International Monetary Policy Spillover in Colombia: An SVAR Analysis

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ABSTRACT

United States monetary policy plays an oversized role in determining worldwide financial conditions. Recent research has demonstrated that emerging markets economies are vulnerable to pressure from the policy stance of the Federal Reserve. Furthermore, monetary authorities in these countries have been shown to systematically respond to the Federal Funds rate, indicating that international monetary policy spillovers have eroded these nations' monetary policy independence. This paper examines the transmission dynamics underlying these spillovers by estimating various structural vector autoregressions (SVARs) in an emerging market economy, Colombia. The analysis finds that U.S. monetary policy shocks are a significant determinant of Colombia's central bank policy rate. In addition, it is shown that the transmission process of these spillovers changed after the global financial crisis of 2008.

Keywords: International monetary policy spillover; Monetary policy independence; Colombian central bank; Structural vector autoregression

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1. Introduction

One of the most pertinent questions in international monetary economics has long been the idea of the "impossible trinity" or "trilemma". This trilemma describes the impossible task of a central bank in attaining three optimal policies: sovereign monetary policy, fixed exchange rates, and free capital flows. Characteristic of sovereign monetary policy is a central bank that has the freedom to conduct its own monetary policy without being subject to external or foreign factors impeding its policies. Fixed exchange rates can be characterized as a currency with a fixed value in international markets, thus protecting a country's money from volatility. Characteristic of free capital flows is a financial market in which capital is unhindered in coming in and out—that is, a financial market having no capital controls. While a central bank would optimally choose to enact all three policies at the same time, in theory and throughout history in practice, this is impossible[2]. In reality, a central bank must choose two of the three possible policies and forego the third.

Ever since the demise of the gold standard in the United States in the 1970s, central banks throughout the world started to implement the choice most commonly practiced by monetary authorities today: floating exchange rates, capital mobility, and monetary policy autonomy. Furthermore, in the 1990s, inflation targeting became the principal objective for most industrialized countries' central banks. This change was celebrated as inflation targeters saw a period of very stable output and inflation. However, it is important to note that this experience was not the same for emerging market (EM) central banks. Following a tumultuous decade full of financial crises and highly volatile periods, at the end of the 1990s, many of these countries started to adopt central bank models following those of the developed world. These

[2] See Obstfeld, Shambaugh, and Taylor (2005) for a more in-depth analysis of the trilemma in the 20th century.

monetary authorities freed their grip on their fixed exchange rates and entered the new century with 'modern' central banks.

The track record of these banks remains uncertain. While these authorities have, as a whole, largely succeeded in seeing periods of stable inflation and output, their vulnerability to external conditions has been questioned, particularly after the recent global financial crisis. Empirical literature in the past 15 years points to the fact that EM central banks are susceptible to foreign shocks (Canova 2005; Chen et al. 2014; Maćkowiak 2007). One must wonder to what extent EM monetary authorities account for these foreign conditions and through what transmission channels they affect central bank policy. Furthermore, if it is the case that EM banks consistently respond to external conditions when making policy decisions, then these countries' supposed monetary policy autonomy could in fact erode.

One foreign factor that could play a large role in the determination of EM central bank policy is Federal Reserve policy. Recent research (Beckworth and Crowe 2013; Edwards 2016; Rey 2016; Taylor 2013) has begun to explore the role of monetary policy 'spillovers' from the Federal Reserve on the rest of the world's central banks. In essence, the question that has been posed is: When controlling for other macroeconomic conditions, do central banks seem to take into account and possibly follow the Federal Reserve's policy stance when deciding on their own policy? The verdict seems to be that, over the past 15 years, the Federal Reserve has in fact had some significant level of influence over global financial conditions. The extent of this influence is even more pertinent in an EM context, since many of these markets can be considered as small open economies, heavily dependent on external trade partners such as the United States. For such countries, a strong reaction to Federal Reserve policy would be an indicator of lack of *de facto* monetary policy independence. If U.S. central bank policy does indeed exert a substantial amount of influence on EM monetary authorities, it is essential to parse out the magnitude and dynamics of such an effect to better understand the intricacies of the current international monetary system.

In this paper, I present a case study analyzing the central bank of one representative emerging market, Colombia. Employing a structural vector autoregression (SVAR) framework, I examine the period from 2000 to 2015, when Colombia first adopted an inflation-targeting central bank objective, to show that Colombian monetary authorities responded in a systematic and consistent way to Federal Reserve policy. Furthermore, I split that 15-year span into a pre-crisis period (2000–2008) and a post-crisis period (2008–2015), to determine if the dynamics of spillovers changed after the financial crisis. For these three periods, I estimate three different specifications of SVARs to assure robustness. The two most important results from this analysis are the following. First, this paper finds a very significant spillover from U.S. Federal Reserve policy rate onto Colombian central bank policy rates in all time periods across all specifications of SVARs, thus indicating a lack of monetary policy independence in Colombia. Furthermore, the makeup of results indicates that the two most plausible channels of the spillovers are "fear of floating" and "the risk-taking and credit channel." Second, this paper also makes the discovery that the transmission process of spillovers experiences a structural change before and after the global financial crisis of 2008. Possible explanations for this change are discussed.

The rest of the paper is ordered as follows: Section 2 provides a survey of existing literature surrounding international monetary policy spillover and relevant SVAR studies. Section 3 presents a brief history and context of Colombian monetary policy in the studied time period. Section 4 provides the paper's methodology and empirical strategy. Section 5 presents the paper's results, a discussion of these, and possible implications. Section 6 offers concluding comments as well as avenues of further research.

2. Literature Review

The general idea of international monetary policy spillovers has existed for quite some time since the pioneering works of Mundell (1963) and Fleming (1962). Their analysis, later extended by Dornbusch (1976), showed various channels through which spillovers can transmit from one country to another. Two basic predictions of such Mundell-Fleming-Dornbusch models are the expenditure-switching effect and domestic demand effect as channels of international monetary policy spillover. The first prediction states that monetary easing by a "domestic" country leads to a terms of trade deterioration (through an exchange rate depreciation), which leads to an improvement in trade balance and thus output in the domestic country and the inverse effect for a "foreign" country. The second prediction posits that the same monetary easing will increase domestic demand (through spending on consumption and investment), which increases domestic imports (and inherently, foreign exports), causing the domestic country's trade balance to worsen and vice versa for the foreign country. As one quickly realizes, the net effect of both spillovers has uncertain outcomes, since each counteracts the other. It is essential here to note that, while analysis of this sort of spillover[3] will be used to motivate some results later on, the use of "international monetary policy spillover" in this paper will designate the *direct* transmission of Federal Reserve policy onto Colombian central bank policy. That is to say, the spillover I measure corresponds to the hypothesis that the Colombian policy rate reacts systematically to changes in the Federal Funds rate, absent typical macroeconomic considerations stipulated by central bank policy frameworks such as the Taylor Rule.

Discussion of this type of international monetary spillover is a rather new development, likely because these spillovers have only now become more pertinent and pervasive in a highly

[3] For a longer treatment of Mundell-Fleming-Dornbusch style spillovers, see Karmin (2015).

globalized world, where many banks have adopted the same type of inflation-targeting, floating exchange regime. An apt starting point in the literature comes not from a direct treatment of international monetary policy spillovers, but from a contribution by Calvo and Reinhart (2002). In their "Fear of Floating" paper, they present the idea and evidence that many EM banks, in floating exchange rate regimes, do not actually allow their currencies to appreciate and depreciate as markets would naturally dictate. In theory, floating regimes should allow currencies to serve as shock absorbers in international markets, levelling out differentials in domestic and foreign markets. However, Calvo and Reinhart show that these 'dirty floaters', in an effort to avoid high exchange-rate volatility, try to control their currency through exchange-rate interventions and interest-rate adjustments. Their findings serve as an interesting jumping-off point, as they demonstrate that EMs show consistent incongruence between *de jure* flexible exchange-rate regimes and systematic *de facto* exchange-rate management. It follows that external shocks, which by nature affect exchange rates, can possibly have a large influence on EM central bank policy.

While efforts[4] were made to empirically identify these external shocks—including notable works by Canova (2005) and Maćkowiak (2007)—much of this research did not wholly address the idea that foreign interest rates could be a large determinant of the influences on central banks. Rather, this novel idea started gaining attention after being introduced in a more general framework in Taylor (2007). Here, Taylor explores the possibility that central banks in the modern, inflation-targeting, floating-regime world might be taking into account the decision making of other monetary authorities throughout the world, and the possible repercussions of such linkages between economies. Taylor (2013) formally presents the

[4] For example, while Canova (2005) finds that U.S. monetary policy explains up to 80% of volatility of output and inflation on a wide set of Latin American countries, this effect is, to a certain extent, a relic of the past. Many of these effects can be explained by the period measured in his paper (1990–2002), since most if not all the countries being analyzed were not employing the inflation-targeting objective common today and were particularly vulnerable to many kinds of external shocks

pervasiveness of monetary policy spillovers, particularly due to large policy deviations seen in industrialized countries in the first half of the 2000s (what he calls “the great deviation”). He argues that these deviations caused international monetary imbalances and that these imbalances caused various spillovers that quickly stacked together, causing harm to economies both domestic and abroad. Edwards (2016) follows Taylor’s insights and provides perhaps the first analysis of the direct influence of Federal Reserve policy on EM central banks. He estimates enhanced Taylor rules for Chile, Colombia, and Mexico for 2000–2008, and finds that there is significant pass-through from U.S. policy to Chile’s and Colombia’s policies. Edwards connects this pass-through of Federal Reserve policy and implied absence of monetary policy dependence to these countries’ “fear of floating,” giving this as the most likely reason for the large degree of spillover.

Along with this work on spillovers in EMs, an important new branch of study started in Rey (2013) and continued in Miranda-Agrippino and Rey (2015), Passari and Rey (2015), and Rey (2016). This research has pointed to the existence of a so called “global financial cycle,” where the monetary policy of the U.S. plays the role of an essential determinant of global financial conditions through portfolio flows and what these papers call, the “international credit and risk-taking” channel. These studies have found that, even in advanced economies, U.S. central bank policy has led to large amounts of international monetary policy spillovers, though not always of the direct central bank to central bank kind that I treat in this paper. While these sorts of channels have not often been treated in an EM context, their role in transmission of Federal Reserve policy to EMs should always be at least considered, since portfolio flows have been shown to have a high degree of spillover and to cause general financial volatility in EMs (Chen et al. 2014).

The studies most closely related to the questions and methodology in this paper come from Rohe and Hartermann (2016) and Anaya et al. (2017). Rohe and Hartermann employ a

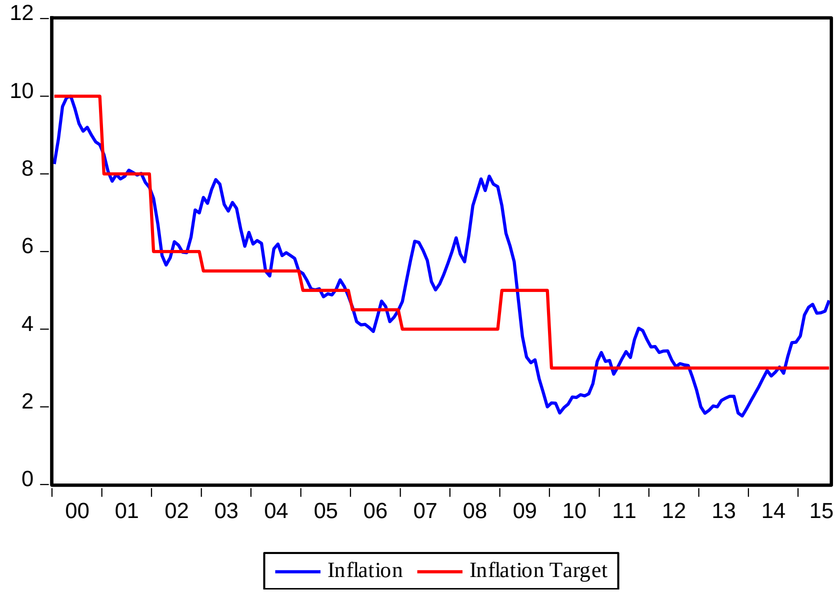
Bayesian SVAR with block exogeneity for Colombian and Brazilian data for 2000–2014 to analyze the interactions of exchange-rate interventions and interest-rate responses to external shocks such U.S. monetary policy and commodity shocks. They find that the Colombian central bank responds to these shocks through a combination of different policies. These approaches include following Federal Reserve policy with pass-through comparable to that of Edwards (2016) and conducting extensive foreign exchange-rate interventions, and again point to "fear of floating" as the main culprit for such reactions. They assert that Colombia follows this sort of dual-instrument monetary policy approach, "inflation-targeting-cum-intervention,"[5] and conclude that, in Colombia, it has been an effective strategy in strengthening monetary policy independence. Their results will serve as a main comparison benchmark for my full sample results. Anaya et al. (2017) estimate a Global SVAR to measure the international monetary spillovers of unconventional monetary policy (UMP) from the Federal Reserve to 19 EM economies after the financial crisis. These researchers find more clear evidence of international monetary spillovers, since the EMs analyzed seem to again exhibit a high degree of pass-through, reacting to Federal Reserve policy changes (in this case, increases in quantitative easing) by correspondingly following with their own policy. Furthermore, they discover that portfolio flows play a large role in these spillovers, backing the arguments of a "global financial cycle" in emerging markets.

[5] This terminology was first employed by Ostry et al. (2012).

3. Monetary Policy in Colombia

Following much emerging market volatility in the 1990s—and in 1998, a domestic financial crisis and subsequent currency crisis—Colombia abandoned its long-standing crawling exchange rate peg as an anchor of its monetary policy, and formally adopted inflation targeting in 1999. Figure 1 shows the trajectory of inflation and Colombian central bank-declared inflation targets. Both of these decrease steadily over the period in question and, since 2010, the central bank has found a steady target of 3 percent around which inflation has seemed to stabilize. It appears that the success of inflation targeting has been relatively high since, apart from volatility following the aftermath of the global financial crisis of 2008 and a subsequent upward revision of the inflation target, that target has served as an apt cap on inflationary expectations. Furthermore, the adoption of inflation targeting has also brought about a lowering of exchange rate pass-through to inflation, a general prediction made by Edwards (2007) and confirmed empirically by Coulibaly and Kempf (2010).

Figure 1: Inflation Targeting in Colombia, 2000-2015



As is common in inflation targeting economies, a repo rate becomes the main instrument of monetary policy once this sort of regime is adopted. In Colombia, the relevant rate has been the policy intervention rate ("Tasa de Intervención"). This instrument works much like the Federal Funds rate in the United States. The Colombian central bank uses this rate to affect the money supply of the economy by setting an interest rate "corridor" where it controls the interbank rate by setting the policy rate it pays for holding the financial systems' banks extra reserves (lower bound) and the rate at which it lends bank reserves (upper bound). Becerra and Melo (2010) assess the transmission of that policy rate into the Colombian economy and conclude that the central bank has been successful in significantly and directly controlling interest rates in financial markets, a prerequisite for an efficient and credible monetary authority. Barajas et al. (2014) confirm that the Colombian policy rate reacts in expected and significant ways to deviations from inflation targets, indicating that the central bank has in fact consistently used its main instrument to conduct monetary policy.

However, as in most emerging market central banks, Colombian policy-rate considerations account for more than just the typical Taylor Rule variables of inflation and output deviations. Most notably, how to respond to misalignments in the exchange rate poses a long-standing policy question that has evolved over time. This debate on whether a monetary authority *should* include the exchange rate in its policy rule is an old one, but one that is still not resolved[6]. Edwards (2007, 30) remains relatively agnostic on the subject, instead presenting a convincing argument that

> If the authorities have modeled the economy correctly (and, in doing so, have incorporated the effects of e on π and y) there is no need to include an exchange rate term . . . . If, however, there is a lagged response of both inflation and output to exchange rate changes, the central bank may want to *preempt* their effect by adjusting the policy

[6] This literature include various point of views such as Ball (1999), who argues that directly accounting for the exchange rate results in more-stable macroeconomic outcomes. Taylor (2001) expresses skepticism about the benefits of such an addition, since the exchange rate already indirectly affects both output and inflation, and is likely to add volatility to any policy rule. Mishkin and Schmidt-Hebbel (2001, 25) express similar counterarguments and conclude, "targeting on exchange rate is likely to worsen the performance of monetary policy."

> stance when the exchange rate change occurs, rather than when its effects on π and y are manifested. (emphasis added)

This introduces the idea, which I later return to in my own analysis, that the central banks might respond in advance to some macroeconomic indicator (such as exchange rate or, perhaps, even the Federal Funds rate), since its effects on domestic conditions are lagged yet expected.

At the same time, as Edwards notes, the degree to which central banks actually respond to the exchange rate remains an empirical matter. Since the "fear of floating" work of Calvo and Reinhart (2002), various studies have empirically estimated that many EM central banks still seem to include exchange rates when setting their policy stances. For example, Aizenman et al. (2011) find that, in a panel Taylor Rule estimation of EMs (including Colombia), the exchange rate plays a large and significant role in determining monetary policy stance. In addition, they highlight the importance of a country's economic structure in determining the significance of the exchange rate in the policy rule, showing that commodity-intensive exporters such as Colombia try to stabilize the volatility of their currencies more than non–commodity-intensive exporters. On the other hand, conclusive evidence that the Colombian exchange rate plays a substantial role in central bank decision making has not been found. In fact, Barajas et al. (2014), through country-specific Taylor Rule estimations from 2000–2012, find that the Colombian policy rule does not seem to be affected by the exchange rate to a significant degree. Rather, they observe that the Colombian central bank responded systematically to misalignments in the exchange rate through foreign exchange rate (FX) interventions.

These sorts of interventions are expected because, since the beginning of inflation targeting in 1999, the Colombian central bank has reserved a "right-to-intervene" exchange rate policy in its mandate (Vargas et al. 2013). This mandate stipulates that the bank may undertake FX interventions with three objectives in mind: maintaining adequate international reserves, fixing short-term exchange rate misalignments, and curbing excess volatility of the exchange rate. Much like the uncertainty surrounding the role of the exchange rate in monetary policy rules, the verdict is still out on whether these interventions actually work. Vargas et al. (2013) provide a survey of studies measuring the effective impact of interventions in a Colombian context, as well as provide their own analysis on the matter. They show that previous studies have found mixed outcomes of FX interventions, from no effects to some significant, yet short-lived, effects. Their own model (DSGE) finds that for the period after the global financial crisis, FX interventions prove to not be useful and, in certain cases, induce unintended financial volatility. They conclude that the two-instrument “inflation-targeting-cum-intervention” monetary policy approach might not be the most effective in a Colombian context. While this past research is in no way a completely definitive answer to the role and real impact of FX interventions in Colombian monetary policy, due to the high degree of uncertainty regarding such policy instruments, this paper’s model, described in the proceeding section, will not directly take into account FX interventions. Instead, I will control for periods of sustained central bank intervention in exchange rate markets, as I describe in my data section.

While much research has been conducted on the dynamics of monetary policy and the instruments used to conduct policy in Colombia, many questions remain. Although the main objective of this paper is to measure the transmission of spillovers from the Federal Reserve to the Colombian central bank, much emphasis will still be placed on the role of exchange rates and other macroeconomic variables in the transmission dynamics in order to provide a complete view of the underlying processes.

4. Methodology

To fully explore the transmission of U.S. monetary policy to Colombian central bank decisions, a structural vector autoregression (SVAR)[7] framework will be estimated. Three different periods will be analyzed: 2000–2015 (full sample), 2000–2008 (pre-crisis sample), and 2008–2015 (post-crisis sample). For each of these periods, three different SVARs will be applied to data, to test various identification schemes. These three specifications will be presented as follows: a recursive SVAR, a recursive SVAR with block exogeneity, and a non-recursive SVAR with block exogeneity. The variables being modeled will include both Colombian and U.S. macroeconomic variables, as described below.

4.1 Data

Quarterly data are used from 2000Q1 to 2015Q3. The full data vector for all variables used in the various models is $\{USGDP, USINF, PC, FFR, CGDP, CINF, COPR, NER\}$ where PC is the log of price of commodity (in this case, the world price of oil), $USGDP$ is the U.S. GDP annual growth rate, $USINF$ is the U.S. deviation from target inflation rate, FFR is the Federal Funds rate, $CGDP$ is Colombian GDP annual growth rate, $CINF$ is the Colombian deviation from target inflation rate, $COPR$ is the Colombian central bank policy rate, and finally, NER is the log of the bilateral nominal exchange rate between the U.S. and Colombia (measured in pesos/dollars). The inclusion of the price of oil is owed to the fact that crude oil represents around 50% of all Colombia's exports[8], and such a measure has proven to be essential in correctly identifying SVARs (Kim and Roubini 2000). Measures of U.S. and Colombian GDP, inflation, and central bank intervention rates were collected from their respective central bank bulletins and the IMF International Financial Statistics database. The

[7] For a broader introduction to this type of model, see Stock and Watson (2001)
[8] IMF Selected Issues Papers 2014

world price of oil was collected from the World Bank Commodity Prices Indexes. Dummy variables for the global financial crisis and periods of high foreign exchange-rate intervention are also included in the estimation. The global financial crisis dummy variable is defined as the period when the U.S. was in a recession, according to the NBER: 2007Q4–2009Q2. The various periods of continued exchange-rate interventions follow those specified in Barajas et al. (2014).[9]

4.2 Structural VAR Modeling

First, assume that the Colombian economy can be described through a structural form equation:

$$A(L)y_t = \varepsilon_t \tag{1}$$

Such that $A(L) = A_0 + A^0(L)$, which implies:

$$A_0 y_t = A^0(L)y_t + \varepsilon_t \tag{2}$$

where y_t is a n x 1 vector of endogenous variables, A_0 is an n x n matrix that specifies the contemporaneous relationships between variables, $A^0(L)$ is a matrix polynomial in the lag operator L without the contemporaneous matrix included, and ε_t is an n x 1 structural disturbances vector. ε_t is serially uncorrelated and var(ε_t) = Λ where Λ is a diagonal matrix whose diagonal elements are the variances of the structural disturbances. For this reason, we can see that these structural disturbances are assumed to be orthogonal.

This SVAR cannot be observed directly; thus, to be able to extract the coefficients of the structural model, a reduced form vector autoregression (VAR) must first be estimated:

$$y_t = B(L)y_t + \mu_t \tag{3}$$

[9] These periods are 2002Q1–2003Q1, 2004Q1–2007Q2, 2008Q2–2009Q1, 2010Q2–2011Q3, and 2012Q2–2012Q4.

where $B(L) = A_0^{-1}A^0(L)$ and is a matrix polynomial in lag operator L and $\mu_t = A_0^{-1}\varepsilon_t$ and is an n x 1 vector of the reduced form errors. These errors are serially uncorrelated where var(μ_t) = Σ. Here, Σ is not assumed to be diagonal and thus is not restricted, indicating that errors across equations may be correlated. Furthermore, since we see that the structural disturbances and the reduced form errors are related through

$$\varepsilon_t = A_0\mu_t \quad (4)$$

it is implied that

$$\Sigma = A_0^{-1}\Lambda A_0^{T^{-1}} \quad (5)$$

From this point, we can find maximum likelihood estimates of A_0 and Λ by using sample estimates of Σ. Since the right hand side of equation (5) has n x $(n$ + 1) parameters that need to be estimated and Σ has n x $(n$ + 1)/2 parameters, the model needs at least n x $(n$ + 1)/2 restrictions. The next step is to normalize the n diagonal elements of A_0 to 1's. Now, only n x $(n$ - 1)/2 restrictions on A_0 are needed to achieve identification of the model. These restrictions take the form of "exclusion" restrictions—that is, setting certain contemporaneous relationships in the A_0 matrix to zero. It should thus be clear that, in this type of SVAR modeling, since the restrictions are being imposed on the A_0 matrix, identification of the contemporaneous interactions of variables to 'shocks' (disturbances) in other variables in the system is in fact the structure of these models. The combinations of possible contemporaneous restrictions chosen for a given VAR are limited only by the researcher's creativity. For this reason, it is necessary that restrictions have *a priori* economic logic and theoretical support, since wrong specifications can quickly lead to unsound inference.

The estimation of SVARs has as a primary goal to correctly identify shocks in a certain variable and to trace the responses over time of the other variables. These responses are presented in the form of impulse-response functions, which estimate the reaction paths to an unexpected structural shock to one variable in the system. Given the question this paper explores, the SVARs I estimate have as their principal objective to identify shocks to the Federal Funds rate onto the Colombian economy, to better understand the transmission of international monetary spillovers.

4.2.1 Structural VAR Modeling with Block Exogeneity

In the setup of the VAR and SVAR from the previous section, the only restrictions imposed on the structure of the model were on the contemporaneous relationships between variables, with no assumptions made about the models' lagged structure. However, this assumption of lagged interactions between all variables is one that should be revisited depending on the context. In the particular case of modeling Colombian macroeconomic conditions and monetary policy stance, and its reactions to U.S. conditions, it would seem a good idea to reflect on whether one can justify lagged effects of Colombian variables on U.S. variables. It is clear that the U.S., Colombia's biggest trade partner and a large determinant of worldwide financial conditions, should affect Colombian conditions. However, it is unclear why Colombia, a small open economy with comparatively little importance to the global economy, would have any influence on U.S. macroeconomic conditions. To account for this assumption of no feedback from Colombian variables to U.S. variables, a block exogeneity approach, first introduced by Cushman and Zha (1997), can be employed to more accurately specify the SVARs.

In a block exogeneity setup, two blocks of vectors are set up, one "foreign" and one "domestic". To better understand this form, it is useful to return to equation (1): $A(L)y_t = \varepsilon_t$, but now, rather than just one vector, two blocks of vectors y_t^f, y_t^d representing the foreign block and the domestic block, respectively, are separated in the structural form of the model such that

$$y_t = \begin{pmatrix} y_t^f \\ y_t^d \end{pmatrix}, \quad A(L) = \begin{pmatrix} A_{ff}(L) & 0 \\ A_{df}(L) & A_{dd}(L) \end{pmatrix}, \quad \varepsilon_t = \begin{pmatrix} \varepsilon_t^f \\ \varepsilon_t^d \end{pmatrix} \tag{6}$$

where y_t^f and ε_t^f are n_f x 1 matrices, y_t^d and ε_t^d are n_d x 1 matrices, $A_{ff}(L)$ is a n_f x n_f matrix, $A_{df}(L)$ is a n_d x n_f, and $A_{dd}(L)$ is a n_d x n_d matrix. The imposition of $A_{fd}(L) = 0$ is in fact the block exogeneity condition. This restriction implies that there are no contemporaneous or lagged effects of domestic variables on foreign variables.

More practically, we can think of the direct effect of this imposition on equations (2) and (3). For the reduced form VAR in (3), the lag-matrices represented by $B(L)$ will have zeros for all coefficients of the domestic lagged variables on foreign variables. Furthermore, in the SVAR of equation (2), for both A_0 and the lag-matrices represented by $A^0(L)$, all the coefficients of domestic variables on foreign variables will also be zero. Other than the imposition of these zero restrictions on the lag structure, block exogenous SVARs are estimated in the same way as before. For the full estimation procedure of SVARs with and without block exogeneity, please see appendix 1.

4.3 Identifying Restrictions

4.3.1 Recursive SVAR

To start the analysis, first consider a SVAR with no block exogeneity—that is, only restrictions on the contemporaneous relationships of variables are imposed. In this case, the estimated SVAR will resemble the model presented in section 4.2, equation (7). A recursive SVAR applies what is commonly called a Cholesky decomposition of variance of reduced form VAR errors, which implies a recursive scheme of the A_0 matrix. This type of structure is a popular point of departure when estimating SVARs, since it assures just-identified models. However, some of the restrictions applied when using this method might seem unrealistic, and thus different specifications are necessary to assure robustness.

This setup creates a lower triangular A_0 matrix where the first variable is not affected contemporaneously by any other variable in the system. The next variable is affected contemporaneously by the first variable and by none below it. The next variable is affected by the preceding two variables, but none after it, and so forth. The process continues down this chain until the last ordered variable that is contemporaneously affected by all variables, but not the other way around. It is worth returning to the idea that, while a good starting point, such a model is very sensitive to different orderings of the variables. For this reason, it is essential to choose an accurate ordering of the variables in the system. This paper's benchmark recursive ordering is presented below, following the form of equation $A_0\mu_t = \varepsilon_t$ (4):

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{bmatrix} \begin{bmatrix} \mu_{usgdp} \\ \mu_{usinf} \\ \mu_{pc} \\ \mu_{ffr} \\ \mu_{cgdp} \\ \mu_{cinf} \\ \mu_{copr} \\ \mu_{ner} \end{bmatrix} = \begin{bmatrix} \varepsilon_{usgdp} \\ \varepsilon_{usinf} \\ \varepsilon_{pc} \\ \varepsilon_{ffr} \\ \varepsilon_{cgdp} \\ \varepsilon_{cinf} \\ \varepsilon_{copr} \\ \varepsilon_{ner} \end{bmatrix} \quad (7)$$

These restrictions impose the order in which shocks reverberate throughout the SVAR system. As one can see, the exact ordering of the variable follows $\{USGDP, USINF, PC, FFR, CGDP, CINF, COPR, NER\}$, where $USGDP$ is ordered first and NER is ordered last. It makes sense to start the recursive ordering with the U.S. variables and the price of oil, since they affect Colombian conditions contemporaneously, while the inverse is unlikely to be true. U.S. GDP and inflation represent large 'sluggish' sectors that are slow-moving and do not react within quarter to other variables. The Federal Funds rate responds to the price of oil within period, since the Federal Reserve is more likely to respond to shocks to the world price of oil (both positive and negative, inflationary and deflationary, respectively) than the price of oil is likely to respond within quarter to a shock to the Federal Funds rate. The Colombian variable ordering follows similar logic. Colombian GDP and inflation are unaffected by the central bank's policy rate, while the inverse is almost certain to be true, since Colombia's inflation-targeting regime for the period analyzed. Having the nominal exchange rate react contemporaneously to all other variables is quite normal in the literature (Cushman and Zha 1997; Kim 2001), since the exchange rate represents a sort of information market, given that the exchange rate is a forward-looking asset that quickly captures changes in all other variables.

4.3.2 Recursive SVAR with Block Exogeneity

To extend the SVAR in the previous section, a recursive SVAR of a similar nature is also estimated, except that here, the block exogeneity assumption is also imposed on the model. Seeing that the A_0 matrix described above already imposes that Colombian variables do not affect U.S. variables contemporaneously, there are no changes made to the contemporaneous restrictions of the recursive SVAR from equation (9). However, this specification now also imposes restrictions on the lag structure between variables. Following the structure explained in equation (8), the eight-variable vector of variables is now split into two different blocks of vectors. The foreign vector y_t^f consists of the U.S. variables and the price of oil: $\{USGDP, USINF, PC, FFR\}$. The domestic vector y_t^d consists of the Colombian variables: $\{CGDP, CINF, COPR, NER\}$. The block exogeneity assumption implies that $A_{fd}(L) = 0$, which simply means that the foreign (U.S.) vector of variables is not affected by the domestic (Colombian) vector of variables, neither contemporaneously nor with lags. Since we already assume that there are no contemporaneous effects of Colombian variables on foreign ones, the only addition of this model is the imposition of the zero effect of lags of the Colombian vector on the U.S. vector.

4.3.3 Non-Recursive SVAR with Block Exogeneity

The last SVAR specification presented takes a non-recursive scheme with block exogeneity. Non-recursive structures are a more general way to apply structure without having to apply the arbitrary restrictions by ordering of the recursive Cholesky decomposition. These SVARs allow for simultaneous interactions between variables and for unsymmetrical restrictions such that the restrictions matrix will no longer look like the lower triangular matrix in preceding sections. The block exogeneity assumption will not be affected by this new structure, since the U.S. block of variables will still not be affected by the domestic variables either contemporaneously or with lags. Using a non-recursive structure, it is now possible to revisit some of the restrictions that the recursive SVAR imposed by its construction that may have seemed unreasonable. Non-recursive restrictions in A_0 are presented below:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & a_{53} & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{65} & 1 & 0 & 0 \\ 0 & 0 & a_{73} & a_{74} & a_{75} & a_{76} & 1 & a_{78} \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{bmatrix} \begin{bmatrix} \mu_{usgdp} \\ \mu_{usinf} \\ \mu_{pc} \\ \mu_{ffr} \\ \mu_{cgdp} \\ \mu_{cinf} \\ \mu_{copr} \\ \mu_{ner} \end{bmatrix} = \begin{bmatrix} \varepsilon_{usgdp} \\ \varepsilon_{usinf} \\ \varepsilon_{pc} \\ \varepsilon_{ffr} \\ \varepsilon_{cgdp} \\ \varepsilon_{cinf} \\ \varepsilon_{copr} \\ \varepsilon_{ner} \end{bmatrix} \tag{8}$$

First, we see that contemporaneous restrictions on the foreign block are not altered such that they retain a recursive chain. The recursive ordering of these foreign variables is not unreasonable, and it is preferable to avoid imposing too many restrictions, given that this SVAR is only trying to identify the effects of a U.S. monetary policy shock on the Colombian economy. The new restrictions of the non-recursive structure thus come when identifying the domestic—that is, Colombian—block. First, U.S. GDP and inflation are assumed to not affect Colombian GDP, inflation, or policy rate within period, since it would seem implausible that Colombian conditions change quickly in reaction to the U.S. sluggish sectors. However, the most important alterations to this new structure are the zero restrictions on the contemporaneous effect of the Federal Funds rate on Colombian GDP and inflation, as well as the addition of the fact that Colombian monetary policy can now respond contemporaneously to the nominal exchange rate. The first restrictions should be self-evident: If Colombian GDP and inflation do not respond within quarter to domestic monetary policy shocks, it is highly unlikely the two variables will respond to foreign monetary policy shocks. The second new important restriction, that of simultaneous reactions between the Colombian policy rate and the nominal exchange rate, follows the idea that in a small open country, heavily reliant on exporting of commodities such as oil, the central bank will take the exchange rate into consideration in an effort to control too much volatility, or as it is called in the literature, "fear of floating." In summary, this non-recursive SVAR with block exogeneity extends the contemporaneous restrictions matrix from previous sections with more-plausible restrictions and again assumes that Colombian variables have no effect on U.S. variables or price of oil either within quarter or with lags.

5. Results and Discussion

In this section, results from the various different SVAR specifications will be presented[10]. These results will take the form of impulse responses showing the path of a variable's response to an unexpected shock to another variable in the system over time, which here will be 12 periods (quarters). Given that the SVARs estimated in the previous section were built with the goal of identifying a U.S. monetary policy shock to the Colombian economy, the impulse response functions to this particular shock will serve as the main avenue of analysis. Shocks to the Federal Funds rate can be interpreted as a 50 basis point contractionary shock. First, the full sample results will be discussed and then, results for each of the sub-samples will be presented. The full period-models have a lag order of two and the two shorter-period models have a lag order of one[11]. It should be noted that for both block exogenous SVARs, standard error bands, which are shown for the simple recursive SVAR, are not estimated[12]. For this reason, the exact point estimates of the impulse response functions presented below should be interpreted with some caution.

5.1 Full Sample Results

First, the impulse responses for the full sample period (2000–2015) will be examined. Figure 2 shows the responses of the Colombian policy rate and nominal exchange rate to a positive (contractionary) 50 basis point shock to the Federal Funds rate. Note that since

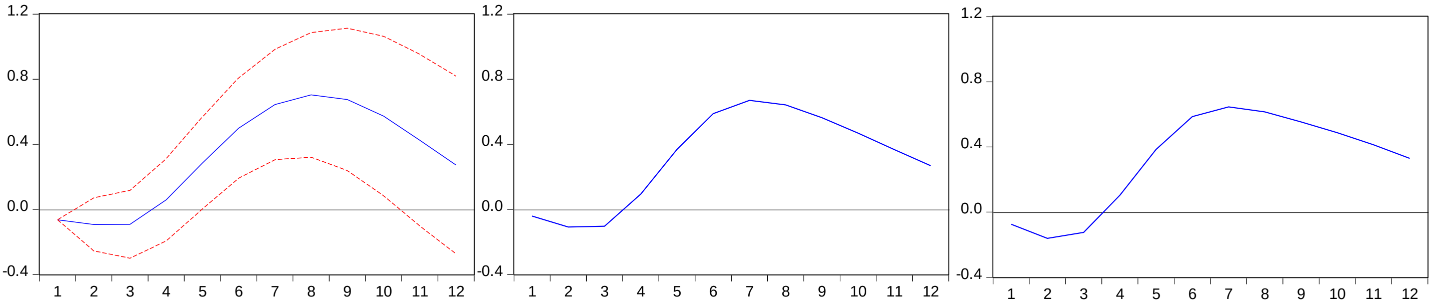
[10] SVARs with different sets of variables, such as some not including U.S. GDP and U.S. inflation, were also originally estimated. They yielded the same general results as the specifications presented in this paper; however, results from those different sets of variables were much less robust and for that reason are not included in this final version.

[11] These lag orders are selected by using the Schwarz Information Criterion (SIC) and by checking that the lag order assures stability of the SVARs.

[12] Given the imposition of block exogeneity and, thus, restrictions on the lag structure of these SVARs, standard error bands cannot be estimated in traditional methods (Zha 1999). Methods such as a Markov chain Monte Carlo estimation based on a Gibbs sampling approach (Waggoner and Zha 2003) exist but implementation with the statistical package used in this paper (EViews) was unfeasible. EViews is not a package particularly tailored for coding large programs such as the MCMC algorithm. Implementation of such estimation methods has been performed in various studies in the literature with statistical packages such as R, RATS, and Matlab.

Figure 2: 2000-2015

Figure 2a – Impulse Response of Colombian Policy Rate to 50 Basis Point Federal Funds Rate Contractionary Shock[13]

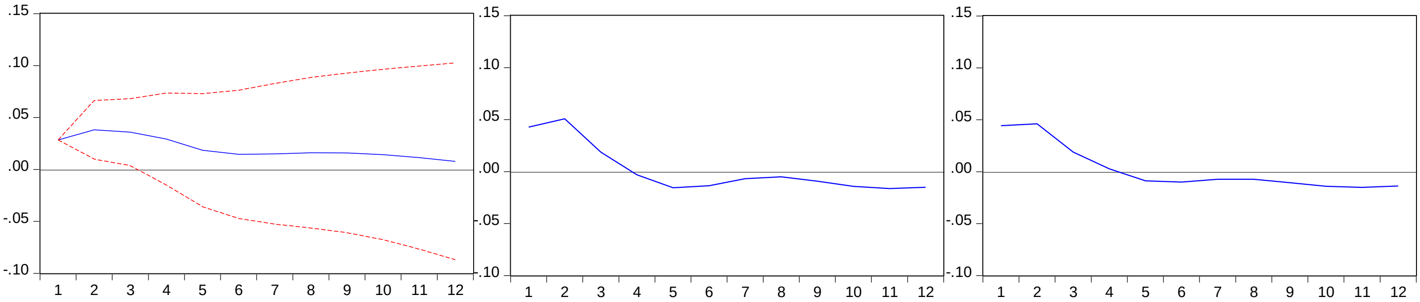


(a) Recursive Only

(b) Recursive w/ Block Exogeneity

(c) Nonrecursive w/ Block Exogeneity

Figure 2b – Impulse Response of Colombian Nominal Exchange Rate to 50 Basis Point Federal Funds Rate Contractionary Shock



(a) Recursive Only

(b) Recursive w/ Block Exogeneity

(c) Nonrecursive w/ Block Exogeneity

nominal exchange rate is denominated in pesos/dollars, a rise in this impulse response can be interpreted as a depreciation and vice versa.

From a first glance at figure 2a, we can quickly see that a Federal Funds rate (FFR) shock has quite a large effect on the monetary policy stance in Colombia. The responses of Colombian monetary policy in all SVAR specification show expected directions and significant effects of international monetary policy spillover from the Federal Reserve, as Colombia seems to be following U.S. policy very closely. To better understand the actual

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[13] Figure 2a graphs policy rate on the y axis, and response over 12 quarters on the x axis

transmission process, it might be helpful to unpack the shapes of the responses. Colombian central bank reaction follows what looks like two distinct phases. The first phase comes right after the impact of the FFR shock. For the first three quarters, policy rates in Colombia do not change significantly and hover around zero. At the same time, the nominal exchange rate experiences an impact depreciation. This first phase would be indicative of a small open country with no "fear of floating"—since the exchange rate, falling because of interest rate differentials between Colombia and the U.S., serves as a shock absorber and the Colombian central bank is able to maintain monetary policy independence. The exchange rate depreciation does not seem to have any real pass-through to inflation (impulse response shown in appendix 2), which does not significantly change after the shock, confirming recent results from Rincón-Castro et al. (2017).[14]

The second phase, however, paints a different picture, starting midway through the third quarter, Colombian policy rate rises steadily leading to a pass-through[15] of U.S. monetary policy rate to Colombian policy of around 1.1 in the recursive-only specification, and a pass through of around 0.8 in the block exogenous specifications. (After initial shock, FFR (appendix 2) in the recursive-only SVAR peaks at 60 basis points, while in block exogenous specifications, FFR reaches a high of 75 basis points.). The Colombian interest rate stays at high levels for some time, peaking in the eighth quarter (after two years), and then begins to slowly descend, pointing to the fact that Federal Reserve spillovers are rather long-lasting (six to eight quarters of significant influence). Interestingly, after the impact depreciation, exchange rates appreciate relatively quickly and stabilize around zero quickly after Colombian policy rates begin to climb. These results point to the fact that Colombian monetary authorities do in

[14] These researchers have recently found that, in Colombia, over the same period as my full sample period, exchange rate pass-through to inflation is "shock dependent". They find that external shocks that affect the exchange rate exhibit less pass-through than internal shocks.

[15] Pass-through of Federal Reserve policy is calculated by dividing the maximum rate attained by the Colombian policy rate, divided by the maximum rate attained by the Federal Funds Rate after the shock.

fact exhibit "fear of floating"—that is, they react to misalignments of the exchange rate, in this case, due to U.S. monetary policy shocks. However, the sustained and rather high response of Colombian policy rates combined with rapidly normalized exchange rates indicates that there might also be other reasons why Colombian authorities follow the Federal Reserve[16].

The two main, most plausible reasons for the persistent response of Colombian policy stance to U.S. monetary shocks are as follows. First, it could simply be the case that extended "fear of floating" could be happening. That is to say, perhaps the only reason the exchange rate stabilizes so well after the initial depreciation, and does not significantly move from zero is because of the large Colombian reaction. This would imply that without Colombian intervention the exchange rate would be more volatile in the face of a U.S. monetary shock. This process could be explained by the idea of Edwards (2007) that a central bank might respond pre-emptively to a shock in a macroeconomic variable (here, the FFR), if its future effect on other variables (here, the exchange rate) takes time to manifest. While he originally uses this idea to talk about the response of central banks to the exchange rate, the same logic would apply when monetary authorities respond to the FFR. The second possible reason has us return to the idea of a "global financial cycle", previously mentioned in Section 2. While, I have not formally modeled portfolio flows in my SVARs, it could certainly be the case that a shock to the FFR could signal and further, induce future portfolio outflows and financial volatility due to the international credit and risk-taking channels (Chen et al. 2014; Miranda-Miranda-Agrippino and Rey 2015; Rey 2016). Thus, Colombian monetary authorities could in fact be reacting (by following Federal Reserve policy) to these specific channels of spillover caused by the role of U.S. monetary policy in the "global financial cycle". Obviously, both of

[16] It is possible that a moderate increase in the Colombian GDP, probably due to a traditional Mundell-Fleming-Dornbusch expenditure switching spillover, could be amplifying the response of the Colombian central bank. However, my results (not depicted) suggest that this effect is likely small, since changes in GDP produce only small reactions in the Colombian policy rate.

these explanations could be playing a role in Colombian policy response at the same time, as is most likely the case.

Having given possible reasons for my full sample results, I now turn to comparing my results with those already existing in the literature, particularly, those of Rohe and Hartermann (2016). My results appear to match up very well to their findings about the effects of a Federal Funds rate shock on the Colombian economy. Their study finds that the pass-through of the FFR to the Colombian policy rate peaks in the range of 0.75, much like my block exogenous SVARs indicate. Additionally, the shape of their model's impulse responses of the Colombian policy rate, inflation, and exchange rate confirm the other results I have previously discussed. However, it seems that the similarity of their paper and my findings casts some doubt on one of their main conclusions: the effectiveness of foreign exchange interventions in Colombia in helping preserve some monetary policy independence.

First, it is important to note that as Kim and Roubini (2000) show, SVARs can quickly be mis-specified (and produce incorrect impulse response functions) due to omission of key variables in the model. Unlike in my models, Rohe and Hartermann use a measure of FX intervention and explicitly include it as a variable in their SVAR, because they hypothesize that these interventions are an essential instrument in Colombian monetary policy. In fact, they attribute the fact that Federal Reserve policy pass-through is not higher to their inclusion of the FX intervention variable. It follows that, if their conclusions were true, the lack of such a variable in my SVARs would mis-specify them and consequently, produce incorrect, or at least significantly different impulse response functions. Given that I arrive at the same results, with no explicit FX intervention variable[17], I am inclined to conclude that the systemic FX

[17] My inclusion of a dummy variable controlling for periods of high FX intervention, described in the data section, is not the same as actually adding a FX intervention variable into an SVAR. Rohe and Hartermann estimate an 11 variable Bayesian SVAR, in which much of their identification relies on their measure of FX interventions.

interventions in Colombia do not particularly aid in preventing direct transmission of U.S. monetary policy into Colombian interest rates[18].

In summary, in the period since Colombia adopted inflation targeting, there has been a large amount of international monetary policy transmission from the Federal Reserve to the Colombian central bank, eroding Colombia's monetary policy independence. Possible reasons include "fear of floating" and the international risk taking and credit channels of the "global financial cycle" theory. Lastly, my results compare well with pre-existing literature and seem present some doubt as to whether exchange rate interventions in Colombia have much of an effect in increasing monetary policy independence.

5.2 Pre- and Post- Financial Crisis Comparison

Having a better understanding of the international monetary policy spillover in Colombia, I now investigate if the transmission of spillovers changed after the global financial crisis of 2008. Figure 3 shows the responses of the Colombian policy rate and nominal exchange rate to a positive (contractionary) 50 basis point shock to the Federal Funds rate, now separated into pre-financial crisis (2000–2008) and post-financial crisis (2008–2015) subsamples.

After examining figure 3, one first notices that much like the full sample period, all SVAR specifications in both periods exhibit significant evidence of international monetary policy spillover from the Federal Reserve to Colombia. The first and clearest difference between the different periods is the change in magnitudes of Colombian central bank response to a FFR shock. While block exogenous SVARs[19] in the pre-crisis period see a long-run pass-

[18] The differences between our two studies do not imply anything about the effectiveness of FX interventions in maintaining exchange rate stability or correcting misalignments. I make no conclusions about that.
[19] This section will focus mostly on the block exogenous SVARs, since they appear more robust than my recursive only SVARs given the strange response of pre-crisis FFR after a shock to itself (appendix 2).

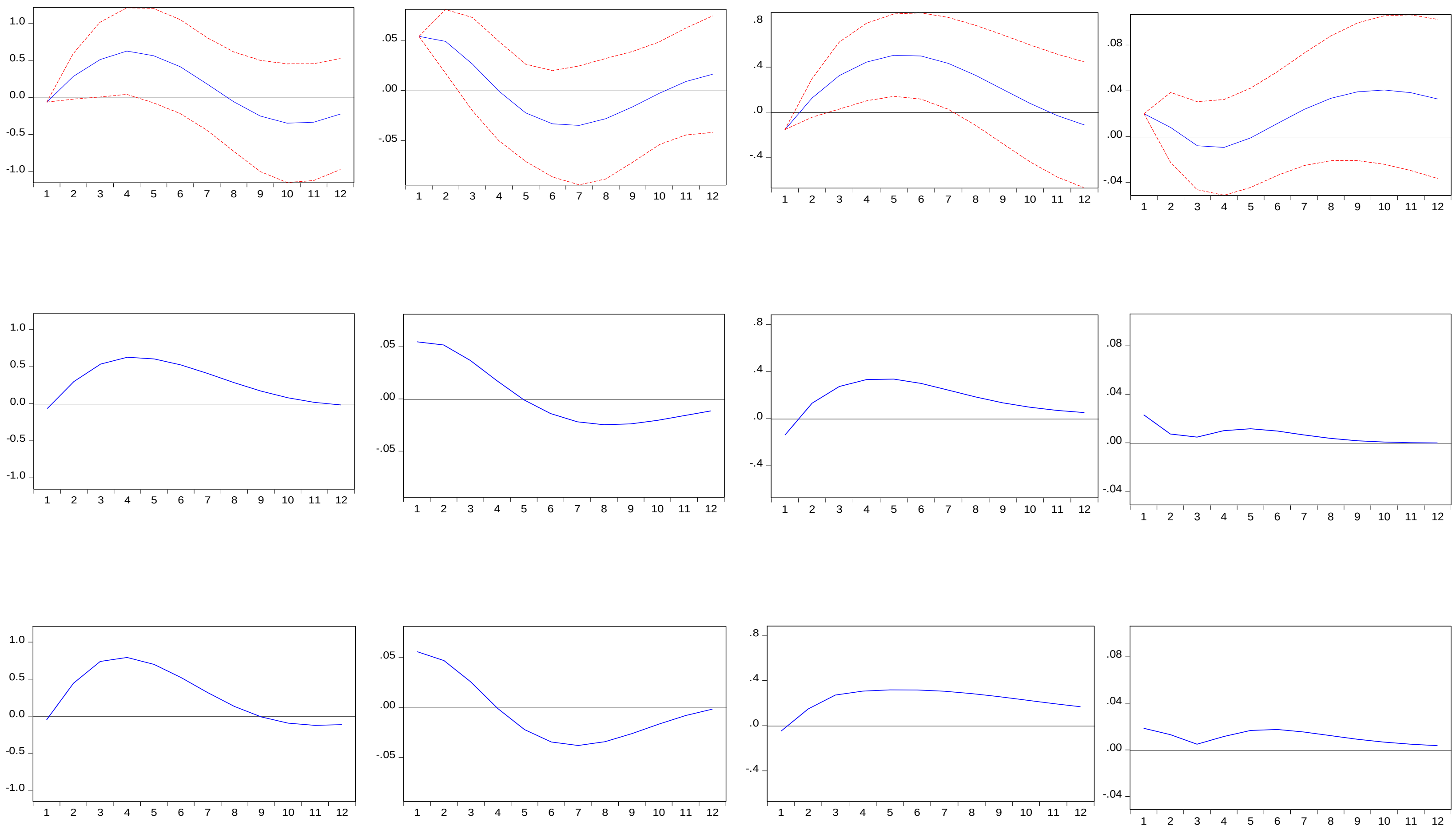
Figure 3: Impulse Response of Colombian Policy Rate and Nominal Exchange Rate to 50 Basis Point Federal Funds Rate Contractionary Shock

	2000-2008		**2008-2015**	
	Policy Rate	Exchange Rate	Policy Rate	Exchange Rate

(a) Recursive Only

(b) Recursive w/ Block Exogeneity

(c) Nonrecursive w/ Block Exogeneity

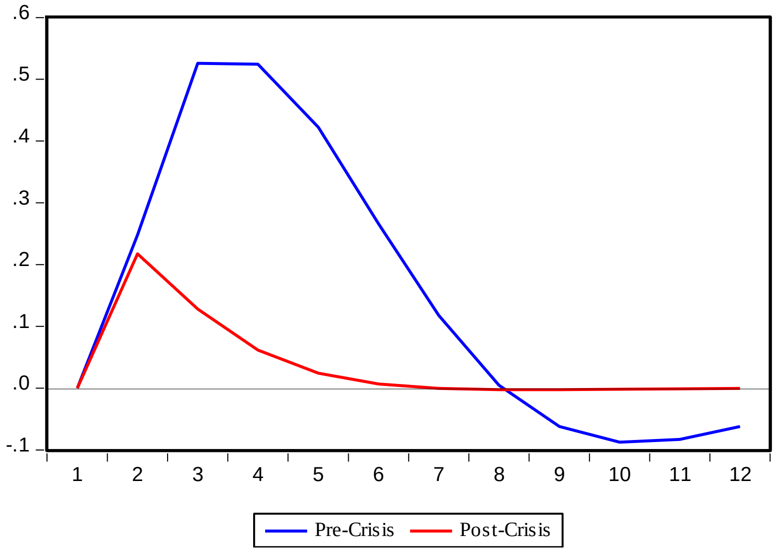


through of 1.2 or greater, the post-crisis specifications show a pass-through of around 0.6. This significant difference is rather intriguing, since it would seem to imply that the transmission of U.S. monetary policy into Colombia's interest rates structurally changed and specifically decreased after the global financial crisis. One of the few studies in the literature performing this sort of pre- and post- crisis spillover analysis, Takáts and Vela (2014), finds the same results—that is, many emerging markets, including Colombia, show less response to Federal Reserve policy post-crisis. However, these researchers do not provide a convincing explanation for this. What could be the possible reasons for such a change?

The first factor in this change appears to be the exchange rate. By comparing its impulse responses in block exogenous SVARs across time, the exchange rate in the pre-crisis period seem much more volatile, depreciating on impact of the shock by 5% and later after four or five quarter swinging in the other direction and showing considerable appreciating tendencies. On the other hand, exchange rates in the post crisis barely depreciate on impact by 2%, and return back to base levels rather quickly, showing great amounts of stability in the long run. There is no easy answer as to why exchange rate show significant change to shocks in FFR. A possible explanation is that during most of the post-crisis period (2009Q1-2014Q4), the peso was at its strongest levels of the 15 year period. This is likely due to the fact, that during the same time period, the price oil reached its highest sustained price point as well. This could have possibly helped insulate the peso and the Colombian economy from external conditions.

Going back to the original question at hand, a worthwhile next step is to investigate the interactions of the Colombian policy rate and the exchange rate, before and after the crisis. It seems within reason that due to a stronger peso, and its apparent resilience to foreign shocks, the Colombian central bank started lessening the degree to which they "feared of floating". This theory is tested by checking how much the Colombian policy rates respond to a shock in the nominal exchange rate across time. Figure 4 shows the pre- and post- crisis responses of the Colombian policy rates to a 10% depreciative shock to the exchange rate in the recursive block exogenous SVAR.[20]

Figure 4: Response of Colombian Policy Rate to a 10% Depreciation Shock of the Exchange Rate



The difference of responses is quite large and indicates that "fear of floating" does seems to have substantially decreased from the pre-crisis period to the post-crisis, both in magnitude and duration. While there is not much previous work on this phenomenon, a recent paper by Cabral et al. (2016) confirms these results for a panel of EMs including Colombia. However, these researchers do not provide much in the way of reasoning about why this structural change occurs. Other than the strength of the peso, a main reason for the structural change could be the lowering of the exchange rate pass-through to inflation after the crisis as observed by Jašová et al. (2016). Their results indicate that the pass-through to inflation decreased significantly in Colombia post-crisis. It follows that Colombian monetary authorities would respond less to the exchange rate if its inflationary effects were subdued. Another conjecture is that while the managed floating exchange rate regime of Colombia *de jure* ended rather abruptly in 1999 with its formal switch to inflation targeting, exchange rate targeting

[20] For the sake of clarity and brevity, I do not include the other block exogenous SVAR responses. They vary slightly in shape but also reflect the fact that pre-crisis period responses to the exchange rate are about twice the size of the post-crisis responses.

was most likely not completely abandoned for quite some time at the beginning of the new decade. Instead, it probably took a couple of years for the Colombian central bank to adapt to the new regime and efficiently implement inflation targeting policy. While I have no hard evidence for this hypothesis, it seems rather logical that at large institutions such as a central bank, regime changes are unlikely to be clean and quick, and rather slow and complicated.

Regardless of the reason, the drop in Federal Funds rate pass-through to the Colombian policy stance after the crisis now seems quite reasonable. With proven diminished "fear of floating" in the post-crisis period, a large channel for U.S. monetary policy spillovers to transmit to Colombia weakened, and consequently, reduced spillover experienced by Colombian monetary authorities. The smaller, still present, spillover in the post-crisis period could be explained by the other main channel of international monetary policy spillovers that I have previously touched upon—the risk-taking and credit transmission channels. These channels do not have to have a direct effect on exchange rates and thus seem like a plausible reason for the post-crisis spillovers. An immediate extension not provided in this paper, but that would most likely enhance the results found here, would be to more accurately model Federal Reserve policy after the crisis. Since I only include the Federal Funds rate, which was stuck at 25 basis points for most of my post-crisis period, my results are probably not accurately depicting the effects of unconventional monetary policy.

6. Conclusion

As the world recovers from the 2008 global financial crisis, the increasing interconnectedness and inter-reliance of modern economies, has taken center stage. Whether you call it international monetary policy spillover, contagion, or the "global financial cycle," recent research has shown that few countries, even industrialized ones, can insulate their economies from external conditions, particularly the large influence of U.S. monetary policy. This fact is especially salient in an emerging market context, since these countries usually exhibit the perfect mix of just enough global financial integration and lack of strong fundamentals to make them particularly vulnerable to foreign interest rate shocks. As the previous Governor of the Bank of Mexico, Carstens (2016, 29) himself states, "A key concern . . . has been that monetary policy decisions by AEs [advanced economies] can create large spillovers, especially for EMEs [emerging market economies] , so some form of coordination is urgently needed." While the literature has provided some answers about the exact processes underlying the transmission of Federal Reserve in emerging markets, many questions remain.

To provide some (partial) answers to these pertinent questions, this paper analyzes the impacts of U.S. monetary shocks on one emerging market economy, Colombia. I find that Federal Funds rate shocks induce significant reactions of Colombian interest rates that follow the direction of the shock, indicating loss of monetary policy autonomy and a high degree of spillover and pass-through. This result is significant through all specifications and time periods. I also find that foreign exchange interventions, in Colombia, might not have a large effect in preserving monetary policy independence. Lastly, by splitting the full sample period into pre- and post- global-financial-crisis crisis periods, I find that the transmission process of Federal Reserve policy to Colombia experiences a structural change. Results show that the reactions of the Colombian policy rate to the Federal Funds rate diminish significantly after the crisis likely due to a combination of lower exchange rate pass-through to inflation, a stronger peso, and perhaps, institutional changes. My analysis indicates that the two most conceivable explanations for the international monetary policy spillover shown in this paper are "fear of floating" and the effects of the international risk-taking and credit channels.

My results complement existing literature in various dimensions. First, I provide further evidence of the influence that U.S. monetary policy has in determining global financial conditions, this time in an emerging market context. This influence is shown to significantly erode monetary policy independence in Colombia, adding support to the Rey (2013) claim that, in a highly financially connected world, exchange rates may no longer serve as efficient shock absorbers and the so-called "trilemma" has in fact become a "dilemma" between independent monetary policy and free capital flows. Second, while not too common in previous studies, splitting up the sample period into pre- and post- crisis subsamples proves to be a worthwhile endeavor. By performing this analysis, the evolution of spillovers over time can be analyzed with more detail and the exact transmission processes better understood.

These results are an encouraging start, but there is still much research to be done on the transmission and subsequent effects on U.S. monetary policy in emerging markets. Some considerations for future studies include: explicitly accounting for the role of capital flows and unconventional monetary policy and using this to more accurately compare pre- and post-crisis spillovers, continuing to explore the exact role of FX interventions play in responding to these external shocks, and analyzing more countries with different economic structures to discern which country-level characteristics induce more vulnerability to spillover.

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Appendix 1: Estimation of SVAR[21]

For more-practical purposes, a detailed version of the estimation procedure for both non-block exogenous and block exogenous SVARs is presented here. The reader should note that this paper's implementation was conducted in EViews.

A1.1 Expanded Form of SVAR with No Block Exogeneity

Following the data vector presented in section 4.1, the variables included in the model are $\{USGDP, USINF, PC, FFR, CGDP, CINF, COPR, NER\}$. A reduced form VAR (following the form of equation (3)), with one lag[22], is estimated first. This reduced form VAR(1) can be simply understood as a system of variables in which each variable is regressed on itself as well as the lags of all other variables. This system of equations can be presented as

$$y_t = B_1 y_{t-1} + \mu_t \tag{9}$$

or

$$\begin{pmatrix} USGDP \\ USINF \\ PC \\ FFR \\ CGDP \\ CINF \\ COPR \\ NER \end{pmatrix} = \begin{pmatrix} B_{USGDP-USGDP} & \cdots & \cdots & B_{USGDP-NER} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ B_{NER-USGDP} & \cdots & \cdots & B_{NER-NER} \end{pmatrix} \begin{pmatrix} USGDP(-1) \\ USINF(-1) \\ PC(-1) \\ FFR(-1) \\ CGDP(-1) \\ CINF(-1) \\ COPR(-1) \\ NER(-1) \end{pmatrix} + \begin{pmatrix} \mu_{usgdp} \\ \mu_{usinf} \\ \mu_{pc} \\ \mu_{ffr} \\ \mu_{cgdp} \\ \mu_{cinf} \\ \mu_{copr} \\ \mu_{ner} \end{pmatrix}$$

where y_t is the vector of endogenous n = 8 variables, y_{t-1} is the vector of endogenous one-lag variables, and B_1 is the n x n matrix of all one-lag variables' parameters in each variable's equation. To estimate the desired SVAR(1) coefficients from the reduced form VAR(1), the variance-covariance matrix of the model's structural disturbances, Λ, must be orthogonalized, and the contemporaneous matrix A_0 must be found. After normalizing the diagonal of the A_0 matrix to 1's, n x (n - 1)/2 restrictions must be made to arrive at complete identification of the SVAR(1). Thus, with n = 8 variables, at least 28 restrictions must be made on the A_0 matrix. Restrictions in this case are represented by setting certain contemporaneous relationships between variables to zero, following economic theory. When the restrictions on the A_0 matrix have been made, the SVAR(1) (following form of equation (1)) can now be represented as:

$$A_0 y_t = A_1 y_{t-1} + \varepsilon_t \tag{10}$$

or

$$\begin{pmatrix} 1 & \cdots & \cdots & A_{0(USGDP-NER)} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ A_{0(NER-USGDP)} & \cdots & \cdots & 1 \end{pmatrix} \begin{pmatrix} USGDP \\ USINF \\ PC \\ FFR \\ CGDP \\ CINF \\ COPR \\ NER \end{pmatrix} = \begin{pmatrix} A_{USGDP-USGDP} & \cdots & \cdots & A_{USGDP-NER} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ A_{NER-USGDP} & \cdots & \cdots & A_{NER-NER} \end{pmatrix} \begin{pmatrix} USGDP(-1) \\ USINF(-1) \\ PC(-1) \\ FFR(-1) \\ CGDP(-1) \\ CINF(-1) \\ COPR(-1) \\ NER(-1) \end{pmatrix} + \begin{pmatrix} \varepsilon_{usgdp} \\ \varepsilon_{usinf} \\ \varepsilon_{pc} \\ \varepsilon_{ffr} \\ \varepsilon_{cgdp} \\ \varepsilon_{cinf} \\ \varepsilon_{copr} \\ \varepsilon_{ner} \end{pmatrix}$$

where all the off-diagonal elements of matrix A_0 must either be estimated as free parameters or be set to zero, and the number of elements set to zero must equal or exceed the minimum

[21] The estimation procedures detailed in this appendix is based on Pagan et al. (2016).
[22] VARs and SVARs can be estimated at different lag lengths and these are designated by the notation S/VAR(p), where p is the lag order. Thus, in this example, with a lag order of one, it is said a VAR(1)/SVAR(1) is being estimated.

number of restrictions, 28 in this case. When sufficient restrictions have been made, the full SVAR system is estimated using full information maximum likelihood, and here the variance-covariance matrix is imposed to be diagonal and thus, orthogonal. Again, it is necessary that the variance-covariance matrix of structural disturbances, var(ε_t) = Λ, be diagonal, such that these structural shocks are uncorrelated, since without this assumption, tracing the effects of a certain shock on the other variables loses its meaning.

A1.2 Expanded Form of SVAR with Block Exogeneity

This section will present the practical effects of imposing the block exogeneity assumption presented in section 4.2.1. Taking the exact same VAR(1) and SVAR(1) from above, we can separate the vector of endogenous variables, y_t, into a foreign and domestic vector representing the U.S. and price of oil variables, and Colombian variables, respectively. Here, the foreign vector, y_t^f, will consist of $\{USGDP, USINF, PC, FFR\}$, while the domestic vector, y_t^d, will consist of $\{CGDP, CINF, COPR, NER\}$. From looking at equation (6), we know that the block exogeneity assumption is that $A_{fd}(L) = 0$, meaning that the vector of Colombian variables does not enter contemporaneously nor lagged into the estimations of the foreign vector variables. Returning, to equations (7) and (8), we can now directly see the implications of said assumption in matrices B_1, A_0, and A_1. Other than the changes to these matrices (described below), the SVAR(1) with block exogeneity is estimated and identified in the same way as in the preceding section.

In equation (7), B_1 now becomes:

$$B_1 = \begin{pmatrix} B_{USGDP-USGDP} & B_{USGDP-USINF} & B_{USGDP-PC} & B_{USGDP-FFR} & 0 & 0 & 0 & 0 \\ B_{USINF-USGDP} & B_{USINF-USINF} & B_{USINF-PC} & B_{USINF-FFR} & 0 & 0 & 0 & 0 \\ B_{PC-USGDP} & B_{PC-USINF} & B_{PC-PC} & B_{PC-FFR} & 0 & 0 & 0 & 0 \\ B_{FFR-USGDP} & B_{FFR-USINF} & B_{FFR-PC} & B_{FFR-FFR} & 0 & 0 & 0 & 0 \\ B_{CGDP-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & B_{CGDP-NER} \\ B_{CINF-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & B_{CINF-NER} \\ B_{COPR-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & B_{COPR-NER} \\ B_{NER-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & B_{NER-NER} \end{pmatrix}$$

and in equation (8), A_0 and A_1 now become:

$$A_0 = \begin{pmatrix} 1 & A_{0_{USGDP-USINF}} & A_{0_{USGDP-PC}} & A_{0_{USGDP-FFR}} & 0 & 0 & 0 & 0 \\ A_{0_{USINF-USGDP}} & 1 & A_{0_{USINF-PC}} & A_{0_{USINF-FFR}} & 0 & 0 & 0 & 0 \\ A_{0_{PC-USGDP}} & A_{0_{PC-USINF}} & 1 & A_{0_{PC-FFR}} & 0 & 0 & 0 & 0 \\ A_{0_{FFR-USGDP}} & A_{0_{FFR-USINF}} & A_{0_{FFR-PC}} & 1 & 0 & 0 & 0 & 0 \\ A_{0_{CGDP-USGDP}} & \cdots & \cdots & \cdots & 1 & \cdots & \cdots & A_{0_{CGDP-NER}} \\ A_{0_{CINF-USGDP}} & \vdots & \vdots & \vdots & \vdots & 1 & \vdots & A_{0_{CINF-NER}} \\ A_{0_{COPR-USGDP}} & \vdots & \vdots & \vdots & \vdots & \vdots & 1 & A_{0_{COPR-NER}} \\ A_{0_{NER-USGDP}} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 1 \end{pmatrix}$$

$$A_1 = \begin{pmatrix} A_{1\,USGDP-USGDP} & A_{1\,USGDP-USINF} & A_{1\,USGDP-PC} & A_{1\,USGDP-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,USINF-USGDP} & A_{1\,USINF-UISNF} & A_{1\,USINF-PC} & A_{1\,USINF-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,PC-USGDP} & A_{1\,PC-USINF} & A_{1\,PC-PC} & A_{1\,PC-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,FFR-USGDP} & A_{1\,FFR-USINF} & A_{1\,FFR-PC} & A_{1\,FFR-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,CGDP-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & A_{1\,CGDP-NER} \\ A_{1\,CINF-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & A_{1\,CINF-NER} \\ A_{1\,COPR-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & A_{1\,COPR-NER} \\ A_{1\,NER-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & A_{1\,NER-NER} \end{pmatrix}$$

A1.3 Estimating Impulse Response Functions for SVAR with Block Exogeneity

While impulse response functions for block exogenous SVARs are not estimated differently than for regular SVARs, many statistical programs (such as EViews) do not provide native functions to estimate SVARs with restrictions on the lag-structure. For this reason, I provide here, the procedure used to extract impulse response functions from an SVAR with block exogeneity. The example presented here will use the SVARs shown previously in this appendix.

First, start with a no-lag restricted SVAR, such as that which is represented by equation (10). After desired lag order chosen (here we have a SVAR(1)), we can present it as below:

$$\begin{pmatrix} 1 & \cdots & \cdots & A_{0(USGDP-NER)} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ A_{0(NER-USGDP)} & \cdots & \cdots & 1 \end{pmatrix} \begin{pmatrix} USGDP \\ USINF \\ PC \\ FFR \\ CGDP \\ CINF \\ COPR \\ NER \end{pmatrix} = \begin{pmatrix} A_{USGDP-USGDP} & \cdots & \cdots & A_{USGDP-NER} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ A_{NER-USGDP} & \cdots & \cdots & A_{NER-NER} \end{pmatrix} \begin{pmatrix} USGDP(-1) \\ USINF(-1) \\ PC(-1) \\ FFR(-1) \\ CGDP(-1) \\ CINF(-1) \\ COPR(-1) \\ NER(-1) \end{pmatrix} + \begin{pmatrix} \varepsilon_{usgdp} \\ \varepsilon_{usinf} \\ \varepsilon_{pc} \\ \varepsilon_{ffr} \\ \varepsilon_{cgdp} \\ \varepsilon_{cinf} \\ \varepsilon_{copr} \\ \varepsilon_{ner} \end{pmatrix}$$

However, we know that the block exogeneity assumption implies that all the lags of domestic (Colombian) variables are entered as zeros in foreign (U.S. and oil) variable equations leading to (from A.1.2):

$$A_1 = \begin{pmatrix} A_{1\,USGDP-USGDP} & A_{1\,USGDP-USINF} & A_{1\,USGDP-PC} & A_{1\,USGDP-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,USINF-USGDP} & A_{1\,USINF-UISNF} & A_{1\,USINF-PC} & A_{1\,USINF-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,PC-USGDP} & A_{1\,PC-USINF} & A_{1\,PC-PC} & A_{1\,PC-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,FFR-USGDP} & A_{1\,FFR-USINF} & A_{1\,FFR-PC} & A_{1\,FFR-FFR} & 0 & 0 & 0 & 0 \\ A_{1\,CGDP-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & A_{1\,CGDP-NER} \\ A_{1\,CINF-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & A_{1\,CINF-NER} \\ A_{1\,COPR-USGDP} & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & A_{1\,COPR-NER} \\ A_{1\,NER-USGDP} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & A_{1\,NER-NER} \end{pmatrix}$$

Then, the structural restrictions must be imposed. This involves setting at least n x (n - 1)/2 restrictions on the A_0 matrix. Using the restrictions from equation (8) on page 19 of this thesis, we arbitrarily choose:

$$A_0 = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{0_{21}} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ A_{0_{31}} & A_{0_{32}} & 1 & 0 & 0 & 0 & 0 & 0 \\ A_{0_{41}} & A_{0_{42}} & A_{0_{43}} & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & A_{0_{53}} & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & A_{0_{65}} & 1 & 0 & 0 \\ 0 & 0 & A_{0_{73}} & A_{0_{74}} & A_{0_{75}} & A_{0_{76}} & 1 & A_{0_{78}} \\ A_{0_{81}} & A_{0_{82}} & A_{0_{83}} & A_{0_{84}} & A_{0_{85}} & A_{0_{86}} & A_{0_{87}} & 1 \end{pmatrix}$$

Now to be able to estimate all the coefficients from the previous matrices, we must set-up the following system of equations:

$$USGDP_t = a_{1_{11}}USGDP_{t-1} + a_{1_{12}}USINF_{t-1} + a_{1_{13}}PC_{t-1} + a_{1_{14}}FFR_{t-1} + \varepsilon_t$$

$$USINF_t = a_{0_{21}}USGDP_t + a_{1_{21}}USGDP_{t-1} + a_{1_{22}}USINF_{t-1} + a_{1_{23}}PC_{t-1} + a_{1_{24}}FFR_{t-1} + \varepsilon_t$$

$$\vdots$$

$$\vdots$$

$$\vdots$$

$$NER_t = a_{0_{81}}USGDP_t + a_{0_{82}}USINF_t + a_{0_{83}}PC_t + a_{0_{84}}FFR_t + a_{0_{85}}CGDP_t + a_{0_{86}}CINF_t + a_{0_{87}}COPR_t + a_{1_{81}}USGDP_{t-1} + a_{1_{82}}USINF_{t-1} + a_{1_{83}}PC_{t-1} + a_{1_{84}}FFR_{t-1} + a_{1_{85}}CGDP + a_{1_{86}}CINF_{t-1} + a_{1_{87}}COPR_{t-1} + a_{1_{88}}NER_{t-1} + + \varepsilon_t$$

Notice here, the foreign variable equations do not include any lags or contemporaneous domestic variables, while domestic variables include all the lags of all the variables in addition to whichever contemporaneous variables we chose according to our A_0 matrix. This system of equations must be estimated using *Full Information Maximum Likelihood*, and here, it is essential that the covariance-variance matrix, call it Λ, be imposed as diagonal (as in A.1.1) and extracted. Having run a FIML estimation, we now have all the matrices representing our SVAR(1) with block exogeneity. These matrices of interest are A_0, A_1, and Λ.

To extract the impulse response functions we now follow the procedure:

- The matrix of 1st period response to shocks, $C_0 = {A_0}^{-1}\Lambda$
- The matrix of 2nd period response to shocks, $C_1 = {A_0}^{-1}A_1{A_0}^{-1}\Lambda$
- The matrix of 3rd period response to shocks, $C_2 = {A_0}^{-1}A_1C_1$
- The matrix of 4th period response to shocks, $C_3 = {A_0}^{-1}A_1C_2$
- The matrix of nth period response to shocks, $C_n = {A_0}^{-1}A_1C_{n-1}$

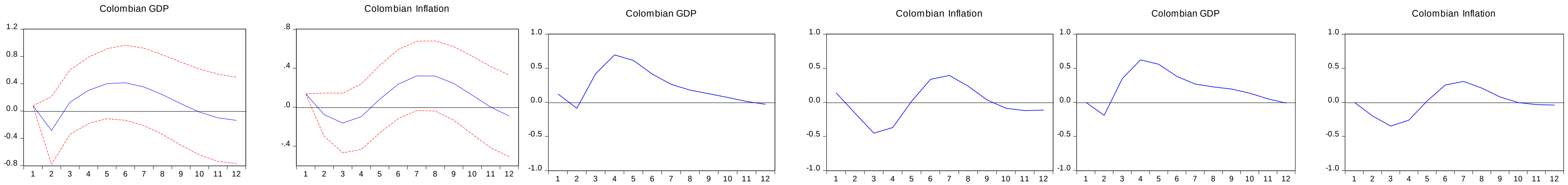
With a given n horizon, all matrices of responses to shocks are found up until n and then mapped. Note that the recursive structure slightly changes depending on the lag order of the SVAR. This exact recursive structure would only work for an SVAR(1).

Appendix 2:

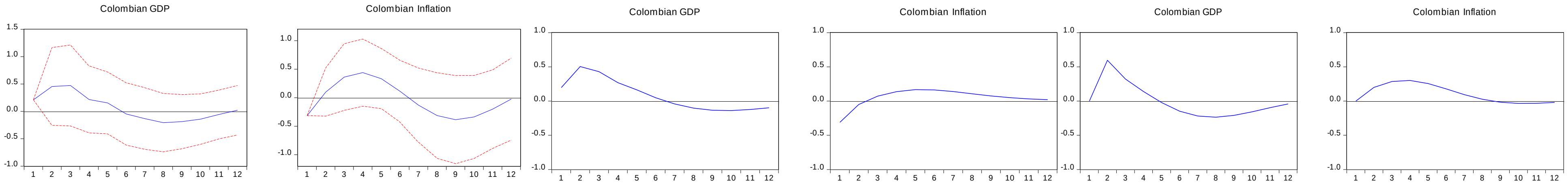
Responses of Colombian GDP and Inflation to Federal Funds Rate Shock

2000-2015

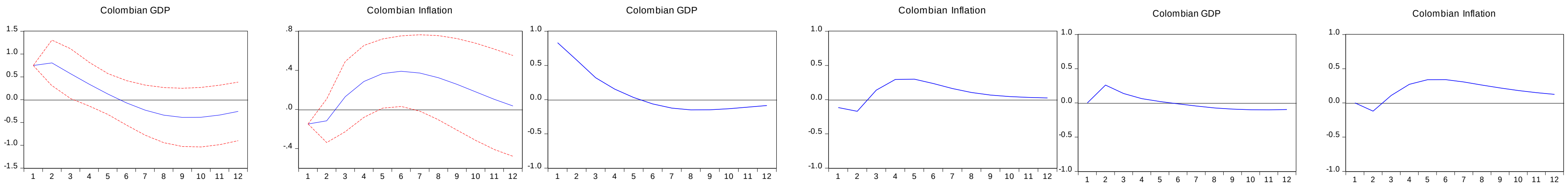
Recursive | **Recursive w/ Block Exogeneity** | **Nonrecursive w/ Block Exogeneity**



2000-2008



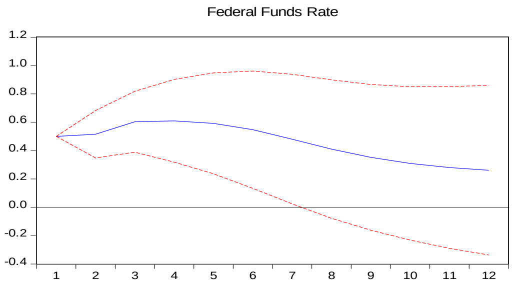
2008-2015



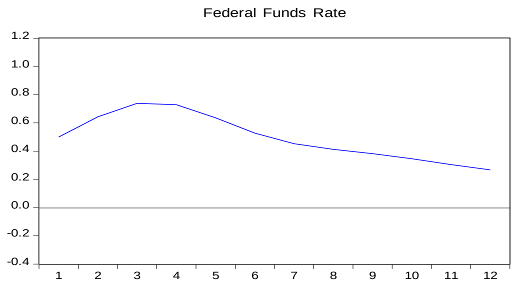
Responses of Federal Fund Rate to Own Shock

2000-2015

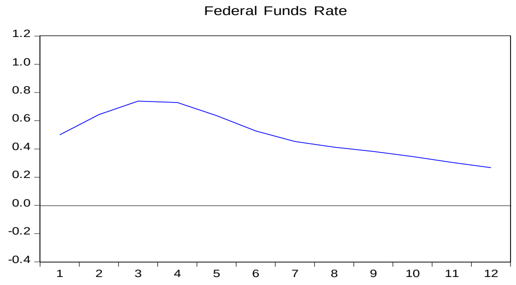
Recursive



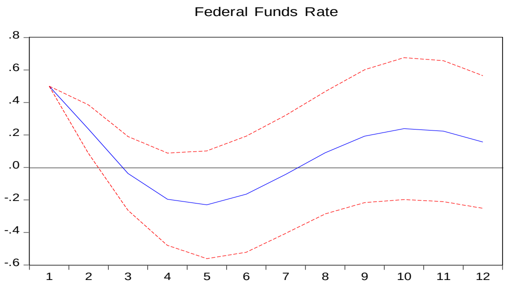
Recursive w/ Block Exogeneity

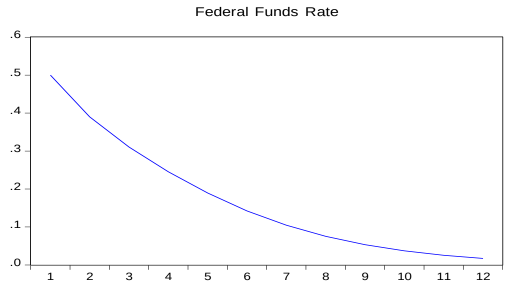


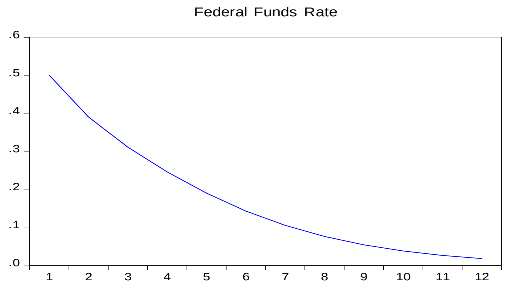
Nonrecursive w/ Block Exogeneity



2000-2008







2008-2015