THE EFFECTS OF U.S. MONETARY POLICY SHOCKS ON LATIN AMERICAN ECONOMIES

Área 4 - Macroeconomia, Economia Monetária e Finanças

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Resumo: Nas duas últimas décadas, a literatura empírica mostrou que as economias emergentes são suscetíveis a choques externos. Um fator que poderia desempenhar um papel importante na determinação da política dos bancos centrais das economias emergentes é a política monetária do Federal Reserve. Este artigo tem como objetivo estimar a ocorrência de spillovers da política monetária dos Estados Unidos nas taxas de juros da política monetária de países da América Latina. Os resultados encontrados sugerem que os choques da política monetária originados pelo Federal Reserve são uma importante fonte de flutuações na política monetária interna dos países da América Latina. Há também, um transbordamento regional ainda maior entre as próprias economias da América Latina.

Palavras-chaves: Transbordamento de Política Monetária, Taxa de Juros, Política Monetária, América Latina.

Abstract: Over the last two decades, the empirical literature has shown that emerging economies are susceptible to external shocks. One factor that could play an important role in determining the policy of emerging economies' central banks is the Federal Reserve's monetary policy. This article aims to estimate the occurrence of United States monetary policy spillovers on Latin America policy interest rates. The results we found suggest that the monetary policy shocks originating by the Federal Reserve are an important source of fluctuations in the internal monetary policy of Latin America countries. There is also an even greater regional spillover among Latin America economies themselves. A magnitude das influências da política monetária internacional se comporta de maneira heterogênea ao longo do tempo, com picos atingidos em momentos de instabilidade política e econômica na América Latina.

Key-words: Spillover of Monetary Policy, Monetary Policy, Interest Rate, Latin America.

Classificação JEL: E50, C58, C22

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1 Introduction

The framework of research in the area of financial spillovers is usually based on a theoretical model of open economies, such as the Mundell-Fleming model and the subsequent advances established by New Open Economy Macroeconomics (NOEM) models (REY, 2016). These models have in common a theoretical consequence known as "open economy trilemma" or "impossible trinity". Obstfeld e Taylor (2017) claim that the trilemma hypothesis can be understood as an impossibility of having, at the same time, a fixed exchange rate, total capital mobility, and an independent internal monetary policy. In a financially integrated world, fixed exchange rates export monetary policy from the central economy to the emerging one. In the opposite case, with fluctuating exchange rates, independent domestic monetary policy is possible, even with free entry and exit of foreign capital.

In the last two decades, the empirical literature points to the fact that Emerging Market Economies (EMEs) are susceptible to external shocks (CANOVA, 2005; MAĆKOWIAK, 2007; CHEN; GRIFFOLI; SAHAY, 2014). It is necessary to ask to what extent the monetary authorities of EMEs are responsible for these external conditions and through which transmission channels they affect central bank policies. It is also important to verify whether EMEs central banks consistently respond to external conditions when making a monetary policy decision. In this case, the autonomy of these countries' monetary policies might in fact not exist. Taylor (2013) notes that floating exchange rates do not offer a complete buffer against the transmission of international financial and monetary shocks. Monetary policies carried out by foreign countries can affect both domestic monetary policies and macroeconomic variables of EMEs. Miranda-Agrippino e Rey (2015), Passari e Rey (2015), and Rey (2016) point out that under a floating exchange rate, there seem to be significant spillovers of monetary policies, especially from decisions made by influential economies. Rey (2016) note that interest rates determined by influential economies can affec both the global financial cycle and the macroeconomic conditions of another country that is part of the global financial system.

One factor that could play an important role in determining the policy of an EMEs' central bank is the Federal Reserve (Fed)'s actions and communications of monetary policy. Recent research (EDWARDS, 2012; TAYLOR, 2013; REY, 2016) has explored the role of the Fed's monetary policy as an important factor in the analysis of financial spillovers. What these articles seek to answer is whether central banks in other countries take into account and follow the monetary policy carried out by the Fed, or whether they adopt a different strategy because they are at another point in the monetary policy cycle. The current article aims to evaluate the effect of the implementation of monetary policies by the Fed on the monetary policy carried out by five Latin America countries: Brazil, Chile, Colombia, Mexico, and Peru. To assess the spillover of American monetary policy to Latin America countries, we use the method proposed by Diebold e Yilmaz (2012). This approach extends the rolling window method found in Diebold e Yilmaz (2009), widely used to analyze spillovers among variables and countries over time. We build spillover indices to account for the spillover of monetary policies between the countries considered. The spillover indices are based on forecast error variance decompositions (FEVDs) from the generalized vector autoregression (VAR) model proposed by Koop, Pesaran e Potter (1996) and Pesaran e Shin (1998). This approach allows for the occurrence of correlated shocks, considering them appropriately using the distribution of errors, which are observed historically.

The results we found suggest that monetary policy shocks carried out by the Fed are an important source of fluctuations in the internal monetary policies of Latin America countries. However, there is an even higher degree of regional spillovers among Latin America countries. In addition, we found that the magnitude of the repercussions of international monetary policy behaves heterogeneously over time, with peaks reached during moments of political and economic instability in Latin America economies, as the case of the 2008 financial crisis. In the static evaluation, we observe that there is a transmission of shocks of international monetary policy among all the countries, with slight differences between the influences sent and received. However, when we evaluate the coefficients dynamically, considering the temporality in the sample, Chile and the U.S. are the dominant transmitters.

In addition to this introduction, this article is divided into four sections. In the second section, we discuss the literature on financial spillovers. In the third section, we discuss methodological aspects of the analysis. In the fourth section, we present the empirical results. Finally, in the fifth section, we present our concluding remarks.

2 International Monetary Policy Spillovers

The fundamental idea of international monetary policy spillovers has been around for some time, at least since the seminal papers of Mundell (1963) andFleming (1962). Their analyses, expanded by Dornbusch (1976), show some channels through which external monetary shocks can influence one country. From the Mundell-Fleming-Dornbusch (MFD) model, we have two basic predictions, given an external shock: (i) the effect of a change in internal consumption; and (ii) the effect of changes in external demand and international monetary policy. This discussion was revisited after the 2008 financial crisis and its repercussions on economies around the world. Although it has been discussed since the beginning of the 21st century, it was from this event that it became clear that policies and external shocks can have increasingly relevant and widespread effects in a highly globalized world, even under the adoption of an inflation targeting and floating exchange rate regime by central banks (DIEBOLD; YILMAZ, 2012).

The study by Calvo e Reinhart (2002) is a good starting point in the literature, even if the authors do not deal directly with the international effects of monetary policy. In their article “Fear of Floating”, the authors show the idea and evidence that many central banks in EMEs, with floating exchange rate regimes, do not allow their exchange rates to appreciate and depreciate as the markets would naturally dictate. In theory, floating regimes should allow currencies to serve as buffers in domestic markets to international markets’ shocks, mainly by eliminating interest-rate differentials. Thus, external shocks should have a major impact only on the exchange rate. However, Calvo e Reinhart (2002) show that such countries, even under the premise of a floating exchange rate, operate in the foreign exchange market in order to control it. Thus, the floating exchange rate is now a “managed float”. Monetary authorities seek, through foreign interventions and interest-rate adjustments, to avoid high exchange rate volatility which can severely affect market agents, especially in countries that export commodities. The authors findings serve as an interesting starting point, as they show that emerging economies have inconsistencies between maintaining a flexible exchange rate regime with systematic management of this variable. They concluded that external shocks, which by nature should affect exchange rates, may have a major influence on the central bank’s policy in emerging countries.

Another branch of the literature try to identify the fact that central banks in emerging economies are susceptible to external shocks, even with fluctuation in the exchange rate. In this sense, Maćkowiak (2007) shows that external shocks are an important source of macroeconomic fluctuations in EMEs. Canova (2005) proposes that U.S.’ monetary policy shocks directly affect interest rates and the exchange rate in an emerging market, with the effect of the American monetary policy shock being higher on the price levels and the real production of an emerging market than on the price levels and the real production of the U.S. itself. These findings are consistent with the idea that U.S.’s monetary policy does in fact impact most countries around the world (DEDOLA; RIVOLTA; STRACCA, 2017).

Among these studies, little attention was paid to the idea that the impact on short-term interest rates in emerging economies, resulting from an external shock, could represent a large part of the impact of shocks as a whole. This understanding gained attention based on the analysis carried out by Taylor (2007), in which the possibility that central banks around the world, under a floating exchange-rate regime and inflation targeting, takes into account the decision-making of other monetary authorities and the repercussions of such decisions on their own monetary policy decisions. Taylor (2013) formally presents the idea that monetary policy spillovers occurred due to sudden changes in monetary policy carried out by industrialized countries in the first half of the 2000s. He argues that these deviations caused international monetary imbalances that have resulted in multiple spillovers between countries. Edwards (2015) follows Taylor's method and investigate the direct influence of the Fed's policy on central banks in EMEs, analyzing the extent to which the Fed's actions are transmitted to the short-term interest rates of Latin America economies. From estimating Taylor's rule for Chile, Colombia, and Mexico for the period between 2000 and 2008, he discovers that there is a significant transfer from the policy of the United States to the policies carried out by the monetary authorities of Chile and Colombia. The results show a significant "political contagion," and that these countries tend to "import" the monetary policies carried out by the Fed. The author also points out that the degree of independence of monetary policy is less due to the *Fear of Floating* faced by the central banks of these countries.

More recently, Rey (2015) develops a study regarding spillovers in EMEs, further developed by Miranda-Agrippino e Rey (2015), Passari e Rey (2015), and Rey (2016). These researches point out that the occurrence of spillovers between shocks and decisions of American monetary policies, is because of the existence of a so-called "global financial cycle," where the monetary policy of the U.S. play an essential role as a determinant of global financial conditions through portfolio investment flows, which is known as the "international credit and risk-taking"channel. These studies found that the Fed's monetary policy had a major impact on international monetary policies even in advanced economies, though their impact was not always directly on interest rates. Chen, Griffoli e Sahay (2014) treat the international credit and risk-taking channels in an EMEs context, pointing out that we should always consider portfolio flow channels when studying the transmission of the Fed's monetary policy to EMEs, since this channel has been shown to have a high degree of spillovers and to cause general financial volatility in EMEs.

Diebold e Yilmaz (2011) propose an index to measure the total and directional spillovers of returns and volatility among five asset markets in the Americas: the U.S., Argentina, Brazil, Chile, and Mexico. The results indicate that both the return and the volatility effects vary widely. Return spillovers, however, tend to evolve gradually, while volatility spillovers exhibit sharp bursts that often correspond to shocks resulting from international economic events. More recently, Gamba-Santamaria *et al.* (2017) applied a spillover method to the stock market indices of the U.S. and four Latin America economies. They found four interesting results: (i) total spillovers vary considerably over time and have been substantially higher between 2008 and 2012; (ii) The U.S. is a net transmitter, however, net spillovers exhibiting significant time heterogeneity (iii) Brazil is a net volatility transmitter for most of the sample period, while Chile, Colombia, and Mexico are net receivers; and (iv) around the Bankruptcy of Lehman Brothers Holdings, the transmission of shocks from the United States to the other economies increased, and even Brazil became a net receiver.

This article aims to estimate the occurrence of spillovers on Latin America monetary policy interest rates arising from U.S.' monetary policy decisions. We note that, although we use the MFD model to motivate some later results, the use of "international monetary policy spillovers," in this analysis will designate the direct transmission of the U.S.'s federal funds rate to interest rates in the Latin America economies. Our hypothesis is that interest rates of Latin America countries will systematically react to changes in the federal fund rates.

3 Measuring Spillover Effects

In this article, we seek to estimate the occurrence of monetary policy spillovers carried out by the Fed on the domestic monetary policies of five countries in Latin America (Brazil, Chile, Colombia, Mexico, and Peru). For this assessment, we use the approach proposed by Diebold e Yilmaz (2012), where we capture the covariation of monetary policy interest rates by the total, directional, and net spillover indices. The spillover indices are based on FEVDs from the generalized VAR proposed by Pesaran e Shin (1998), and Koop, Pesaran e Potter (1996), which is invariant to the ordering of the variables. Finally, we explore the temporal dynamics of the relationships between countries through rolling windows estimations. We emphasize that, although the object of research is the impact of the Fed's policies on the monetary policies of Latin America central banks, the analysis will also capture the effects of the decisions made by these monetary authorities among themselves. This will also make it possible to assess whether any of these monetary authorities have greater influence over the others.

Initially, N variables with stationary covariance VAR(p) are considered, given by:

$$x_t = \sum_{n=1}^{p} \Phi x_{t-n} + \varepsilon_t, \tag{1}$$

where $\varepsilon_t \sim (0, \Sigma)$ is a vector of independent and identically distributed random disturbances. This structure can be transformed into a moving average representation given by:

$$x_t = \sum_{n=0}^{\infty} A_n \varepsilon_{t-n}. \tag{2}$$

The $N \times N$ matrices of A_i coefficients described in equation (2) obey the following recursion:

$$A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \cdots + \Phi_p A_{i-p}, \tag{3}$$

where A_0 is a $N \times N$ identity matrix and $A_i = 0$ for $i < 0$.

The moving average coefficients (or transformations such as impulse-response functions or variance decompositions) are the key to understanding the dynamics of the system. Through the variance decompositions, we can analyze the variances of the forecast errors, resulting from shocks in the system for each variable and their respective effect on the other variables. The variance decompositions allow us to account the fraction of variance of the error H steps forward, in the forecast x_i which is due to shocks in x_j, $\forall i \neq j$, for each i.

In the traditional VAR framework, the calculation of variance decompositions requires innovations to be orthogonal, but the VAR innovations are correlated contemporaneously. We can obtain independent errors through Cholesky factorization, but the variance decompositions will depend on the ordering of the variables. This issue can be treated through the generalized VAR structure proposed by Koop, Pesaran e Potter (1996), and Pesaran e Shin (1998). This modeling allows for the variance decompositions to be invariant to ordering. The authors propose that, instead of trying to orthogonalize shocks, correlated shocks are allowed and considered by the historical observed distribution of errors. This implies that the sum of the contributions for the variance of the forecast errors may take different values from one, since the shocks in each variable are not orthogonalized.

The forecast errors variance decompositions H-steps forward for $H = 1, 2 \ldots$ is denoted by:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \tag{4}$$

where Σ is the variance matrix for the error vector ε; σ_{jj} is the standard deviation of the error term for the j-th equation; and e_i is the selection vector, with one as the i-th element and zeros otherwise. Equation (4) allows us to compute the fraction of the H-step-ahead errors variance in forecasting x_i that is due to shocks to x_j, $\forall i \neq j$, which we call cross-variance shares (or spillovers) and the own-variance portions are defined as the fractions of the variations of the H-step-ahead errors' variance in forecasting x_i that is due to shocks to x_i, for $i = 1, 2, \ldots, N$, which we call own variance shares. Moreover, given the non-orthogonality of the decomposition, we have that the sum of the elements in each line of the variance decomposition table is not equal to 1: $\sum_{j=1}^{N} \theta_{ij}^{g}(H) \neq 1$. In order to simplify the information obtained through equation (4), we normalize each entry in the variance decomposition matrix by:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)}. \tag{5}$$

We build the total spillover index using the contributions from the variance decomposition of the Koop, Pesaran e Potter (1996) method. The Total Spillover Index (TSI) measures the contribution of shocks to the total variance of the forecast errors:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100. \tag{6}$$

The generalized VAR approach allows us to identify the direction of spillovers among the monetary policy interest rate for each country. As the generalized impulse responses and the variance decompositions are invariant to the ordering of the variables, the directional spillover indices were calculated using the normalized elements of the generalized variance decomposition matrix. The impact of shocks received by the market i from all other markets j are measured as:

$$S_{i}^{g}(H) = \frac{\sum_{\substack{j=1 \\ j \neq i}}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100. \tag{7}$$

The net spillover index provides summary information on how much each i market contributes to all other j markets, in net terms:

$$S_{i}^{g}(H) = S_{\cdot i}^{g}(H) - S_{i \cdot}^{g}(H). \tag{8}$$

Finally, the net spillover between pairs are examined. The index that measures the spillovers between only two countries is defined as:

$$S^g_{ij}(H) = \left(\frac{\tilde{\theta}^g_{ji}(H) - \tilde{\theta}^g_{ij}(H)}{N} \right) \times 100. \tag{9}$$

3.1 Vector Error Correction Model

The VAR model is appropriate to analyze the dynamics between a set of variables treated as endogenous, which we use in the financial spillover model. Such models are able to accurately capture the reality of macroeconomic dynamics. However, when the variables are non-stationary (i.e., they have a stochastic trend), using the VAR methodology implies the loss of relevant information. A particular case arises when the level series are cointegrated. In this situation, it is possible to show that the estimators are consistent, converge quickly, and still maintain information about levels. In the presence of cointegration, Engle e Granger (1987) recommend using a Vector Error Correction (VEC) Model, where the use of the error correction vector represents the long-term behavior. By a reparametrization of a VAR model, (1), a VEC model can be obtained as follows:

$$\begin{aligned} \Delta x_t &= \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Pi x_{t-1} + \varepsilon_t, \\ \Gamma_i &= -\left(I - \Pi_{i+1} + \ldots + \Pi_p\right), \quad i = 1, \ldots, p-1 \\ \Pi &= -\left(I - \Pi_1 - \ldots - \Pi_p\right). \end{aligned} \tag{10}$$

where I is a $(k \times k)$ identity matrix and Γ_i is the matrix that captures the long-term effect.

For the left side of equation (10) to be stationary, it is necessary that the rank of matrix Π be greater than one. This implies that there are fewer linearly independent columns (r) than the maximum rank (K). If the matrix does not have full rank, there will be two matrices $(K \times r)$ such that, $\Pi = \alpha\beta'$. The r columns of β are the cointegrating vectors that represent the long-term relationships between the x_t series. We use the Johansen test to analyze the existence of cointegration between variables, which evaluates the rank of the matrix that represents the long-term properties of the system, Π. Finally, the VEC model is re-transformed to a VAR structure allowing to obtain equations (1) and (2) for the estimation of the financial spillover indices.

4 Empirical Evaluation

4.1 Data

The database consists of six time series of interest rates from government Treasury bonds with a three-month maturity, for each country analyzed. Interest rates for Brazil, Chile, Mexico, and the U.S. were obtained from Federal Reserve Bank of St. Louis (FRED) database service. For Colombia and Peru, interest rates were obtained from their respective central banks. The sample size and choice of interest rates maturity is purely driven by data availability. The data comprise the period between January 2000 and August 2019 with observations on a monthly basis, which resulted in a sample of 236 observations for each series. We use three-month maturity interest rates to capture both the monetary policy decision and market expectations. We choose the frequency and forecast window to perform the FEVDs following Sowmya, Prasanna e Bhaduri (2016). The authors say that 6 to 12 months is the time necessary to observe changes in economies resulting from monetary policy decisions, and usually a decision is made from one to two months, so a monthly periodicity and a 12-month forecast window should capture the spillover effect.

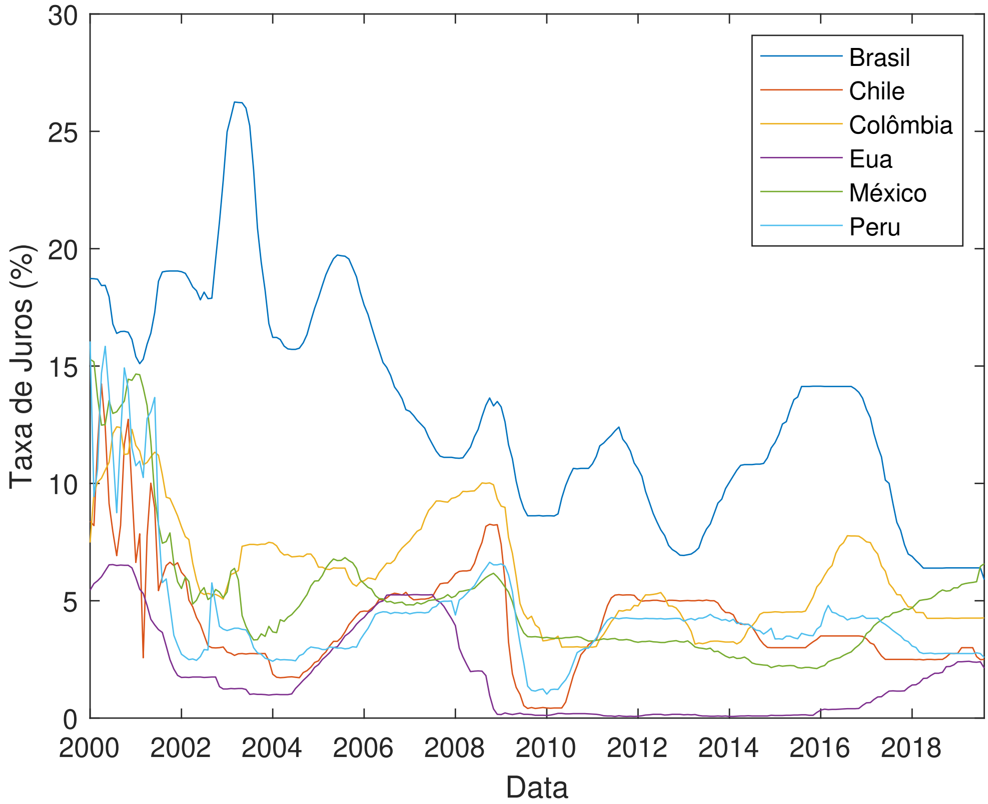


Figura 1 – Monetary Policy Interest Rates

In Figure 1 we present the six time series from 2000 to 2019. In Table 1 we show the descriptive statistics for the interest rates with the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, which assesses the presence of unit roots; the Jarque-Bera (JB) normality test, which checks whether the data have the skewness and kurtosis of a normal distribution; and the Ljung-Box (Q) test to assess the serial correlation in the data. The average and volatility of interest rates are highest in Brazil, with rates between 5.90% and 26.25%, and lowest in the United States, with rates between 0.07% and 6.54%. Regarding the KPSS test, we found that all series are non-stationary. The data do not follow a normal distribution, with the null hypothesis of the Jarque-Bera test being rejected at the 1% significance level. Regarding the Ljung-Box test, the results showed serial autocorrelation for all series.

As the method we proposed requires the stationarity of series or a cointegrating relationship, we tested the existence of cointegration between the series by Johansen test, which is presented in Table 2. We found three cointegrating relationships among the variables, which allows us to proceed with the proposed method and use a model with error correction vectors. Taylor (2013) justified the existence of cointegration in our system due to the hypothesis that there is coordination in implementing monetary policy, especially among EMEw, which can cause more than one long run relationship to exist between the behavior of interest rates.

Tabela 1 – Descriptive Statistics for Interest Rates

	Brazil	Chile	Colombia	U.S.	Mexico	Peru
Mean	13.15	4.17	6.23	1.78	5.00	4.39
Std. Deviation	4.64	2.27	2.36	1.93	2.80	2.64
Minimum	5.90	0.41	3.02	0.07	2.11	1.02
Maximum	26.25	14.24	12.41	6.54	15.29	16.05
Skewness	0.56	1.28	0.66	1.03	2.09	2.52
Kurtosis	-0.08	2.83	-0.40	-0.20	4.36	6.74
KPSS	**2.11**	**0.87**	**1.94**	**1.80**	**2.07**	**1.00**
JB	**200.61**	**146.99**	**18.92**	**42.92**	**365.58**	**711.41**
$Q(20)$	**223.69**	**201.32**	**230.24**	**230.65**	**218.75**	**193.15**

Note: Table 1 reports summary statistics; the KPSS Test for stationarity; the Jarque-Bera (JB) test for normality; and the Ljung-Box (Q) test for serial correlation. Jarque-Bera (JB) alternative hypothesis: not a normal distribution. Ljung-Box (Q) alternative hypothesis: serial correlation exists. KPSS alternative hypothesis: Non-stationarity. In bold, results statistically significant at the 5% level.

Tabela 2 – Johansen Test Results

	Coefficients	Stat. 10%	Stat. 5%	Stat. 1%
r <= 5	4.71	6.50	8.18	11.65
r <= 4	8.15	12.91	14.90	19.19
r <= 3	18.13	18.90	21.07	25.75
r <= 2	**31.34**	24.78	27.14	32.14
r <= 1	**33.86**	30.84	33.32	38.78
r = 0	**67.65**	36.25	39.43	44.59

In bold, results are statistically significant at the 5% level.

4.2 Spillover Indices

In Table 3 we report the estimates of the spillover indices for each series, based on the methodology of Diebold e Yilmaz (2012). We consider the entire sample period, with a forecast horizon of 12 periods. The diagonal values are the own-country influences on their own monetary policy rate. The values in each row represent the influence of the other countries upon a country's monetary policy rate. The values in each column represent the influences of the respective countries on the monetary policy rates of other countries. The Total Spillover Index (TSI) is calculated as total contribution to other countries, divided by the total contribution including own-country influences. The net spillover index is the difference between total spillover and the total forecast error variance for each country. We can observe that the influences of the country's own monetary policy explain the major part of the variation of the forecast errors, since the diagonal elements have higher values compared to the elements outside the diagonal.

The U.S. is the country least affected by foreign monetary policies, with the country's own share comprising 92.51% of its variance, so only 7.49% of the forecast errors variance came from shocks resulting from the monetary policies of the other countries. In contrast, Colombia, followed by Mexico, is the country most affected by foreign monetary policies. The most important transmitters of monetary policy shocks are Peru, transmitting 67.93%, followed by Chile with 53.57% and the

Tabela 3 – Static Spillover Indices

	Brazil	Chile	Colombia	U.S.	Mexico	Peru	From
Brazil	88.91	7.60	0.45	1.76	0.90	0.37	11.08
Chile	1.38	60.33	4.96	2.02	1.94	29.38	39.68
Colombia	3.51	16.17	39.68	3.49	0.78	36.37	60.32
U.S.	1.42	1.04	0.24	92.51	3.80	0.98	7.48
Mexico	0.42	0.39	5.76	32.92	59.68	0.83	40.32
Peru	0.08	28.37	8.99	2.52	12.38	47.66	52.34
Spillover to Others	6.81	53.57	20.40	42.71	19.80	67.93	211.22
Total Spillover	95.72	113.90	60.08	135.22	79.48	115.59	**TSI:**
Net Spillover	-4.28	13.90	-39.92	35.22	-20.52	15.59	**35.20**

Note: The diagonal values are the own country influences on their monetary policy. The values in each row represent the influence of the other countries on the domestic monetary policy. The values in each column represent the influences of the respective countries on the monetary policy of other countries. "From" (column 7) is the spillover received by the country. Spillover to Others is the spillover transmitted. The total spillover index is calculated as total contribution to others divided by total contribution including own. The net spillover index is the difference between the total spillover and the total forecast errors variance for each country.

U.S. with 42.71%. The countries that received the most influence from external monetary policies were Colombia, receiving 60.32%; followed by Peru with 52.34%, and Mexico with 40.32%. It is an interesting result because expose a strong connection between Chile and Peru in carrying out their internal monetary policies. There are some moments where one of these countries acts first, and others in which the other country acts first.

When we evaluate the net spillover index (the amount transmitted, discounted from the influence received), reported in the last line of Table 3, we see that the dominant net transmitter is the U.S. with a share of 35.22% in all the system forecast errors variance. This result points to the high power of the United States to impact Latin America economies while suffering little, if any, contrary influence. These results corroborate past studies on financial spillovers (TAYLOR, 2013; EDWARDS, 2012; REY, 2016) through a different approach, providing additional support for the literature. It is known that the U.S. influences the monetary policy of other countries in the world, receiving few shocks to its economy, meaning that the U.S. is a central economy in the international financial system (REY, 2016). This fact can also be observed in our results. Table 3 presents the static TSI, reported in the lower right corner. This index expresses how much of the variance in the forecast error in monetary policy shocks is due to spillovers from shocks between countries, considering all the observations in the sample. The results indicate that, on average, 35.20% of the variance of the forecast errors in the monetary policy rates are due to external shocks.

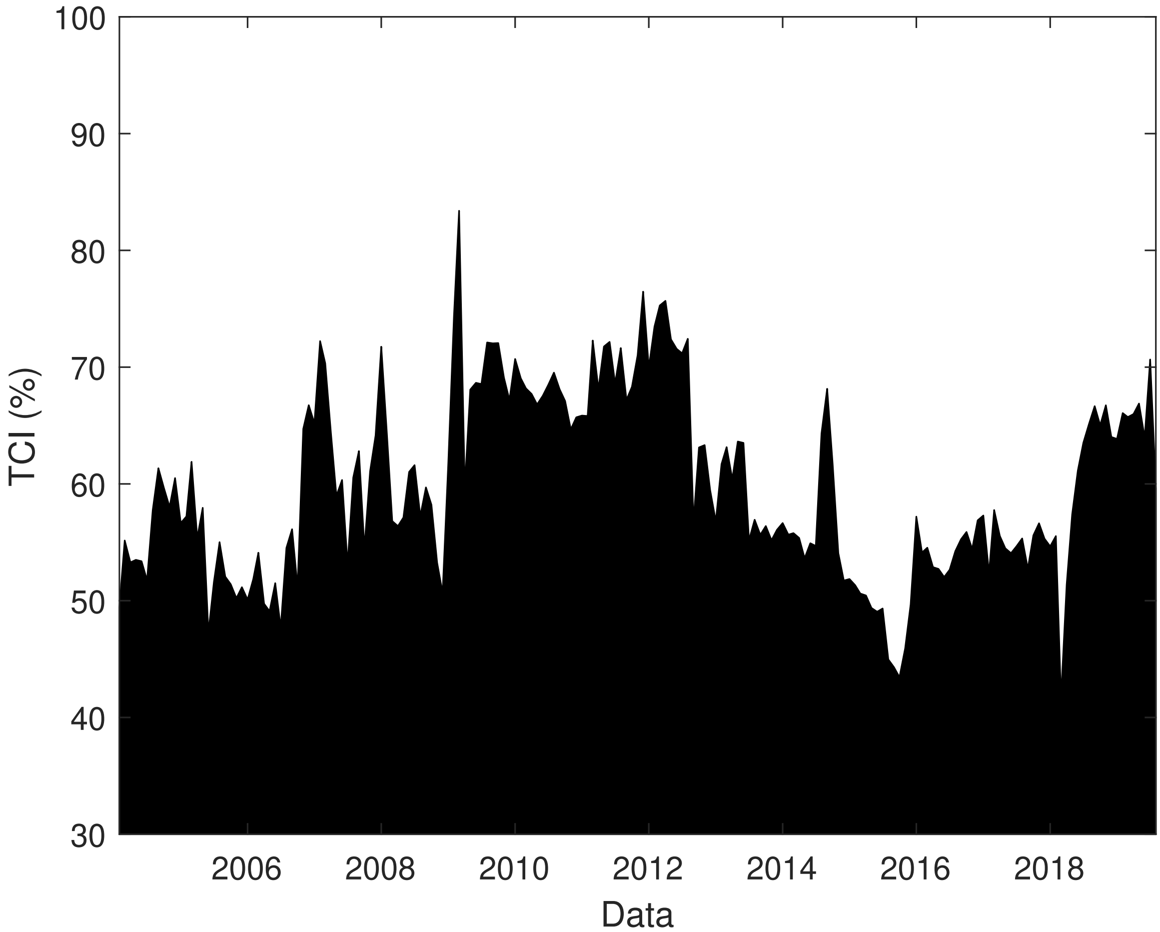
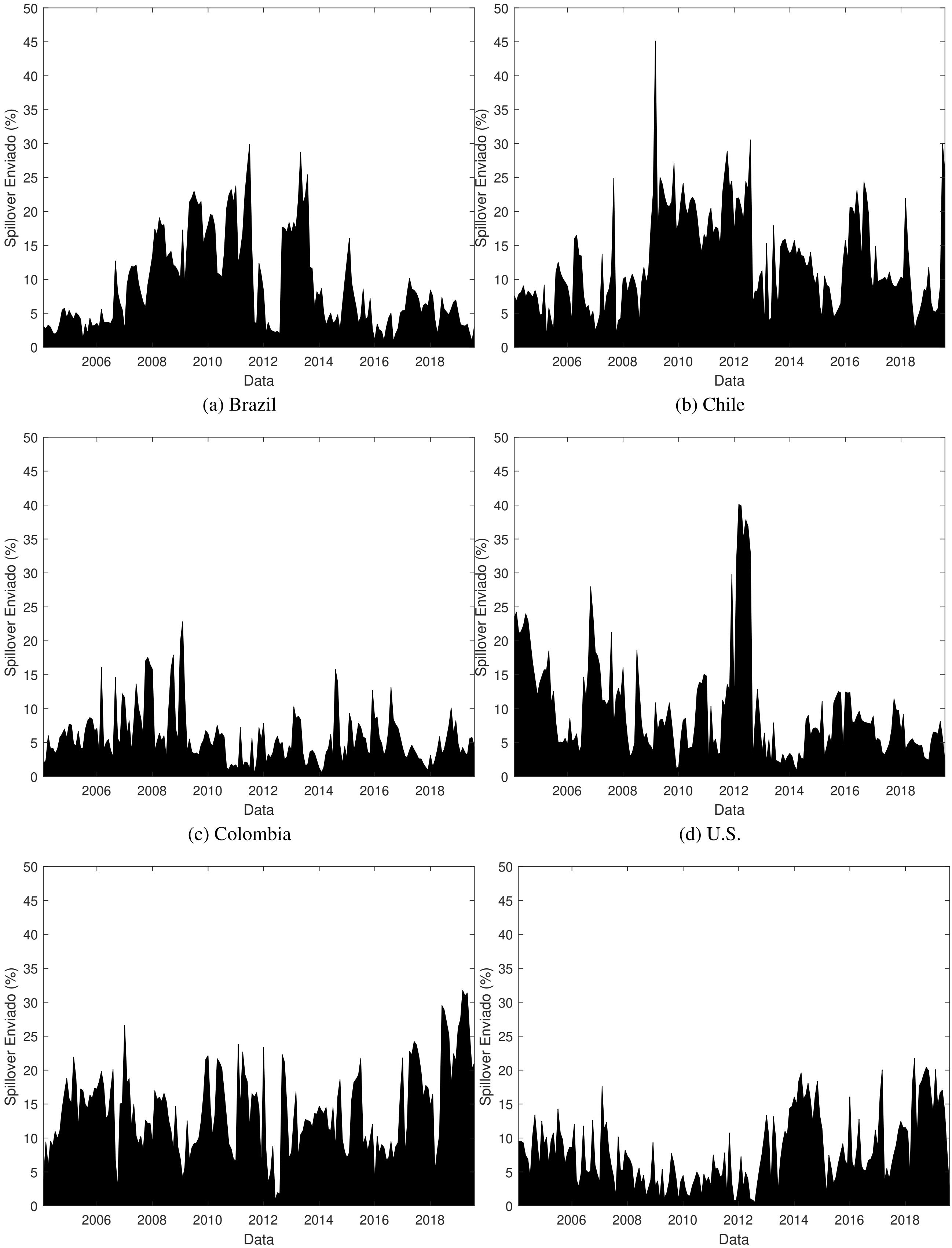


Figura 2 – Dynamic Total Spillover Index

Now we turn our attention to interpreting the spillover graphs based on the time-varying estimates of the various spillover indices obtained through a rolling window estimation. We consider samples of 50 observations, with a forecast horizon of 12 periods. In Figure 2 we present the results for the TSI over time. We can observe great variation in the total spillover rate, which responds to extreme economic events such as the global financial crisis of 2008 and later periods, which were characterized by interventions of unconventional monetary policy (BLINDER, 2010). In particular, the spillover of monetary policy peaked in the month in which the United States announced its first unconventional monetary policy program, in March 2009.

This type of monetary policy, which became known as quantitative easing, involved the massive expansion of central bank balance sheets, seeking to influence interest rates other than the usual official short-term rates (JOYCE *et al.*, 2012). This occurred because the U.S. was already working with short-term rates close to zero and having weak effects on operational variables and final objectives (BLINDER, 2010). The total spillover levels remained high until 2012, when the US reduced its quantitative easing policy. In Figure 2 there is a increase in the TSI after 2016, we associate the increase in TSI levels with the recovery of the U.S. economy, along with political instability in Latin America countries. The improvement of the American economy induced an outflow of foreign capital from Latin America countries which necessitated for intervention by EMEs' central banks in credit policies, interest rates, and exchange rates. The concomitance of these interventions led to an increase in the TSI in the period, which remained until the end of the analysis.



(a) Brazil

(b) Chile

(c) Colombia

(d) U.S.

(e) Mexico

(f) Peru

Figura 3 – Spillover Transmitted by Each Country

Tabela 4 – Dynamic Spillover Indices

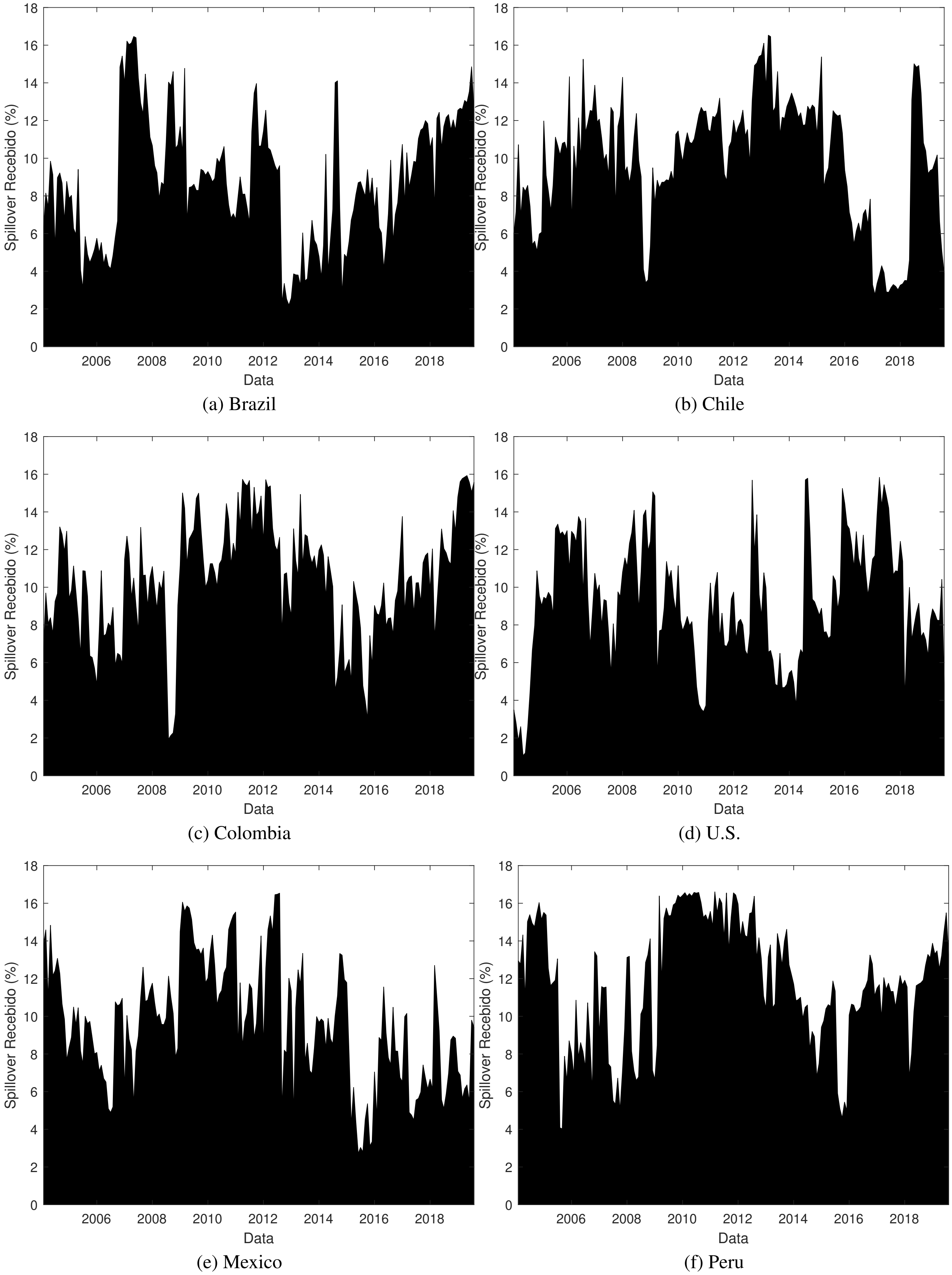
	Brazil	Chile	Colombia	U.S.	Mexico	Peru	From
Brazil	47.15	12.11	7.58	7.03	18.26	7.87	52.85
Chile	11.84	40.74	6.09	11.35	17.26	12.72	59.26
Colombia	7.36	17.68	37.33	11.84	16.83	8.96	62.67
U.S.	8.16	10.84	8.49	44.43	17.71	10.37	55.57
Mexico	14.32	15.47	6.81	12.22	42.14	9.04	57.86
Peru	13.31	20.62	5.99	16.25	14.97	28.85	71.15
Spillover to Others	54.99	76.72	34.97	58.68	85.04	48.96	359.36
Total Spillover	102.14	117.47	72.29	103.11	127.18	77.81	**TSI:**
Net Spillover	2.14	17.47	-27.71	3.11	27.18	-22.19	**59.89**

Note: The diagonal values are the own country influences on their monetary policy. The values in each row represent the influence of the other countries on the domestic monetary policy. The values in each column represent the influences of the respective countries on the monetary policy of other countries. “From” (column 7) is the spillover received by the country. Spillover to Others is the spillover transmitted. The total spillover index is calculated as total contribution to others divided by total contribution including own. The net spillover index is the difference between the total spillover and the total forecast errors variance for each country.

Table 4 shows the coefficients that summarize the behavior of the spillover indices that consider temporal dynamics. We show the average coefficients that we obtained by a rolling window estimation of sub-samples with 50 observations. The difference, in comparison to the static table (results in Table 3), gives us indications of a possible structural break. The spillover of monetary policy is more expressive, and the interactions among monetary policies substantially increase. In this estimation, Mexico becomes the country with the highest potential to influence the monetary policies of other countries. We relate this finding to the strong economic instability of Latin America countries, especially Mexico, in the initial period of the sample. An interesting fact highlighted by these results is the high variability of the spillover among values over time, an effect not present for the whole-sample estimation. This results point to a change in the interconnection of countries over time, resulting from a coalition of monetary policies as proposed by Taylor (2007), Taylor (2013) and Edwards (2015).

In Figure 3 we present the spillovers transmitted over time, the monetary policy shocks transmitted from each of the countries to the others, or the variance share in the forecast errors arising from a shock generated by one country over the others. By visual inspection, we can see that the directional spillovers of the series reach values close to 50%, which shows a high transmission of monetary policy shocks. In addition, we can see that the indices behave heterogeneously over time and follow a pattern similar to what we found for the TSI. For example, monetary policy spillovers peaked during the 2008 crisis and posterior adoption of unconventional monetary policies. Chile and the U.S. are the countries with the highest variability of the directional spillover index, having the highest shares of influence over the other countries in the period between 2008 and 2014. Mexico had a relatively high average participation over the entire period. Brazil began to influence other monetary policies since 2008, exerting a greater impact between 2016 and 2018. Regarding Colombia and Peru, we can see that they had little influence over the entire period considered.

These results diverge from Diebold e Yilmaz (2011) and Gamba-Santamaria *et al.* (2017), which analyze stock market’ spillovers in Latin America economies. The authors found that Brazil is a net volatility transmitter for most of the sample period, while Chile, Colombia, and Mexico are net receivers of shocks in their stock market indices. In contrast, we found that Chile, the U.S., and



(a) Brazil (b) Chile

(c) Colombia (d) U.S.

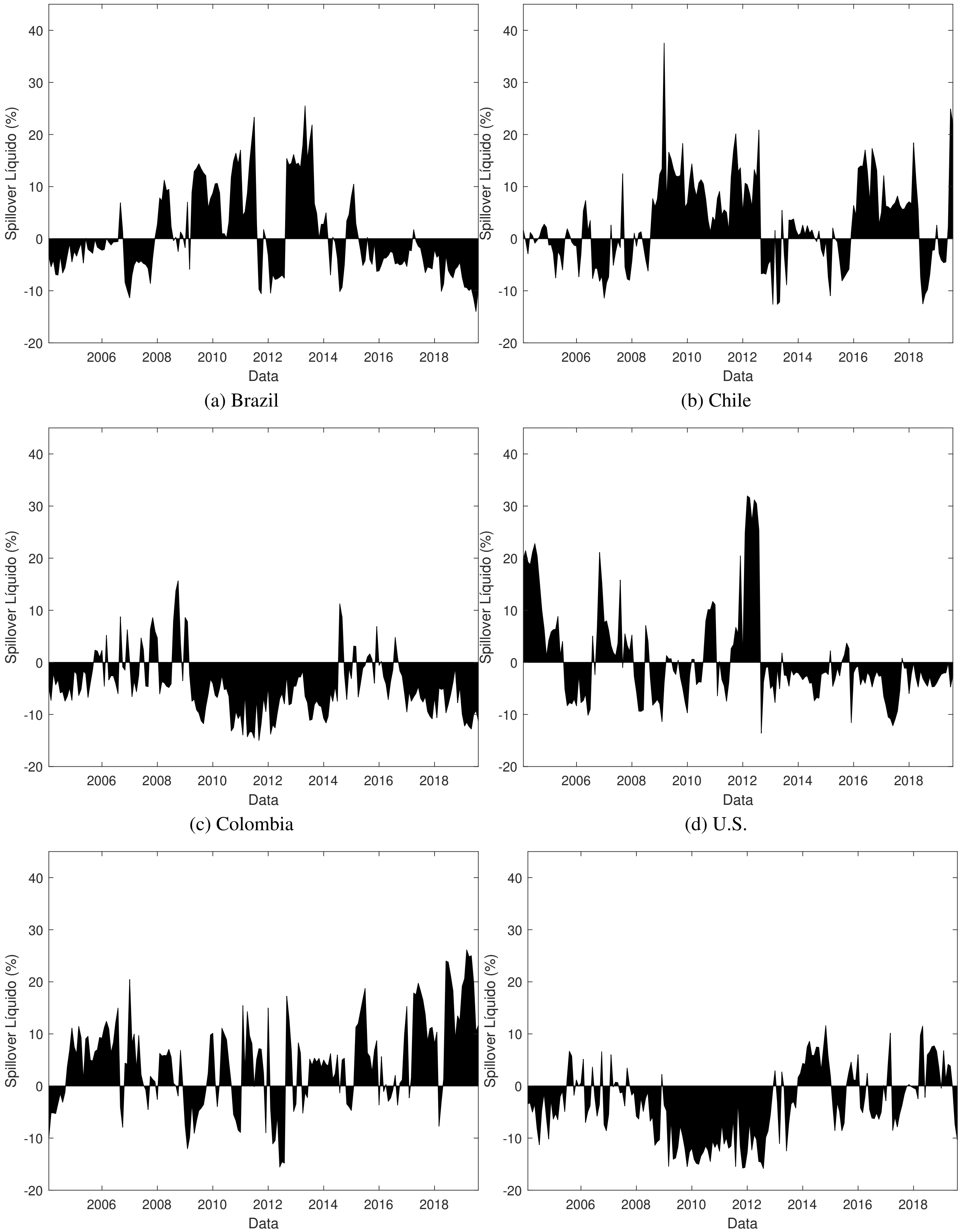
(e) Mexico (f) Peru

Figura 4 – Spillover Received by Each Country

Mexico are the countries that exert the most influence over the others. These results imply that the Brazilian bond market operates in a different way in comparison to its stock market. Usually Brazil had higher interest rates and more instability in its monetary policy compared to their pairs, which explain why exert less influence in this market. In addition, Gamba-Santamaria *et al.* (2017) found that the TSI is substantially higher between 2008Q3 and 2012Q2, and shock transmission from the U.S. to Latin America stock markets substantially increased around the Bankruptcy of Lehman Brothers.

In Figure 4 we present the dynamic influences received by each country from external monetary policy shocks - the variation of the forecast error absorbed by a country arising from shocks generated by the other countries. As in Figure 3, they behave heterogeneously over time. The influence received reaches levels close to 17% for all countries evaluated: Brazil, Chile, Colombia, the U.S., Mexico, and Peru. We also analyzed the dynamic graphs of net spillovers, as is illustrated in Figure 5. The net spillover index can be understood as the difference between the influence transmitted and the influence received by a country. From Figure 5, we see that Colombia and Peru can be considered mainly as net receivers of monetary policy shocks during the sample period. Chile and Mexico are net transmitters of monetary policy shocks, with Chile having a high influence in the period between the 2008 financial crisis and the end of the quantitative easing. The U.S. is also a net transmitter of monetary policy shocks. Brazil has heterogeneously interactions, sometimes act as a net receiver and sometimes as a net transmitter of monetary policy shocks.

Finally, in Figure 6, we focus on the net spillover index of monetary policy shocks between pairs - the difference of monetary policy shocks transmitted and received between pairs of countries. We can observe the following empirical regularities: first, in net terms, the monetary policy spillovers are of higher magnitude among pairs of Latin America countries, particularly the relationships between Brazil and Chile with other countries. The U.S. and Chile appear to be the dominant net transmitters of monetary policy shocks for all countries. However, while Chile's influence is concentrated in the period between 2008 and 2014, the U.S. is dispersed throughout the analyzed period. Colombia and Peru appear to be the main net receivers, receiving strong influences on their monetary policies throughout the sample period. Moreover, Brazil and Mexico have varying influences on the other countries, sometimes receiving and sometimes transmitting monetary policy shocks.



(a) Brazil (b) Chile

(c) Colombia (d) U.S.

(e) Mexico (f) Peru

Figura 5 – Net Spillover for Each Country

5 Concluding Remarks

In this study, we examine the international transmission of monetary policy shocks in Brazil, Chile, Colombia, the U.S., Mexico, and Peru, from 2000 to 2019. We use the methodology proposed by Diebold e Yilmaz (2012), measuring the spillover effects with a series of indices. The spillover indices were built using FEVDs based on a generalized VAR model. The results of our empirical analysis suggest that international monetary policy shocks are an important source of fluctuations in domestic monetary policy. In addition, the magnitude of the effects of external monetary policy behaves heterogeneously over time. The temporal dynamics of the spillover indices were captured through a rolling window, showing peaks in the spillover index during the 2008 financial crisis and the subsequent periods in which unconventional monetary policies occurred.

The dominant transmitters of international monetary policy shocks are the U.S. and Chile. In contrast, Colombia and Peru are the most receivers of international monetary policy shocks. One interesting point is that international monetary policy shocks originating in the U.S. were the greatest during the period of interest rates close to zero and the era of quantiative easing and unconventional monetary policy actions, indicating potential gains from monetary policy coordination. Although we limit ourselves to analyzing the repercussions of monetary policy in five Latin America economies, as part of future research, it would be interesting to analyze them in a larger set of developed and developing countries. It is worth mentioning that the methodology can capture the relationships and assess the spillovers of monetary policy in among a big set of countries.

The results we found corroborate and expand the results obtained by Canova (2005), Maćkowiak (2007), and Taylor (2013) for Latin America EMEs. This further supports the validity of the hypothesis that the interest rates of Latin America countries react systematically to changes in the federal funds rate. These studies also point to a strong interrelationship between the behavior of the interest rates of the Latin America countries among themselves. Lastly, the results serve as a framework for understanding how the monetary policies of other countries can affect other macroeconomic variables through the monetary policy transmission effects. The comovements of these policies are crucial for understanding the impact of changes in short-, medium-, and long-term rates, given the transmission process necessary to affect sectors of the economy that are sensitive to long-term interest rates, such as housing, durable goods consumption, and fixed investment. Such an understanding can reaffirm the study of Taylor (2013), in which greater coordination is proposed between the actions of central banks worldwide.

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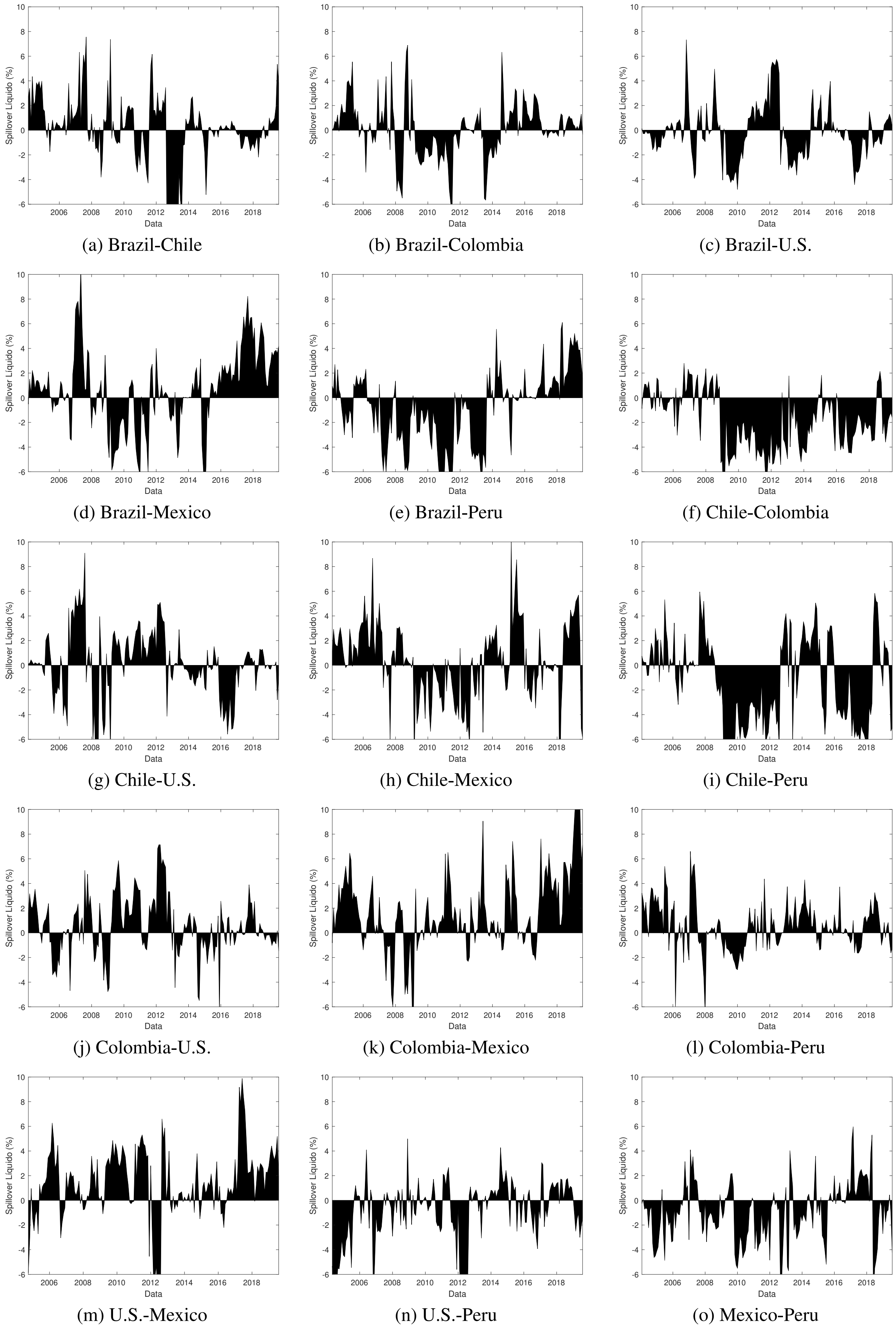

Figura 6 – Net Spillover Between Country Pairs

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