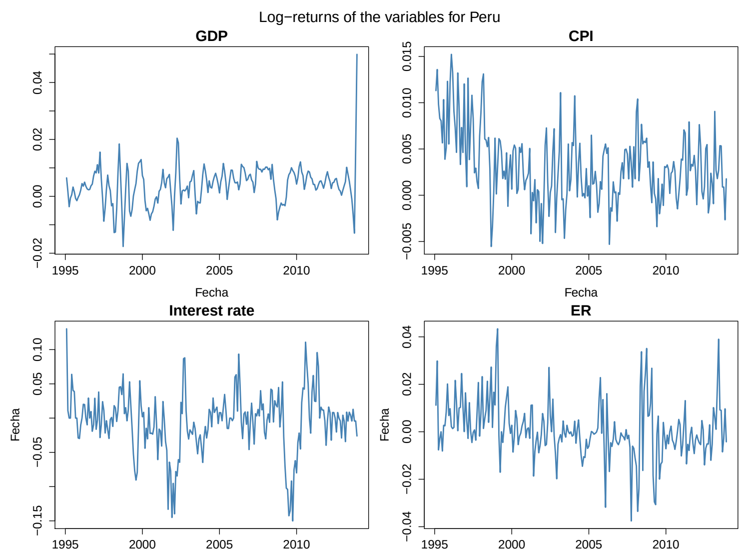

Figure 4: Returns of the variables for Peru.

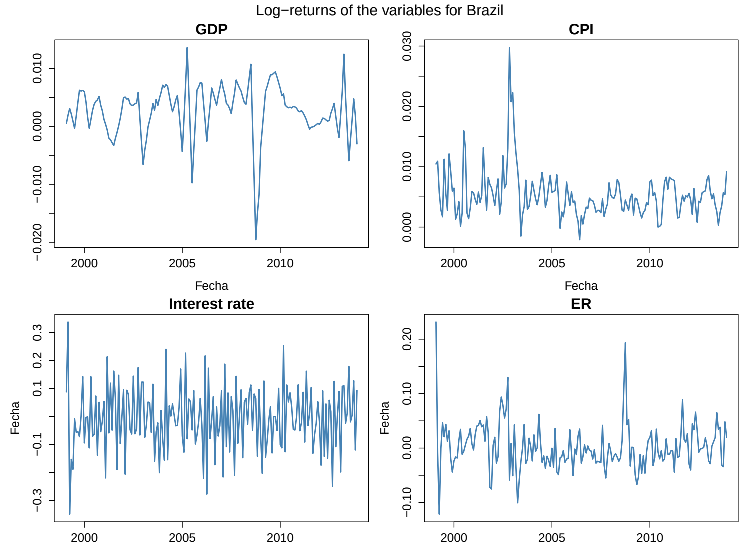

Figure 5: Returns of the variables for Brazil.

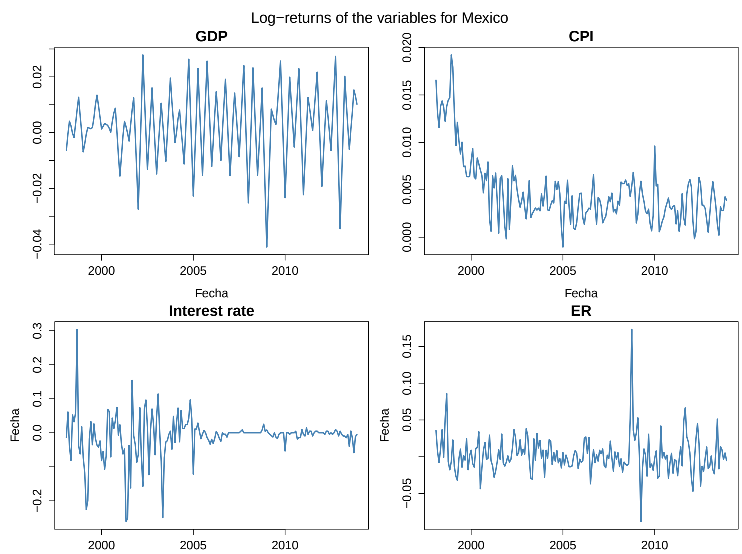

Figure 6: Returns of the variables for Mexico.

B Impulse response functions for the SVM model

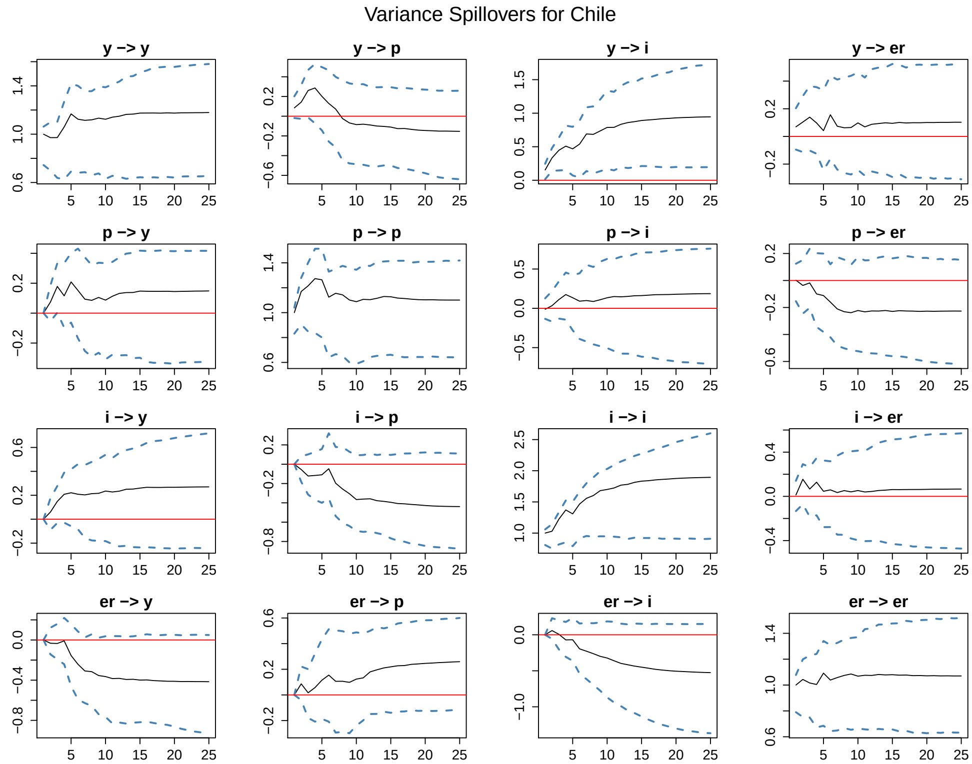

Figure 7: Volatility Spillovers for Chile (cumulative IRF)

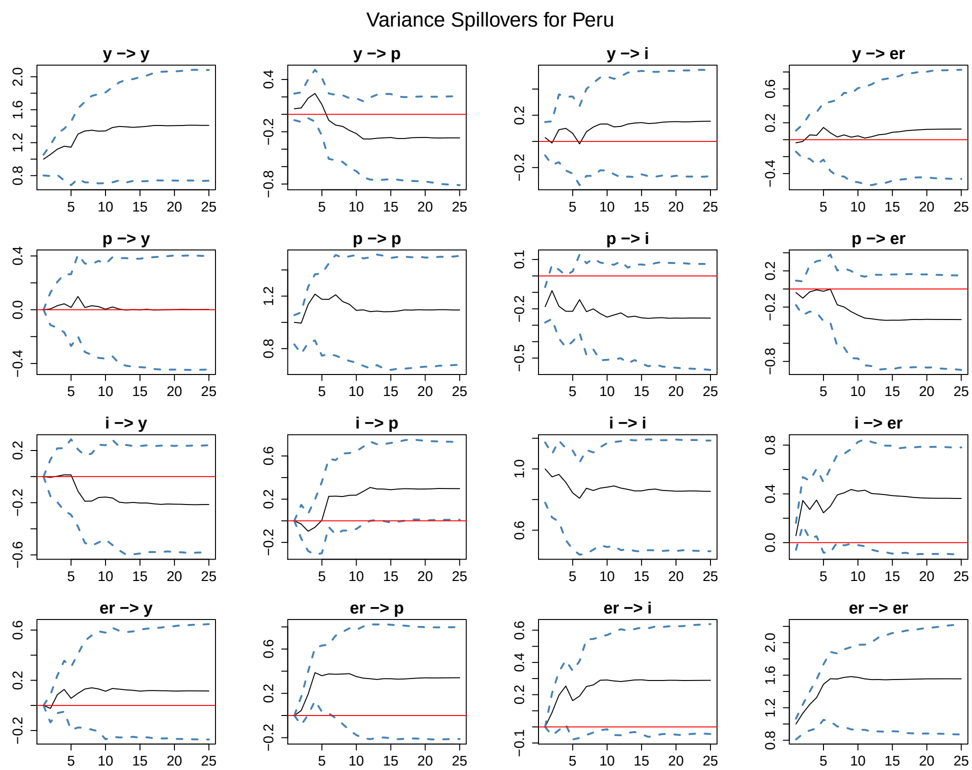

Figure 8: Volatility Spillovers for Peru (cumulative IRF)

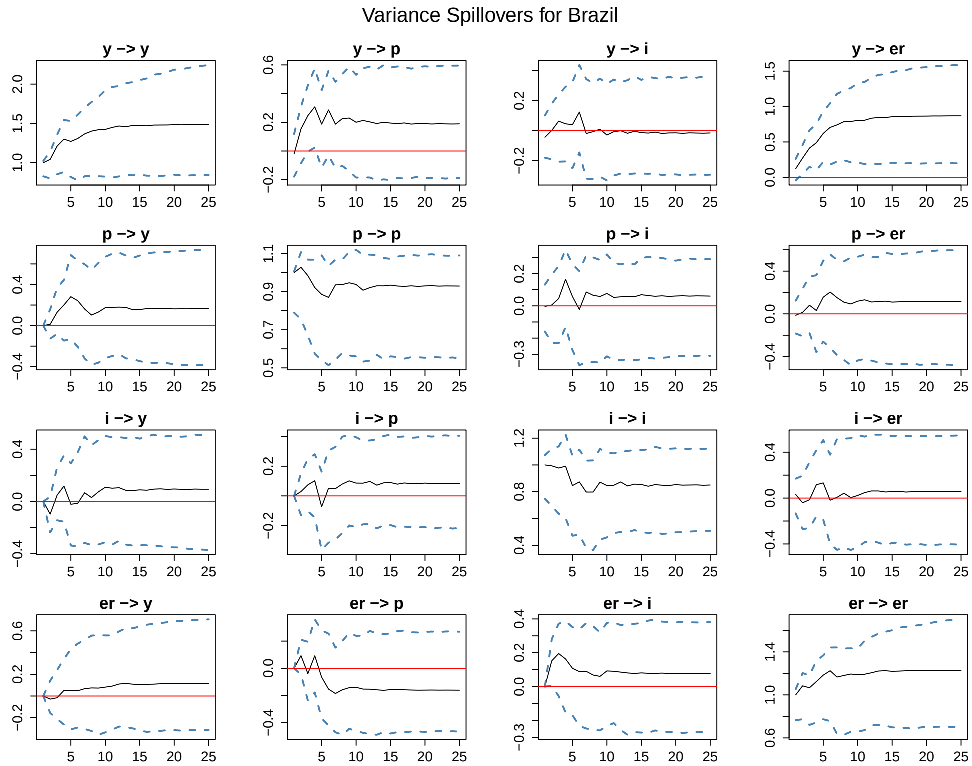

Figure 9: Volatility Spillovers for Brazil (cumulative IRF)

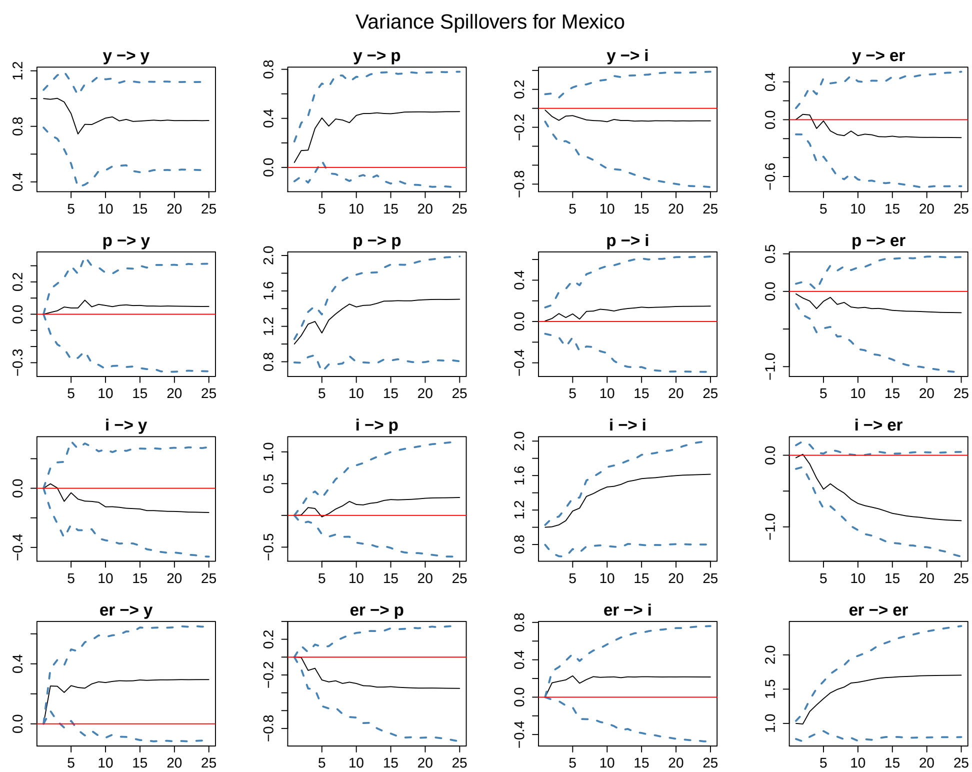

Figure 10: Volatility Spillovers for Mexico (cumulative IRF)