Monetary Policy Spillovers in Emerging Economies*

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Abstract:

This paper explores for spillovers from monetary policy in the United States to a number of emerging market economies. We estimate the Elder and Serletis (2010) bivariate structural GARCH-in-Mean VAR in the U.S. monetary policy rate and the policy rate of each of six emerging economies that target the inflation rate — Brazil, Chile, Mexico, Romania, Serbia, and South Africa. We also estimate the same model in the U.S. monetary policy rate and the exchange rate (against the U.S. dollar) of each of six emerging economies that target the exchange rate — Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro. Our evidence suggests that positive (negative) U.S. monetary policy shocks tend to appreciate (depreciate) the currencies of the exchange rate targeting emerging economies, but have an ambiguous effect on the policy rates of the inflation-targeting emerging economies. Moreover, monetary policy uncertainty in the United States leads to an increase in policy rates in those emerging economies that target the inflation rate and to a depreciation of the currencies of those emerging economies that target the exchange rate.

JEL classification: E4; E52; E58.

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1 Introduction

Monetary policy in the United States, and the role of the U.S. dollar as an international currency, play an important role in determining global financial conditions. As Edwards (2018, p. 85) put it, "even under flexible exchange rates, there is significant policy interconnectedness across countries. In a highly globalized setting, even when there are no obvious traditional reasons for raising interest rates, some central banks will follow the Fed. This phenomenon may be called 'policy spillover,' and could be the result of a number of factors, including the desire by central banks to protect domestic currencies from 'excessive' volatility. If this is indeed the case, then even under flexible exchange rates there is no such a thing as true 'monetary independence.' " Motivated by these considerations, in this paper we explore for spillovers from monetary policy in the United States to a number of emerging market countries. These economies are becoming extremely relevant for global economic growth, as they account for about 70 percent of global growth in output and consumption, and as Serletis and Azad (2018) recently put it in the Conclusion, "the growth prospects of emerging market economies are becoming extremely relevant for global economic growth."

We estimate the Elder and Serletis (2010) bivariate structural GARCH-in-Mean VAR in the U.S. monetary policy rate and the policy rate of each of six emerging economies that target the inflation rate — Brazil, Chile, Mexico, Romania, Serbia, and South Africa. We also estimate the same model in the U.S. monetary policy rate and the exchange rate (against the U.S. dollar) of each of six emerging economies that target the exchange rate — Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro. We associate the U.S. monetary policy rate VAR residual with exogenous U.S. monetary policy shocks, use the conditional standard deviation of the forecast error for the change in the U.S. monetary policy rate as a measure of monetary policy uncertainty in the United States, and investigate the relationship between the U.S. monetary policy rate and the policy stance in each of the emerging economies.

We estimate the structural (identified) GARCH-in-Mean VAR using full information maximum likelihood, avoiding Pagan's (1984) generated regressor problems associated with estimating the variance equation separately from the conditional mean equation. We use monthly data and two new data sets, recently compiled by the Bank for International Settlements (BIS) — one on monetary policy rates (for 38 countries) and one on exchange rates (for 190 countries). We investigate the effects of positive and negative U.S. monetary policy shocks, and also whether monetary policy uncertainty in the United States has had statistically significant spillover effects on each of the emerging economies. Our evidence suggests that positive (negative) U.S. monetary policy shocks tend to appreciate (depreciate) the currencies of the exchange rate targeting emerging economies, but have an ambiguous effect on the policy rates of the inflation-targeting emerging economies, and that monetary policy uncertainty in the United States leads to an increase in policy rates in those emerging economies that target the inflation rate and leads to depreciation of the currencies of those

emerging economies that target the exchange rate.

The paper contributes in two ways to the existing literature. First, the paper uses two novel data sets, recently made available by the Bank for International Settlements, to investigate for monetary policy spillovers from U.S. monetary policy to inflation targeting and exchange rate targeting emerging economies. The second contribution to the existing empirical literature is that the paper provides an empirical investigation of the Dornbusch (1976) overshooting hypothesis in the context of emerging economies. In this regard, most of the existing studies investigate the overshooting hypothesis in the context of advanced economies, as in Eichenbaum and Evans (1995), and very few studies have been conducted in the context of emerging economies. Our paper investigates the overshooting hypothesis in the context of the United States economy, where the response of the U.S. dollar against the currencies of six exchange rate targeting emerging economies is investigated due to a monetary policy shock in the United States.

The outline of the paper is as follows. Section 2 discusses monetary policy strategies for emerging market economies, in particular, exchange rate targeting and inflation targeting. Section 3 presents the data and discusses their time series properties using unit root and stationarity tests. In Section 4, we briefly explain the Elder and Serletis (2010) empirical model while in Section 5 we present and discuss the empirical results. The last section briefly concludes the paper.

2 Nominal Targets for Monetary Policy

What economic variable should serve as the nominal anchor? There are several monetary policy strategies that could be used to promote price stability, including the money supply, the exchange rate, the inflation rate, the price level, and nominal GDP. In what follows we briefly discuss exchange rate targeting and inflation targeting. In this regard, after the abandonment of monetarism in the early 1980s by the Federal Reserve in the United States and other industrialized countries around the world, because of unstable money demand functions (due to velocity shocks), between the mid-1980s and mid-1990s, the dominant approach for many developing countries to lower inflation rates was the use of the exchange rate as the monetary policy target. In recent years, however, a large number of emerging and developing economies started targeting the inflation rate and have given their central banks greater independence, following the success of inflation targeting in advance economies, such as New Zealand, Canada, and the United Kingdom.

2.1 Exchange Rate Targeting

As already noted, a monetary policy strategy that could be used to promote price stability is exchange rate targeting (also refered to as an exchange rate peg). It involves fixing

the value of the domestic currency to that of a large, low-inflation country (the anchor country). It requires an easing of monetary policy when there is a tendency for the domestic currency to appreciate and a tightening of monetary policy when there is a tendency for the domestic currency to depreciate. It has the advantage of increasing international trade and investment by reducing transaction costs and exchange risk and by preventing speculative bubbles. Moreover, if the nominal anchor of an exchange rate target is credible (i.e., expected to be adhered to), it helps mitigate the time inconsistency problem associated with rule type monetary policy making.

Exchange rate targeting, however, requires giving up an independent monetary policy. For example, the central bank of the targeting country cannot use monetary easing (increase the money supply, reduce interest rates, or devalue its currency), in response to domestic bad shocks. Also, under exchange rate targeting, shocks to the anchor country are directly transmitted to the pegging country, and so changes in interest rates and the inflation rate in the anchor country lead to corresponding changes in interest rates and the inflation rate in the targeting country. Another problem with exchange rate targeting is that it leaves the targeting country open to speculative attacks on its currency. For example, if the anchor country is practicing tight monetary policy, the pegging country is subjected to a negative demand shock that leads to a decline in economic activity. If speculators reason that the pegging country will not tolerate the decline in economic activity and start to question its commitment to the exchange rate peg, there could be speculative attacks on the pegging country that can lead to full-scale financial crises (examples are the speculative attacks to the European ERM countries in September 1992, Mexico in 1994, East Asia in 1997, and Argentina in 2002).

Over the years, exchange rate targeting has been effective in controlling inflation in both industrialized countries as well as in emerging market economies. However, the emerging market currency crises that started in the early 1990s and ended in the early 2000s, all involved the abandonment of exchange rate targeting. In many countries (including Mexico and Argentina), this happened because of speculative attacks that led to gradual but sustained losses of international reserves, and so forced the abandonment of exchange rate anchors. Other countries such as, for example, Chile and Colombia, preemptively switched to floating exchange rates. Also, some smaller countries responded by moving to institutionally locked-in arrangements, such as currency boards or full dollarization.

In a currency board arrangement, the domestic currency is backed 100% by a foreign (reserve) currency (such as the U.S. dollar) and the exchange rate between the two currencies is fixed. A currency board is thus a variant of a fixed exchange-rate regime with an even stronger commitment mechanism, since domestic money can be issued only if it is fully backed by foreign reserves. In fact, a currency board arrangement is the modern day equivalent of a fully backed gold standard with foreign reserves taking the place of gold reserves. Currency boards have been adopted by Hong Kong (in 1983), Argentina (in 1991), and Lithuania (in 1994) with the U.S. dollar, and Estonia (in 1992), Bulgaria (in 1997), and Bosnia and

Herzegovina (in 1999) with the euro.

Another possible exchange rate arrangement is 'dollarization' — one country's use of another country's money (which may not be the U.S. dollar). Dollarization is another variant of a fixed exchange-rate regime, with an even better commitment device than a currency board. In particular, dollarization avoids the possibility of a speculative attack on the domestic currency and also eliminates the inflation-bias problem of discretionary policy (arising from attempts to stimulate the economy and incentives to monetize the public debt). However, dollarization is subject to the usual disadvantages of a fixed exchange-rate regime — it implies the loss of an independent monetary policy, the inability of the central bank to act as a lender of last resort, and the loss of seigniorage (the revenue that the government receives by issuing money). Recently, Ecuador (in 2000) and El Salvador (in 2001) adopted full dollarization.

Currency boards and dollarization, however, are strong measures that tend to be applied in extreme circumstances. They have been advocated as monetary policy strategies for emerging market countries, especially in parts of Latin America that have had a long history of monetary instability. In sum, as Frankel (2011, pp. 1457) put it, "from the longer-term perspective of the four decades since 1971, the general trend has been in favor of floating exchange rates."

2.2 Inflation Targeting

In recent years, a large number of emerging and developing economies switched from exchange rate targeting to inflation targeting, following the success of inflation targeting in advanced economies. Brazil, Chile, Colombia and Mexico switched from exchange rate pegs to inflation targeting in 1999, as well as Armenia, Hungary, Poland, and the Czech Republic, while they were making the transition from centrally planned to market economies. Israel, Korea, South Africa, and Thailand also switched from exchange rate targets to inflation targeting about the same time. Then Mexico followed in 2001, Indonesia and Romania in 2005, and Turkey in 2006. Currently there are 66 advanced, emerging, and developing economies around the world that target the inflation rate, and many other countries are moving toward this monetary policy framework.

As already noted, inflation targeting has been very successful in industrialized countries. In emerging market and developing economies, however, inflation targeting can be vulnerable to temporary supply (price) shocks, which tend to be larger than for advanced countries, because it builds unnecessary procyclicality into the automatic monetary mechanism. In the case, for example, of a temporary negative supply shock, short-run inflation stabilization requires a significant autonomous tightening of monetary policy, and leads to a larger deviation in aggregate output from potential, relative to a no policy response, with the entire fall in nominal GDP being borne by real GDP.

In this regard, it should be kept in mind that inflation-targeting central banks typically

target headline (based on total CPI) inflation, mainly for transparency and communication reasons (i.e., the public is more likely to understand what the central bank is doing). Inflation-targeting central banks also use core (or underlying) inflation (the rate of inflation based on core CPI that excludes food, energy, and the effects of changes in indirect taxes) to "look through" temporary changes in total CPI and focus on the underlying trend of inflation. However, it has been argued that targeting headline inflation (sticky price inflation) leads to distortions in relative prices and less-than-full output stabilization whereas targeting core inflation without sticky prices (of food and energy) is always optimal. In this regard, Pourroy *et al.* (2016) argue that the optimal monetary policy depends on a country's income level. In particular, headline inflation targeting is optimal in low- and medium-income countries (which have a high share of food and energy goods in the consumption basket). In high-income countries, the optimal choice is core inflation.

Also, if the supply shocks are terms of trade shocks (shocks to the price of imports relative to exports, both expressed in domestic currency), then CPI inflation targeting can be destabilizing, because it requires monetary tightening (and thereby currency appreciation) when the price of imports increases, but not when the price of exports increases on world markets, exactly the opposite of the desired pattern of response. That is, the headline CPI inflation rate they target does not exclude terms of trade shocks. For this reason, a nominal anchor that accommodates, rather than exacerbating, the macroeconomic effects of movements in the terms of trade will be a better choice in the case of small countries with exportable and importable goods.

3 The Data

We use monthly data on monetary policy rates and exchange rates for a large number of emerging market countries and the United States — see International Monetary Fund (2016, Table 2) for a classification of exchange rate arrangements and monetary policy frameworks. The United States is used as an indicator of the global economy, because as Kose *et al.* (2017, p. 1) put it, "developments in the U.S. economy, because of its size and international linkages, are bound to have substantial implications for the global economy. The United States is the world's single largest economy (at market exchange rates), accounting for almost 22 percent of global output and over a third of stock market capitalization. It is prominent in virtually every global market, accounting for about one-tenth of global trade flows, one-fifth of global FDI stock, close to one-fifth of remittances, and one-fifth of global energy demand."

We use the newly constructed monetary policy rate series by the Bank for International Settlements (BIS), made publicly available for research on September 2017 — see Bank for International Settlements (2018). Although the data set consists of monetary policy rates for 38 countries, we use the data for six inflation-targeting emerging market countries — Brazil, Chile, Mexico, Romania, Serbia, and South Africa. It is to be noted that the information on

monetary policy rates is provided by the national central banks to the Bank for International Settlements, which in turn reports the specific interest rate that each national central banks considers as the monetary policy rate. We restrict our analysis to the period after the adoption of inflation targeting in the respective emerging economies (see column 1 in panel A of Table 1).

We also use exchange rate data for six exchange-rate targeting emerging market countries — Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro. We obtain the monthly exchange rate series (against the United States dollar) also from the Bank for International Settlements — see Bank for International Settlements (2017). Like the database on policy rates, this newly constructed BIS database contains nominal exchange rate data for 190 countries. Again, we restrict our analysis to the period after the adoption of exchange rate targeting (see column 1 in panel B of Table 1).

3.1 Inflation Rate Targeters

In panel A of Table 1 we list the six emerging market countries that target the inflation rate, together with the year when inflation targeting was adopted (in column 1) and the inflation target range (in column 2). In this regard, after experiencing double-digit inflation, Chile was the first among the emerging economies in the world to adopt inflation targeting as the primary monetary strategy in the early 1990s. In September 1999, the central authority officially adopted full inflation targeting with a floating exchange rate. The objective is to keep the inflation rate based on the Consumer Price Index (CPI) at 3% with ±1 percentage point tolerance level — see the central bank of Chile's website (at http://www.bcentral.cl). Around the same time (in mid-1999), Banco do Brasil, the central bank of Brazil, adopted a full inflation targeting monetary policy strategy after adopting a floating exchange rate earlier in the year. Banco do Brasil targets an annual target of 4.5%, with a tolerance range of ±1.5% — see the Banco do Brasil's website (at https://www.bcb.gov.br). After the balance of payments crisis in 1994-1995, known as the Tequila crisis, Banco de Mexico (Mexico's central bank), switched to a free-floating exchange rate regime. In 2001, Banco de Mexico formally adopted an inflation targeting framework. The target inflation rate is 3% with a tolerance range of 1%. A free-floating exchange rate and an inflation target has facilitated to bring the inflation rate down from double digits (an inflation rate of around 50% in late 1995 and early 1996) to less than 5% today — see the Banco de Mexico's website (at http://www.banxico.org.mx/).

Banca Nationala a Romaniei, the central bank of Romania, adopted inflation targeting in August 2005. Their primary aim was to bring the annual inflation rate down to single-digit levels. Currently, the central bank of that country targets the annual inflation rate at 3% with the tolerance range being ±1% — see the Banca Nationala a Romaniei's website (at http://www.bnr.ro). Also, the National Bank of Serbia manages money and interest rates to keep the medium-term inflation rate within the target tolerance band of 3% (±1%) and

formally adopted direct inflation rate targeting in 2006. The targeted inflation rate, is calculated as an annual percentage change in the CPI. The domestic economy aims to meet nominal, real and structural convergence to the European Union countries through its inflation targeting strategy — see the National Bank of Serbia's website (at https://www.nbs.rs). Finally, the South African Reserve Bank adopted a flexible inflation-targeting framework in February 2000 with the inflation target set at a range of 3%-6% annual increase in the headline CPI on a continuous basis. When the inflation targeting framework was first adopted, the target was CPIX and not CPI. CPIX is a variation of CPI and consisted of CPI for urban and metropolitan areas and excluded interest rates on mortgage bonds from the calculation. However, over time due to changes in the treatment of housing, interest rates on mortgage bonds were included in the computation — see the South African Reserve Bank's website (at https://www.resbank.co.za).

3.2 Exchange Rate Targeters

We list the six emerging economies that target the exchange rate, together with the year when exchange rate targeting was adopted and the exchange rate regime in panel B of Table 1. The Central Bank of Bosnia and Herzegovina adopted a fixed exchange rate regime with the motivation to provide monetary, institutional, and political stability in the country in the post-war period. After starting its operation in August 1997, the domestic currency was pegged to the German Deutsche mark, but after the introduction of the euro in January 1999, the currency was pegged to the euro at the same rate as for the Deutsche mark (1.95583 per euro) — see the Central Bank of Bosnia and Herzegovina website (at https://www.cbbh.ba) and Kovačević (2003) for more details.

After the hyperinflation episode in late 1996 and early 1997, the Bulgarian National Bank adopted a currency board on July 1, 1997 and managed to bring inflation to single digit levels by mid-1997. At first the Bulgarian lev was pegged to the Deutsche mark and then the euro after its introduction in 1999. The Bulgarian National Bank maintains an exchange rate regime which allows the central note-issuing authority to issue its own currency, the Bulgarian lev. The Bulgarian lev is fully backed by euro reserves by the Bulgarian National Bank — see the Bulgarian National Bank's website (http://www.bnb.bg/). With the help of the fixed exchange rate regime, the country has been able to maintain macroeconomic stability despite adverse external shocks such as the Russian financial crisis in 1998, the global financial crisis in 2007-2009, and the Kosovo conflict.

Since Comoros gained independence, the country has issued its own franc. First, Institut d' Emission des Comores issued domestic franc during the period from 1976 to 1984, then the Banque Centrale des Comores from 1984 to the present. In 1994, the Comoros franc was fixed against the French franc, but after the introduction and subsequent adoption of the euro by France, the Comoros franc was pegged to the euro in 1999 — see the Banque Centrale des Comores's website (at http://www.banque-comores.km) and Lamine (2006) for

more details.

After Croatia declared independence from Yugoslavia in 1991, the economy became heavily euroised. The domestic currency, kuna, was first pegged to the Deutsche mark during the period from October 1994 to January 1999 and then the euro, after its introduction. The domestic currency can fluctuate within a low tolerance range about the target currency. The exchange rate anchor has allowed the country to tackle hyperinflation and provide macroeconomic stability after the war — see the Croatian National Bank's website (at https://www.hnb.hr) and Crespo-Cuaresma *et al.* (2005) for more details. The National Bank of the Republic of Macedonia adopted a strategy of targeting the nominal exchange rate of the Denar against the Deutsche mark in October 1995 to meet the primary objective of price stability. In January 2002, the peg was switched against the Euro. For a small open emerging economy like the Republic of Macedonia, maintaining Denar exchange rate stability helps to increase transparency and maintain credibility. Prior to the adoption of the fixed exchange rate regime, the National Bank of the Republic of Macedonia had targeted the money supply (M1) as their primary medium run monetary policy — see the National Bank of the Republic of Macedonia's website (at http://www.nbrm.mk).

Finally, at the beginning of 1999, the government of Montenegro adopted a fixed exchange rate regime with the Deutsche mark. The country established a parallel currency system where the Deutsche mark was the legal tender and was allowed to float freely alongside the Dinar, the other legal tender in the country. Until November 1999, the country was under unofficial dollarization. Montenegro underwent full dollarization against the euro in 2002 — see the Central Bank of Montenegro's website (at http://www.cb-cg.org) and Fabris *et al.* (2004) for more details.

3.3 Unit Root Tests

We start by conducting a battery of unit root and stationary tests in the levels of the policy rates of the countries that have adopted inflation targeting and the logarithms of the exchange rates of the countries that have adopted exchange rate targeting. The sample periods are different across countries and start when inflation rate targeting was adopted in the case of the inflation-targeting countries (see column 1 of panel A of Table 1) and when exchange rate targeting was adopted in the case of the exchange-targeting countries (see column 1 of panel B of Table 1).

In particular, we use the Augmented Dickey-Fuller (ADF) test [see Dickey and Fuller (1981)] assuming both a constant and trend, to test the null hypothesis of a unit root. The optimal lag length is selected using the Schwarz information criterion (SIC). We also conduct Phillips-Perron (PP) unit root tests [see Phillips and Perron (1988)]. For both the ADF and PP unit root tests, the null hypothesis of the presence of a unit root in each of the series cannot be rejected at conventional significance levels. This leads us to the conclusion that all the series representing the levels of the policy rates and the logarithms of

the exchange rates of the emerging economies are non-stationary. We also conduct the KPSS test [see Kwiatkowski *et al.* (1992)] on the levels of the policy rates and the logarithms of the exchange rates of the emerging economies to test the null hypothesis of stationarity against the alternative of a unit root, assuming both a constant and a linear trend. Consistent with our findings with the ADF and PP tests, we reject the hypothesis that the time series are stationary at conventional significance levels. These results are not reported but are available upon request.

In Table 2, we report ADF, PP, and KPSS tests using the first level differences of the policy rates of the countries that have adopted inflation targeting (see panel A of Table 2) and the logarithmic first differences of the exchange rates of the countries that have adopted exchange rate targeting (see panel B of Table 2). As can be seen, the null hypothesis of the presence of unit root is rejected at conventional significance levels by both the ADF and PP test statistics in all 13 time series. Results from the KPSS tests on the first differences of the policy rates of inflation-targeting economies and the logged first differences of the exchange rates of exchange-rate targeting emerging market economies show that the null hypothesis of stationarity cannot be rejected at 1% significance level for all 13 series.

Thus, all first level differences of the policy rates of the countries that have adopted inflation targeting (Brazil, Chile, Mexico, Romania, Serbia, and South Africa) and the United States are stationary, and all logarithmic first differences of the exchange rates of the countries that have adopted exchange rate targeting (Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro) are also stationary. In what follows, we use the stationary series.

4 The Structural GARCH-in-Mean VAR

We use a bivariate structural VAR model with GARCH-in-Mean errors. More specifically, we measure the uncertainty about U.S. monetary policy as the standard deviation of the one-step-ahead forecast error, conditional on the contemporaneous information set. The standard deviation of the one-step-ahead forecast error is a measure of the dispersion in the forecast and hence is a proxy for uncertainty about the impending realization of the U.S. policy rate. Time series, such as policy rates and exchange rates, exhibit different volatilities and, more importantly, time varying volatilities. Not considering time varying volatilities, will lead to misleading conclusions about the effects of monetary policy changes in the United States on the monetary policy of emerging economies. The bivariate structural GARCH-in-Mean model helps us overcome the limitations of existing studies by accounting for reverse causality as well as volatility in policy rates and exchange rates. The structural model adopted in this paper, allows the conditional variance of one or more variables in a simultaneous equations system to affect the conditional mean of one or more other variables. That is, the model assumes that the conditional variance is heteroscedastic and not homoscedastic as is done

in most of the existing studies. The GARCH-in-Mean VAR model analyses the impact of U.S. monetary policy uncertainty on the monetary policy regime of each of the emerging economies through the standard VAR transmission channels and an additional channel, the volatility channel, as it is captured by the GARCH term.

Our model is based on Elder and Serletis (2010), and is a bivariate (identified) structural GARCH-in-Mean, as follows

$$\boldsymbol{B}\boldsymbol{z}_t = \boldsymbol{C} + \boldsymbol{\Gamma}_1\boldsymbol{z}_{t-1} + \boldsymbol{\Gamma}_2\boldsymbol{z}_{t-2} + ... + \boldsymbol{\Gamma}_p\boldsymbol{z}_{t-p} + \boldsymbol{\Lambda}\sqrt{\boldsymbol{H}_t} + \boldsymbol{\epsilon}_t \tag{1}$$

where

$$\boldsymbol{B} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}; \quad \boldsymbol{\Gamma}_i = \begin{bmatrix} \gamma_{11}^j & \gamma_{12}^j \\ \gamma_{21}^j & \gamma_{22}^j \end{bmatrix}; \quad \boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ \lambda & 0 \end{bmatrix}.$$

In the case of emerging market countries that target the inflation rate, the vector $\boldsymbol{z}_t$ includes the change in the monetary policy rate in the United States, Δf_t, and the change in the policy rate of the emerging economy, Δi_t. In the case of those emerging market countries that target the exchange rate, $\boldsymbol{z}_t$ includes Δf_t and the logged change in the exchange rate of the emerging economy, $\Delta \log s_t$. In equation (1), $\boldsymbol{\epsilon}_t$ is the vector of structural disturbances, and it is assumed that $\boldsymbol{\epsilon}_t \left|\Omega_{t-1}\right. \sim$ iid $N\left(\mathbf{0},\, \boldsymbol{H}_t\right)$ where $\mathbf{0}$ is the null vector and $\boldsymbol{H}_t$ is the covariance matrix, Ω_{t-1} denotes the information set at time $t-1$, which includes variables dated $t-1$ and earlier, and $\boldsymbol{\Lambda}$ is a matrix of coefficients that relates U.S. monetary policy rate volatility to the conditional mean of the variables in the VAR. This specification allows the matrix of conditional standard deviations, denoted $\sqrt{\boldsymbol{H}_t}$, to affect the conditional mean. Testing whether uncertainty in the U.S. policy rate affects the policy rates of inflation targeting emerging economies and the exchange rates of exchange rate targeting emerging economies is a test of restrictions on the elements of $\boldsymbol{\Lambda}$, that relate the conditional standard deviation of U.S. policy rates, given by the appropriate element of $\sqrt{\boldsymbol{H}_t}$, to the conditional mean of the variables in the VAR. The system is identified by assuming that the diagonal elements of contemporaneous correlation matrix, $\boldsymbol{B}$, are unity, that $\boldsymbol{B}$ is a lower triangular matrix, and that the structural disturbances, $\boldsymbol{\epsilon}_t$, are contemporaneously uncorrelated.

The conditional variance is modeled as

$$diag\left(\boldsymbol{H}_t\right) = \boldsymbol{C}_v + \sum_{j=1}^{q} \boldsymbol{F}_j\, diag\left(\boldsymbol{\epsilon}_{t-j}\boldsymbol{\epsilon}_{t-j}'\right) + \sum_{i=1}^{r} \boldsymbol{G}_i\, diag\left(\boldsymbol{H}_{t-i}\right) \tag{2}$$

where *diag* is the operator that extracts the diagonal elements from a square matrix. We impose the additional restriction that the conditional variance of $\boldsymbol{z}_t$ depends only on its own past squared errors and its own past conditional variance such that the matrices $\boldsymbol{F}_j$ and $\boldsymbol{G}_i$ are also diagonal.

Impulse responses are computed as in Elder (2003). We also show one-standard error bands based on the Monte Carlo method described in Hamilton (1994, p. 337). Confidence

intervals are constructed by simulating 1000 impulse responses that are retrieved randomly from the sampling distribution of the maximum likelihood estimates. The covariance matrix of the maximum likelihood estimates is derived from an estimate of Fisher's information matrix.

5 Empirical Evidence

Each of the 12 bivariate GARCH-in-Mean VARs, consisting of equations (1) and (2), is estimated by full information maximum likelihood, thus avoiding Pagan's (1984) generated regressor problems associated with estimating the variance function parameters separately from the conditional mean parameters. The procedure is to maximize the log likelihood with respect to the structural parameters — see Elder and Serletis (2010) for more details. We estimate each model after we optimally select p in equation (1) using the Akaike Information Criterion (AIC), and set $q = r = 1$ in equation (2).

We report the point estimates of the mean and variance function parameters in Tables 3-8 for the emerging countries that target the inflation rate and in Tables 9-14 for those countries that target the exchange rate. The primary coefficient of interest in each of the 12 bivariate structural models is the GARCH-in-Mean coefficient, λ — the coefficient on the conditional standard deviation of the U.S. monetary policy rate in the mean equation. This coefficient indicates the effect of uncertainty in monetary policy in the United States on the monetary policy stance in each of the emerging market countries. In Table 15, we report the coefficient of interest and the corresponding p-value for each of the 12 bivariate models we estimate.

We also simulate the response of the monetary policy stance in each of the emerging market countries to both a positive and negative U.S. policy rate shock in order to investigate whether the responses to positive and negative U.S. monetary policy shocks are symmetric or asymmetric. Those impulse responses are shown in Figures 1-6 for the inflation-targeting emerging market countries and in Figures 7-12 for those that target the exchange rate. The impulse responses are based on a U.S. policy rate shock equal to the annualized unconditional standard deviation of the change in the U.S. policy rate and are calculated as in Elder (2003).

5.1 Inflation Targeters

Regarding countries that target the inflation rate, as can be seen in Tables 3-8 (and the summary Table 15), the estimated coefficient of interest $\hat{\lambda}$ is 19.857 with a p-value of 0.000 for Brazil, 3.630 with a p-value of 0.000 for Chile, 0.139 with a p-value of 0.001 for Mexico, 0.357 with a p-value of 0.000 for Romania, 0.714 with a p-value of 0.000 for Serbia, and 0.113 with a p-value of 0.017 for South Africa, respectively. The null hypothesis that the true value of $\hat{\lambda}$ is zero is rejected for all countries, indicating that uncertainty in U.S. monetary policy

has a statistically significant effect on the monetary policy rate in all the inflation-targeting emerging economies in our sample. Specifically, monetary policy uncertainty in the United States has a positive and statistically significant effect on the monetary policy rate in each of Brazil, Chile, Mexico, Romania, Serbia, and South Africa.

These results are different from those reported by Nsafoah and Serletis (2018) for advanced economies; they showed that monetary policy uncertainty in the United States has a negative and statistically significant effect on the monetary policy rate in each of Canada, Denmark, the Eurozone, Japan, Switzerland, and the United Kingdom. They are, however, consistent with the findings of Canova (2005) who finds that a contractionary U.S. monetary shock induces a significant and instantaneous increase in Latin American short-term nominal interest rates. Iacoviello and Navarro (2018) also find that in emerging economies, policy rates increase in response to a contractionary monetary policy shock in the United States, and Caceres *et al.* (2016, p. 31) argue that "the share of sovereign debt in domestic currency that is held by foreigners has been increasing substantially over the last few years, especially in emerging market economies. In this context, portfolio rebalancing by international investors following a rise in U.S. rates can potentially have a larger impact on the capital account. Central banks may then need to raise policy rates in an attempt to attenuate outflow pressures, irrespective of domestic macro conditions."

Next, we simulate the response of policy rates in inflation-targeting emerging economies to both positive and negative U.S. policy rates shocks to investigate whether the responses to positive and negative federal funds rate shocks are asymmetric or symmetric in nature. We also report one-standard error bands based on the Monte Carlo method described in Hamilton (1994, p. 337). As can be seen in the first panel of Figures 1-6, accounting for the impact of uncertainty in the federal funds rate, a positive shock in the federal funds rate tends to significantly reduce the policy rate immediately in Brazil and Serbia and tends to significantly increase the policy rate immediately in each of Chile, Mexico, Romania, and South Africa. The second panel in Figures 1-6 shows that a negative shock in the U.S. policy rate immediately increases the policy rate in Brazil, Mexico, Romania, Serbia, and South Africa while in the case of Chile the policy rate tends to decrease immediately in response to a negative shock in the U.S. policy rate.

It must be noted that in the absence of a formal statistical test of the null hypothesis of symmetric impulse responses, the responses of monetary policy rates in inflation-targeting emerging economies to positive and negative shocks in the U.S. policy rate are not very informative as to whether they are symmetric or not. Finally, in the third panel of Figures 1-6 we compare the response of changes in policy rates of the inflation-targeting emerging economies to a positive shock in the U.S. federal funds rate as estimated in our model to the responses from a model in which the uncertainty in the federal funds rate has been restricted from entering the policy rate equation of the inflation-targeting emerging economy. As can be seen, accounting for uncertainty in the U.S. federal funds rate tends to have an ambiguous effect on the dynamic response of the policy rate in each of the emerging market economies

to an unfavorable (positive) shock in the U.S. federal funds rate.

5.2 Exchange Rate Targeters

As can be seen in Tables 9-14 (and the summary Table 15), the estimated coefficient of interest $\hat{\lambda}$ is positive for all six countries. In particular, it is 0.114 with a p-value of 0.000 for Bosnia and Herzegovina, 0.141 with a p-value of 0.000 for Bulgaria, 0.035 with a p-value of 0.000 for Comoros, 0.031 with a p-value of 0.000 for Croatia, 0.115 with a p-value of 0.000 for the Former Yugoslav Republic of Macedonia, and 0.166 with a p-value of 0.000 for Montenegro. The null hypothesis that the true value of $\hat{\lambda}$ is zero is rejected at the 1% level for all countries, indicating the high level of statistical significance of $\hat{\lambda}$ in our exchange rate analysis. Thus, higher monetary policy uncertainty in the United States has a positive and statistically significant effect on the exchange rate of each of the emerging economies in our sample.

Our results are consistent with the findings of Tillman (2016) that uncertainty about future U.S. monetary policy leads to a depreciation of local currencies in emerging economies. They are also consistent with Gupta *et al.* (2017, p. 3) who show that a surprise monetary tightening in the United States, "estimated by an increase in 2-year Treasury yield on the day of the FOMC announcement, results in exchange rate depreciation, decline in equity prices, and increase in bond yields in emerging economies." In this regard, when the domestic currency depreciates, there is a tendency for borrowers (both banks and nonfinancial firms) in emerging market financial systems to borrow less in U.S. dollars. In doing so, they assume less risk (since their assets and products are priced in domestic currency), but the domestic depreciation causes a deterioration in firms' balance sheets, because it increases the domestic currency value of debt denominated in U.S. dollars.

As with the inflation-targeting emerging economies, we simulate the response of exchange rates to both positive and negative federal funds rate shocks. The first panel of Figures 7-12 shows that, accounting for the impact of uncertainty in the federal funds rate, a positive shock in the federal funds rate tends to significantly reduce the percentage change in exchange rate, that is leads to an appreciation of the local currency for all six exchange-targeting emerging economies. Our results show that positive (contractionary) monetary policy shocks in the United States lead to appreciation of the currencies of the emerging economies on impact, with the maximum effect during the first month, before gradually depreciating to the baseline. That is the U.S. dollar depreciates against the currencies of the emerging economies in response to a contractionary monetary policy adopted by the Federal Reserve. This is in contradiction to the Dornbusch (1976) overshooting model which predicts that a contractionary monetary policy shock, led by a rise in the U.S. nominal rate of interest, should cause an instantaneous appreciation of the U.S. dollar. After the initial instantaneous appreciation, the exchange rate gradually depreciates in line with uncovered interest parity. Bjørnland (2009) finds empirical support for the Dornbusch (1976) hypothesis in the context

of four advanced economies with floating exchange rates, namely Australia, Canada, New Zealand, and Sweden. Our results show that the Dornbusch (1976) hypothesis does not hold for the U.S. economy in context of bilateral spot exchange rates of exchange rate targeting emerging economies. Eichenbaum and Evans (1995) find that contractionary shocks to U.S. monetary policy lead to sharp, persistent appreciation of the U.S. nominal and real exchange rates. We find that contractionary shocks to U.S. monetary policy lead to initial sharp depreciation of the U.S. dollar against the currencies of emerging economies, before eventually appreciating to the baseline level. The second panel in Figures 7-12 shows that a negative shock to the federal funds rate tends to significantly increase the exchange rate, leading to a depreciation of the domestic currency in all six emerging economies, Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro.

Finally, in the third panel of Figures 7-12, we compare the response of the exchange rate to a positive shock in the U.S. federal funds rate as estimated in our model to the responses from a model in which $\lambda = 0$. As can be seen, accounting for uncertainty in the U.S. federal funds rate tends to amplify the negative dynamic response of exchange rate changes (i.e. higher appreciation of the domestic currency) to an unfavorable (positive) shock in the U.S. federal funds rate.

6 Conclusion

In this paper, we investigate spillovers from monetary policy in the United States to 12 emerging market countries. We make a distinction between two groups of emerging market economies; those that target the inflation rate — Brazil, Chile, Mexico, Romania, Serbia, and South Africa — and those that target the exchange rate — Bosnia and Herzegovina, Bulgaria, Comoros, Croatia, the Former Yugoslav Republic of Macedonia, and Montenegro. In doing so, we use the Elder and Serletis (2010) bivariate structural GARCH-in-Mean VAR and two new monthly data sets (compiled by the Bank for International Settlements), one on (central bank) monetary policy rates and the other on exchange rates (against the U.S. dollar).

We find statistically significant monetary policy spillovers from the United States to all twelve emerging economies. Some of our findings are as follows:

- Positive (negative) U.S. monetary policy shocks tend to appreciate (depreciate) the currencies of the exchange rate targeting emerging economies, but have an ambiguous effect on the policy rates of the inflation-targeting emerging economies.

- Monetary policy uncertainty in the United States leads to an increase in policy rates in those emerging economies that target the inflation rate and leads to depreciation of the currencies of those emerging economies that target the exchange rate.

- Accounting for uncertainty in U.S. monetary policy tends to amplify the appreciation of the currencies of those emerging economies that target the exchange rate, but the effect on those emerging economies that target the inflation rate is ambiguous.

In our investigation for monetary policy spillovers from the United States to emerging economies, we assumed that the dynamics of the structural VAR could be summarized by a linear function of the variables of interest and a term related to U.S. monetary policy uncertainty. That is, we ignored those variables that usually enter into a central bank's policy reaction function, such as the inflation gap and the output. Addressing this issue, in the context of a higher-dimensional structural VAR, is an area for future research.

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Table 1. Inflation targeting and exchange rate targeting economies

A. Inflation rate targeters

Country	Adoption year	Target inflation rate (percent)
Brazil	1999	4.5 ± 1
Chile	1999	3 ± 1
Mexico	2001	3 ± 1
Romania	2005	3 ± 1
Serbia	2006	$4 - 8$
South Africa	2000	$3 - 6$

B. Exchange rate targeters

Country	Adoption year	Regime
Bosnia and Herzegovina	1997	Currency Board
Bulgaria	1997	Currency Board
Comoros	1994	Conventional peg
Croatia	1993	Crawl-like arrangement
Former Yugoslav Republic of Macedonia	1995	Stabilized arrangement
Montenegro	1999	Unilateral use of Euro

Table 2. Unit root tests in first differences of policy rates and exchange rates

Country	ADF	PP	KPSS
A. Inflation rate targeters			
Brazil	−5.004	−8.753	0.042
Chile	−13.052	−13.052	0.033
Mexico	−4.872	−12.546	0.099
Romania	−9.165	−9.360	0.095
Serbia	−10.278	−10.242	0.042
South Africa	−4.310	−14.207	0.043
United States	−4.771	−14.072	0.069
B. Exchange rate targeters			
Bosnia & Herzegovina	−11.461	−11.258	0.108
Bulgaria	−11.067	−11.096	0.097
Comoros	−12.507	−12.448	0.072
Croatia	−12.553	−12.506	0.086
Former Yugoslav Republic of Macedonia	−11.039	−11.039	0.101
Montenegro	−11.161	−11.191	0.098

Notes: The 1% asymptotic critical value for both the ADF and PP tests is -4.022 for the series in panel A and -3.994 for the series in panel B. The 1% asymptotic critical value for the KPSS test is 0.216 for all the series.

Table 3. Estimates of the GARCH-in-Mean VAR for Brazil

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.002\ (0.989) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -0.006\ (0.594) \\ -3.478\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.0634\ (0.226) & -0.003\ (0.571) \\ -0.435\ (0.000) & 0.327\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.347\ (0.000) & 0.001\ (0.596) \\ -0.121\ (0.406) & 0.232\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.229\ (0.000) & -0.010\ (0.414) \\ 0.200\ (0.104) & 0.173\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 19.857\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.031\ (0.000) \\ 0.040\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.008\ (0.000) \\ 0.172\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.630\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1999:8 - 2018:4. Numbers in parentheses are *p*-values.

Table 4. Estimates of the GARCH-in-Mean VAR for Chile

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ 0.057\ (0.280) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -0.006\ (0.564) \\ -0.638\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.021\ (0.596) & -0.051\ (0.018) \\ 0.225\ (0.000) & 0.395\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.363\ (0.000) & -0.032\ (0.122) \\ 0.615\ (0.000) & 0.059\ (0.280) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.262\ (0.000) & -0.010\ (0.729) \\ 0.126\ (0.000) & 0.117\ (0.001) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 3.630\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.027\ (0.000) \\ 0.002\ (0.025) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.011\ (0.000) \\ 0.301\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.699\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1997:3 - 2018:4. Numbers in parentheses are p-values.

Table 5. Estimates of the GARCH-in-Mean VAR for Mexico

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.209\ (0.000) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} 0.016\ (0.091) \\ -0.011\ (0.285) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.423\ (0.000) & 0.021\ (0.133) \\ 0.060\ (0.341) & 0.310\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.068\ (0.116) & 0.014\ (0.311) \\ 0.038\ (0.252) & 0.140\ (0.044) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.019\ (0.543) & -0.016\ (0.119) \\ -0.047\ (0.386) & 0.307\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_4 = \begin{bmatrix} -0.027\ (0.634) & 0.029\ (0.018) \\ -0.116\ (0.089) & -0.124\ (0.004) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.139\ (0.001) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.012\ (0.000) \\ 0.006\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} 0.874\ (0.000) \\ 0.593\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.404\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 2001:2 - 2018:4. Numbers in parentheses are p-values.

Table 6. Estimates of the GARCH-in-Mean VAR for Romania

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ 0.115\ (0.120) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} 0.039\ (0.000) \\ -0.054\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.343\ (0.000) & 0.136\ (0.000) \\ 0.003\ (0.943) & 0.350\ (0.001) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.220\ (0.000) & -0.117\ (0.000) \\ -0.021\ (0.788) & 0.037\ (0.700) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} -0.019\ (0.663) & 0.117\ (0.000) \\ 0.145\ (0.236) & 0.149\ (0.147) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_4 = \begin{bmatrix} -0.010\ (0.807) & 0.066\ (0.000) \\ -0.0204\ (0.820) & -0.014\ (0.887) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.357\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.005\ (0.000) \\ 0.001\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} 0.982\ (0.000) \\ 0.276\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.724\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 2005:2 - 2018:4. Numbers in parentheses are *p*-values.

Table 7. Estimates of the GARCH-in-Mean VAR for Serbia

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.121\ (0.420) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -9.9002e-005\ (0.991) \\ -0.144\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.468\ (0.000) & -1.1989e-003\ (0.978) \\ -0.203\ (0.261) & 0.447\ (0.001) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} -0.042\ (0.481) & 4.2217e-004\ (0.991) \\ -0.107\ (0.574) & -0.050\ (0.546) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} -5.1028e-003\ (0.904) & 6.2472e-004\ (0.988) \\ -0.154\ (0.166) & 0.086\ (0.287) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.714\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.014\ (0.000) \\ 6.9669e-004\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} 0.899\ (0.000) \\ 0.216\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.784\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 2006:2 - 2018:4. Numbers in parentheses are *p*-values.

Table 8. Estimates of the GARCH-in-Mean VAR for South Africa

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.186\ (0.000) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} 0.002\ (0.864) \\ -0.031\ (0.009) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.463\ (0.000) & -0.026\ (0.546) \\ 0.106\ (0.014) & 0.013\ (0.872) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.056\ (0.281) & 0.012\ (0.630) \\ 0.163\ (0.000) & 0.454\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.030\ (0.425) & -0.008\ (0.860) \\ -0.030\ (0.475) & 0.201\ (0.001) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.113\ (0.017) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.020\ (0.000) \\ 0.002\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} 0.761\ (0.000) \\ 0.127\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.840\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 2000:2 - 2018:4. Numbers in parentheses are *p*-values.

Table 9. Estimates of the GARCH-in-Mean VAR for Bosnia and Herzegovina

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.004\ (0.072) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -0.004\ (0.754) \\ -0.020\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.043\ (0.009) & 0.301\ (0.660) \\ -0.011\ (0.000) & 0.350\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.363\ (0.000) & -0.370\ (0.660) \\ 0.002\ (0.000) & -0.048\ (0.388) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.227\ (0.000) & 0.880\ (0.398) \\ 0.004\ (0.266) & -0.075\ (0.225) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.114\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.031\ (0.000) \\ 0.000\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.012\ (0.000) \\ 0.076\ (0.001) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.726\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1999:02 - 2018:04. Numbers in parentheses are p-values.

Table 10. Estimates of the GARCH-in-Mean VAR for Bulgaria

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -3.7289e-003\ (0.000) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -3.5485e-003\ (0.706) \\ -0.025\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.044\ (0.000) & 0.466\ (0.000) \\ -0.012\ (0.000) & 0.342\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.365\ (0.000) & -0.402\ (0.000) \\ 3.3926e-003\ (0.000) & -0.069\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.226\ (0.000) & 0.830\ (0.000) \\ 3.6497e-003\ (0.000) & -6.6004e-003\ (0.651) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.141\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.031\ (0.000) \\ 1.6570e-005\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.012\ (0.000) \\ 0.049\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.766\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1999:02 - 2018:04. Numbers in parentheses are p-values.

Table 11. Estimates of the GARCH-in-Mean VAR for Comoros

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -4.9350e-003\ (0.015) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -2.8767e-003\ (0.773) \\ -6.2152e-003\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.029\ (0.432) & 0.553\ (0.468) \\ -9.4182e-003\ (0.002) & 0.345\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.292\ (0.000) & -0.060\ (0.934) \\ -6.8328e-005\ (0.977) & -0.103\ (0.040) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.300\ (0.000) & 0.641\ (0.489) \\ 2.4627e-003\ (0.469) & 8.2781e-003\ (0.887) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.035\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.030\ (0.000) \\ 1.5151e-005\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.015\ (0.400) \\ 0.069\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.760\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1994:02 - 2018:04. Numbers in parentheses are p-values.

Table 12. Estimates of the GARCH-in-Mean VAR for Croatia

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -4.2732e-003\ (0.029) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -4.2188e-003\ (0.672) \\ -5.1780e-003\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.036\ (0.330) & 0.430\ (0.623) \\ -8.1703e-003\ (0.004) & 0.330\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.299\ (0.000) & -0.236\ (0.752) \\ 1.7510e-004\ (0.944) & -0.010\ (0.063) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.280\ (0.000) & 0.581\ (0.548) \\ 1.6921e-003\ (0.625) & -0.030\ (0.604) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.031\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.029\ (0.000) \\ 7.9834e-006\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.014\ (0.474) \\ 0.016\ (0.035) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.899\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1994:07 - 2018:04. Numbers in parentheses are p-values.

Table 13. Estimates of the GARCH-in-Mean VAR for Former Yugoslav Republic of Macedonia

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -0.004\ (0.065) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -0.004\ (0.204) \\ -0.020\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.043\ (0.000) & 0.272\ (0.654) \\ -0.011\ (0.000) & 0.344\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.363\ (0.000) & -0.300\ (0.402) \\ 0.004\ (0.154) & -0.074\ (0.179) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.228\ (0.000) & 0.849\ (0.416) \\ 0.003\ (0.000) & -0.001\ (0.968) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.115\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.031\ (0.000) \\ 0.000\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.012\ (0.000) \\ 0.055\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.781\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1999:01 - 2018:04. Numbers in parentheses are p-values.

Table 14. Estimates of the GARCH-in-Mean VAR for Montenegro

A. Conditional mean equation

$$\boldsymbol{B} = \begin{bmatrix} 1 & 0 \\ -4.1851e-003\ (0.000) & 1 \end{bmatrix}; \boldsymbol{C} = \begin{bmatrix} -3.6297e-003\ (0.732) \\ -0.029\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_1 = \begin{bmatrix} 0.049\ (0.070) & 0.528\ (0.543) \\ -0.012\ (0.000) & 0.338\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_2 = \begin{bmatrix} 0.367\ (0.000) & -0.598\ (0.445) \\ 4.0601e-003\ (0.000) & -0.075\ (0.000) \end{bmatrix};$$

$$\boldsymbol{\Gamma}_3 = \begin{bmatrix} 0.222\ (0.000) & 0.906\ (0.000) \\ 2.7311e-003\ (0.000) & -0.012\ (0.849) \end{bmatrix};$$

$$\boldsymbol{\Lambda} = \begin{bmatrix} 0 & 0 \\ 0.166\ (0.000) & 0 \end{bmatrix}.$$

B. Conditional variance equation

$$\boldsymbol{C}_v = \begin{bmatrix} 0.031\ (0.000) \\ 1.6647e-005\ (0.000) \end{bmatrix};$$

$$diag\boldsymbol{F} = \begin{bmatrix} -0.011\ (0.000) \\ 0.064\ (0.000) \end{bmatrix}; diag\boldsymbol{G} = \begin{bmatrix} 0.000\ (0.000) \\ 0.754\ (0.000) \end{bmatrix}.$$

Note: Sample period, monthly data: 1999:02 - 2018:04. Numbers in parentheses are p-values.

Table 15. Coefficient of interest, $\hat{\lambda}$, from GARCH-in-Mean equation

Country	$\hat{\lambda}$	p-value
A. Inflation rate targeters		
Brazil	19.857	0.000
Chile	3.630	0.000
Mexico	0.139	0.001
Romania	0.357	0.000
Serbia	0.714	0.000
South Africa	0.113	0.017
B. Exchange rate targeters		
Bosnia & Herzegovina	0.114	0.000
Bulgaria	0.141	0.000
Comoros	0.035	0.000
Croatia	0.031	0.000
Former Yugoslav Republic of Macedonia	0.115	0.000
Montenegro	0.166	0.000

Figure 1. Impulse response functions for Brazil

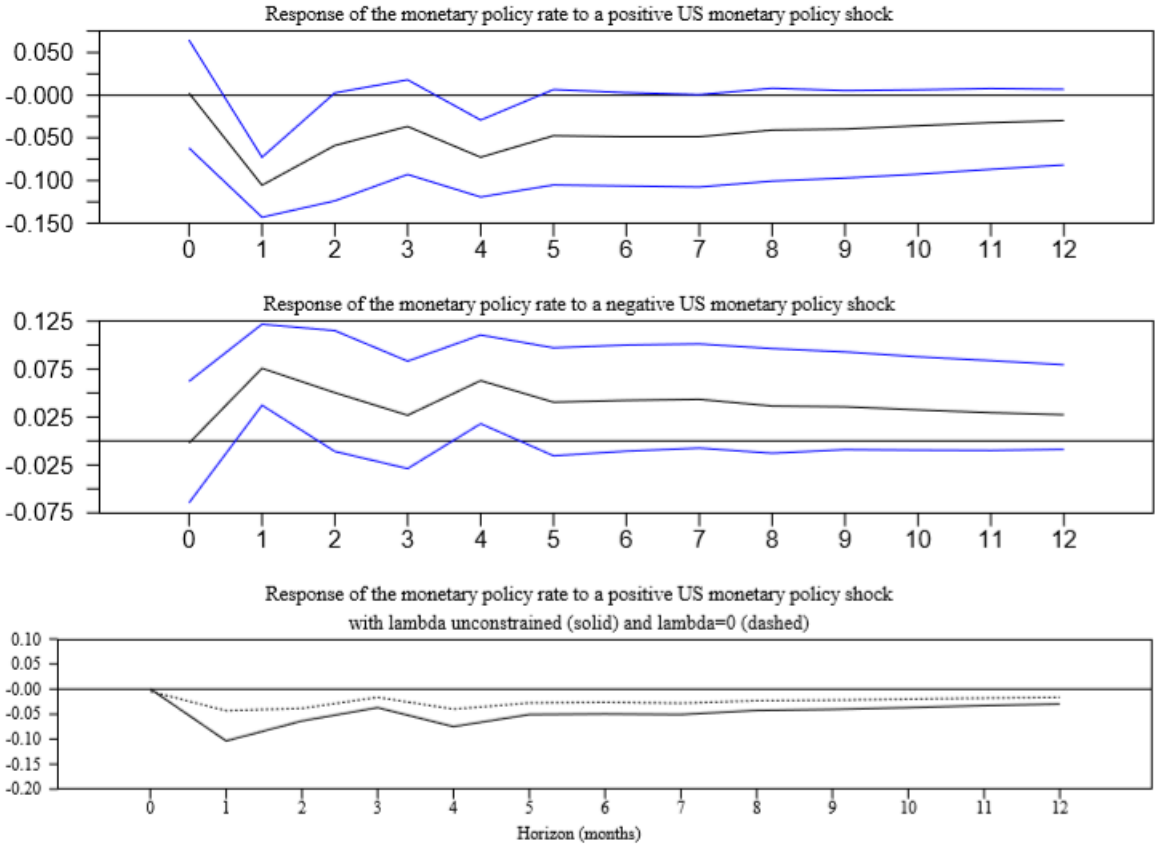

Figure 2. Impulse response functions for Chile

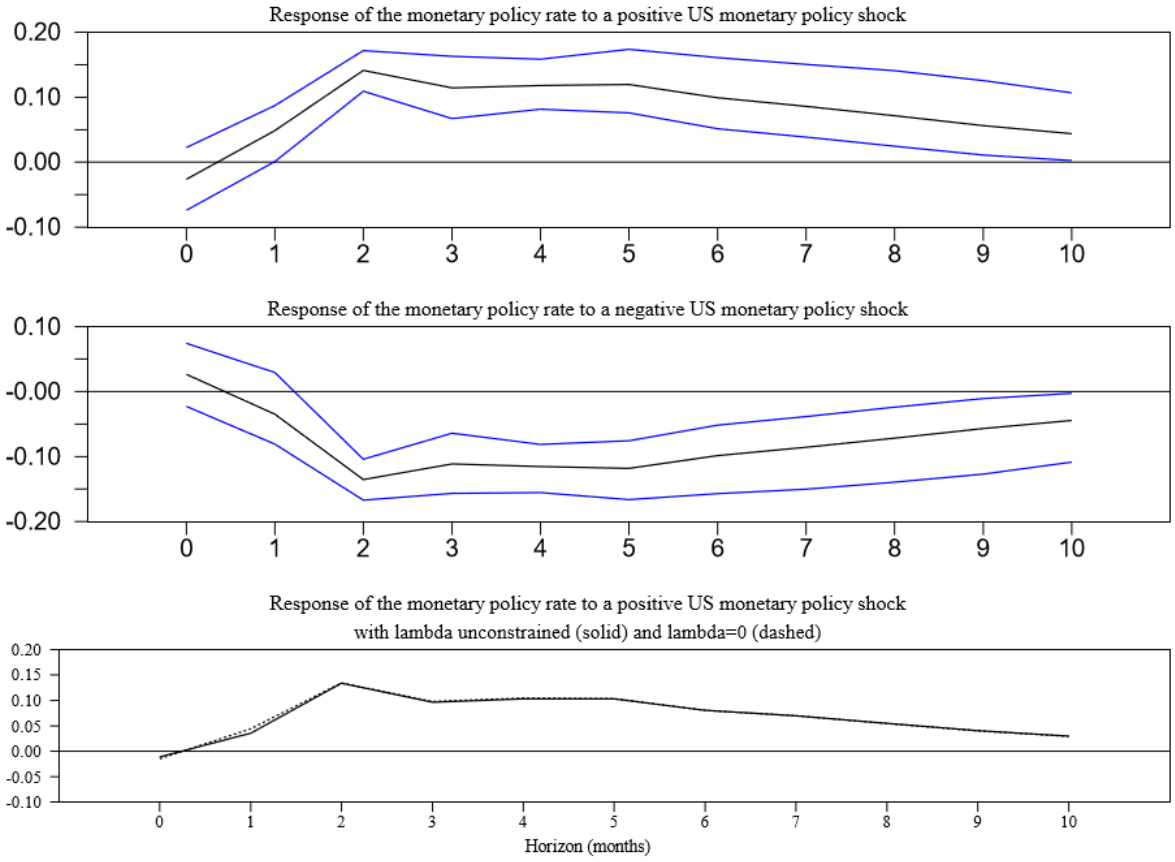

Figure 3. Impulse response functions for Mexico

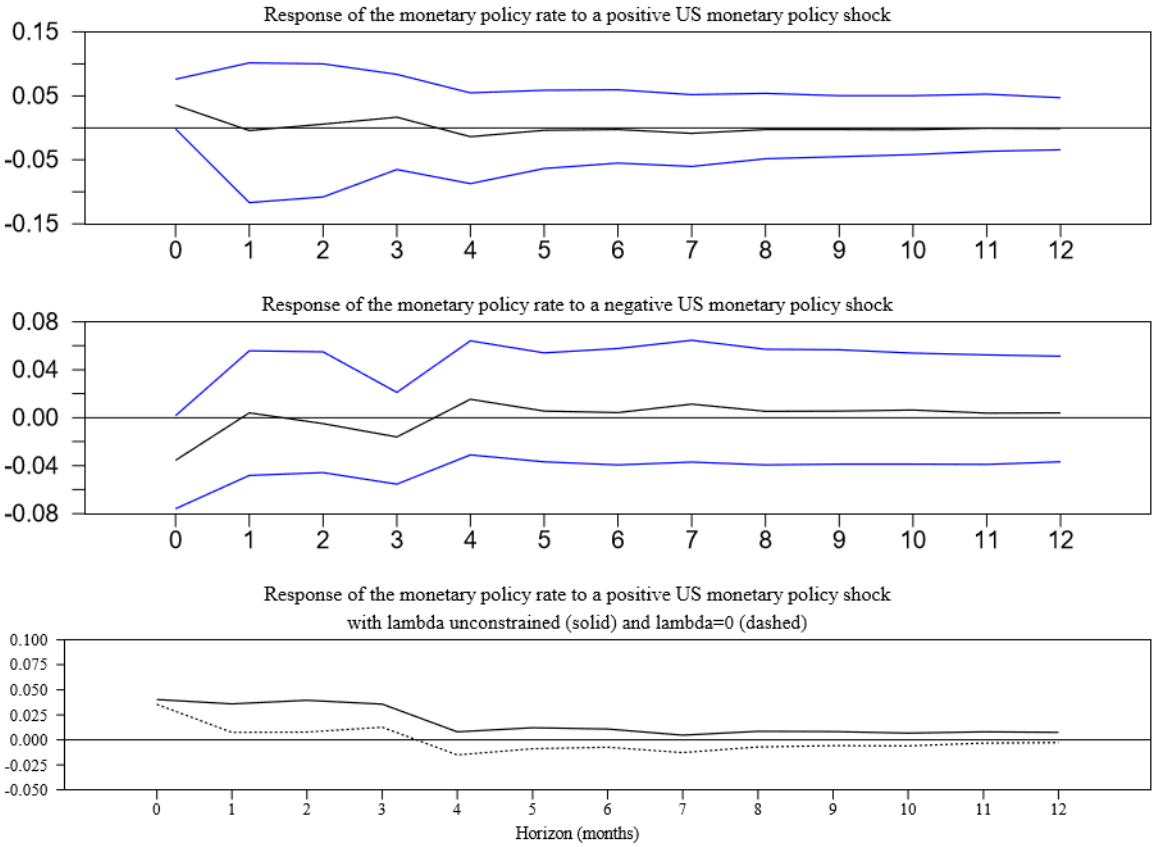

Figure 4. Impulse response functions for Romania

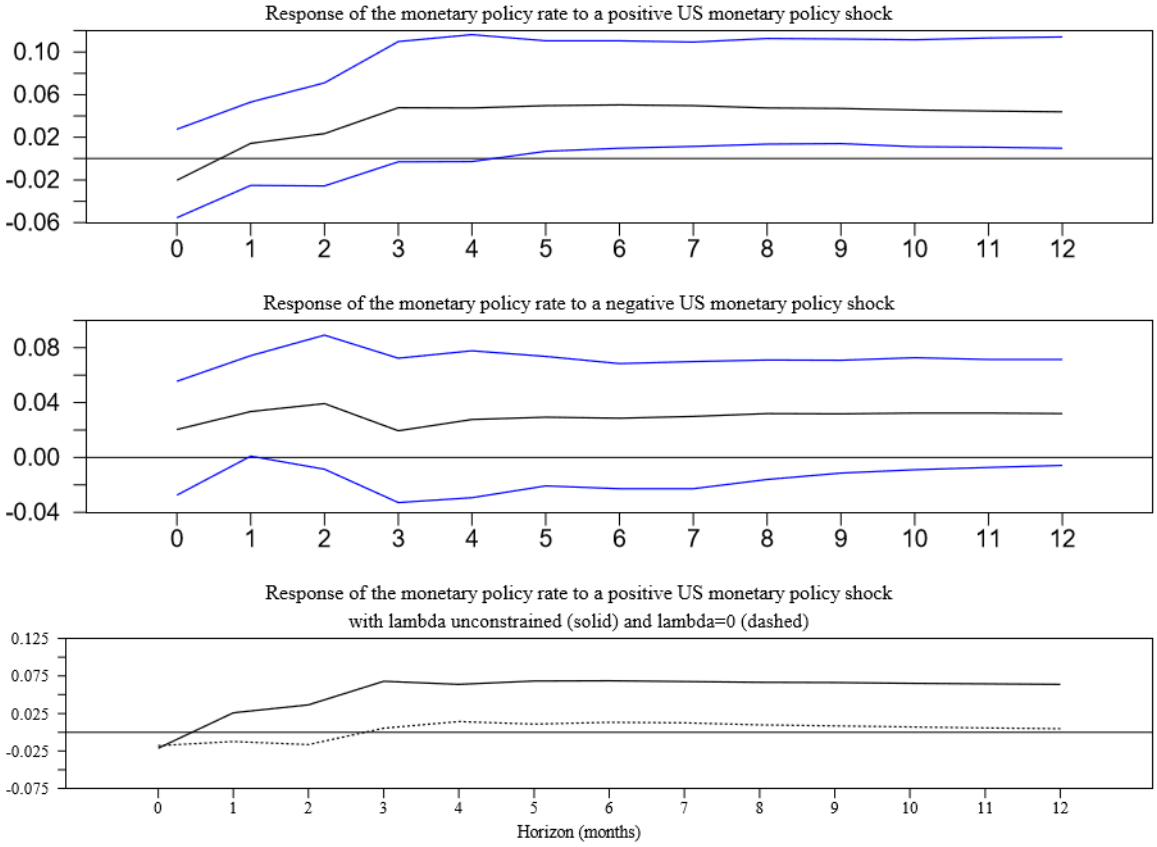

Figure 5. Impulse response functions for Serbia

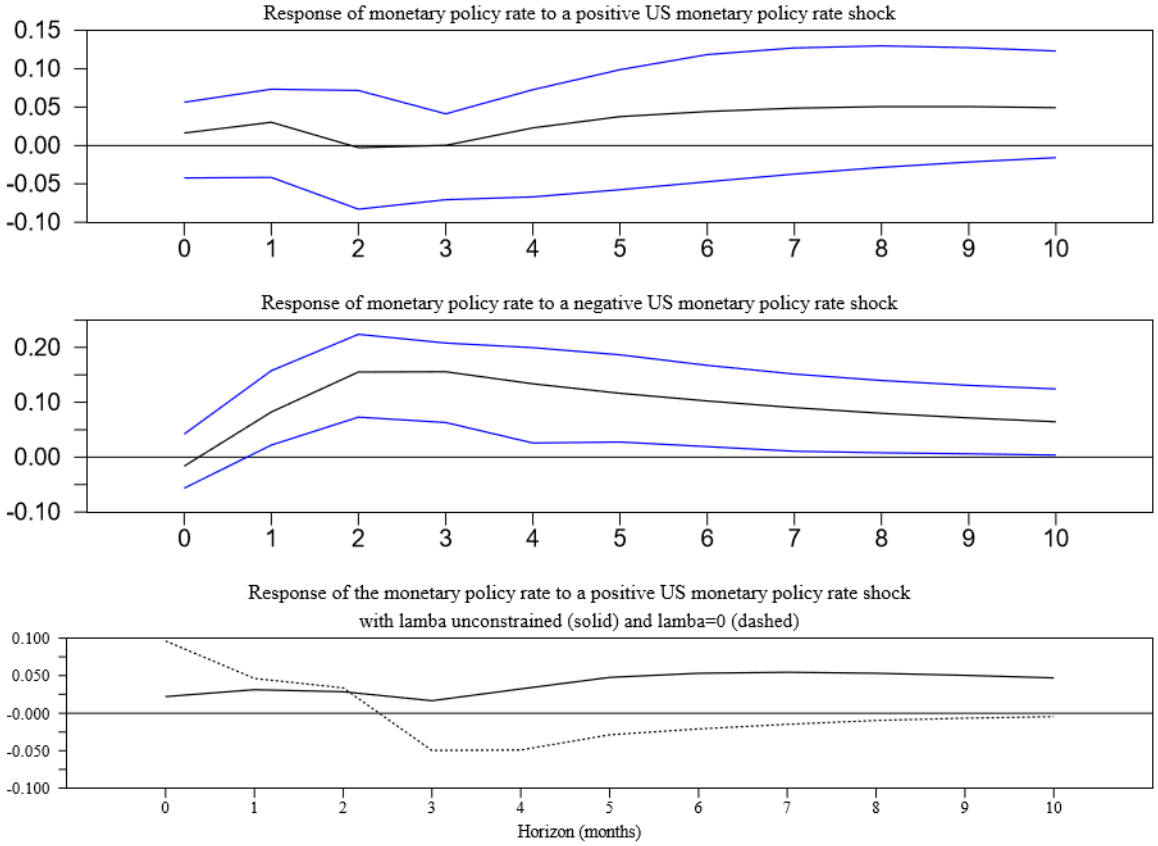

Figure 6. Impulse response functions for South Africa

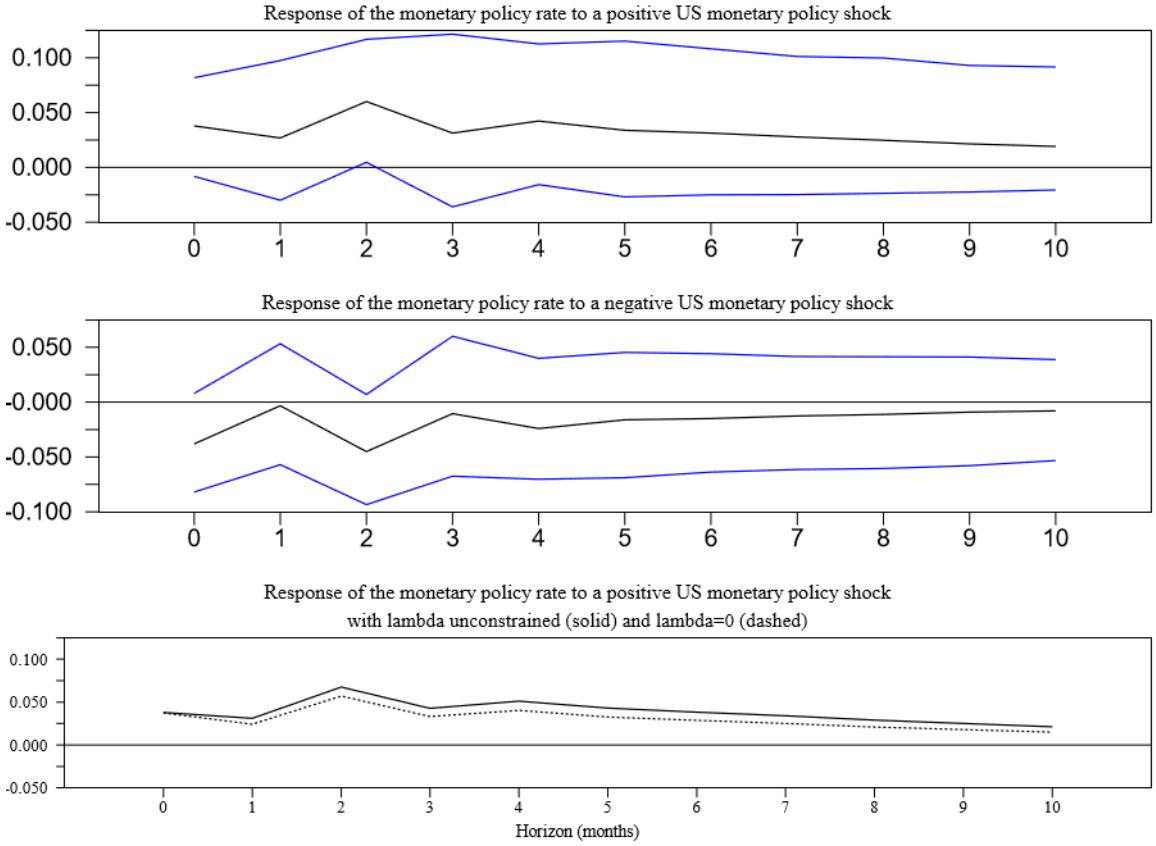

Figure 7. Impulse response functions for Bosnia and Herzegovina

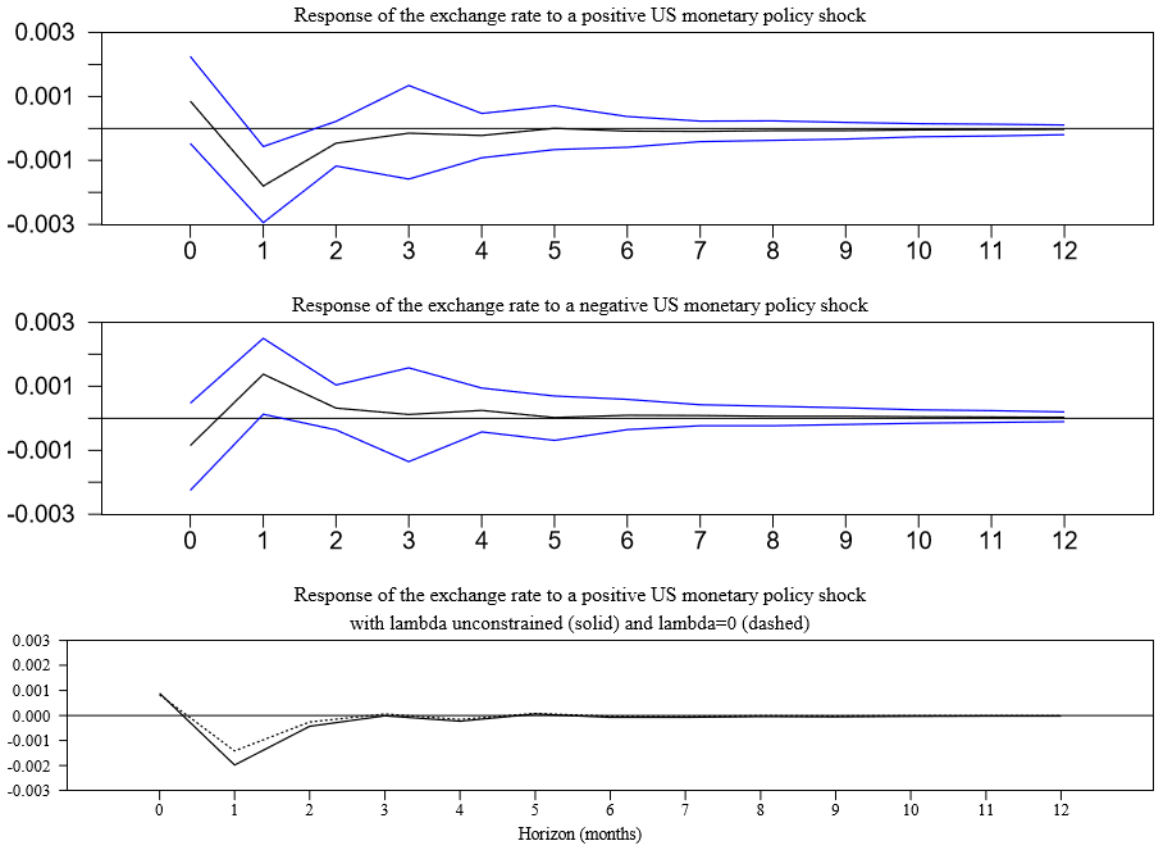

Figure 8. Impulse response functions for Bulgaria

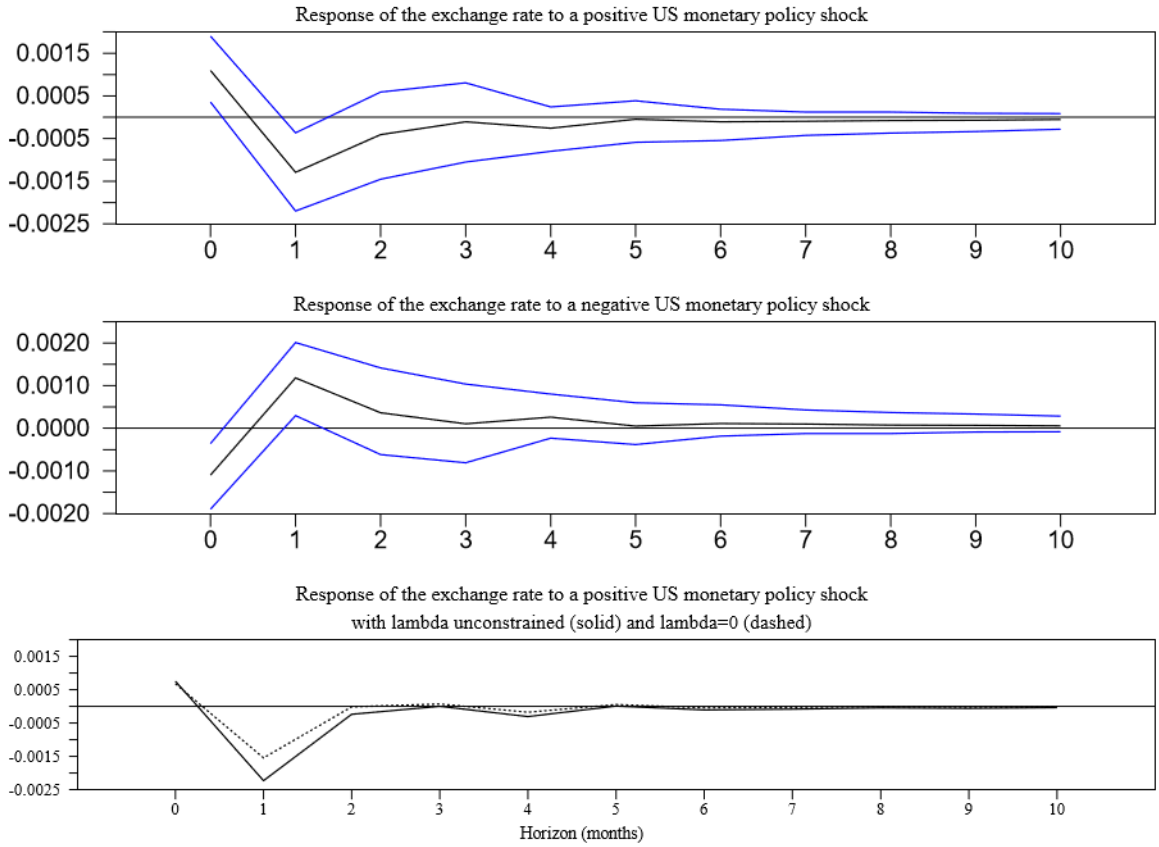

Figure 9. Impulse response functions for Comoros

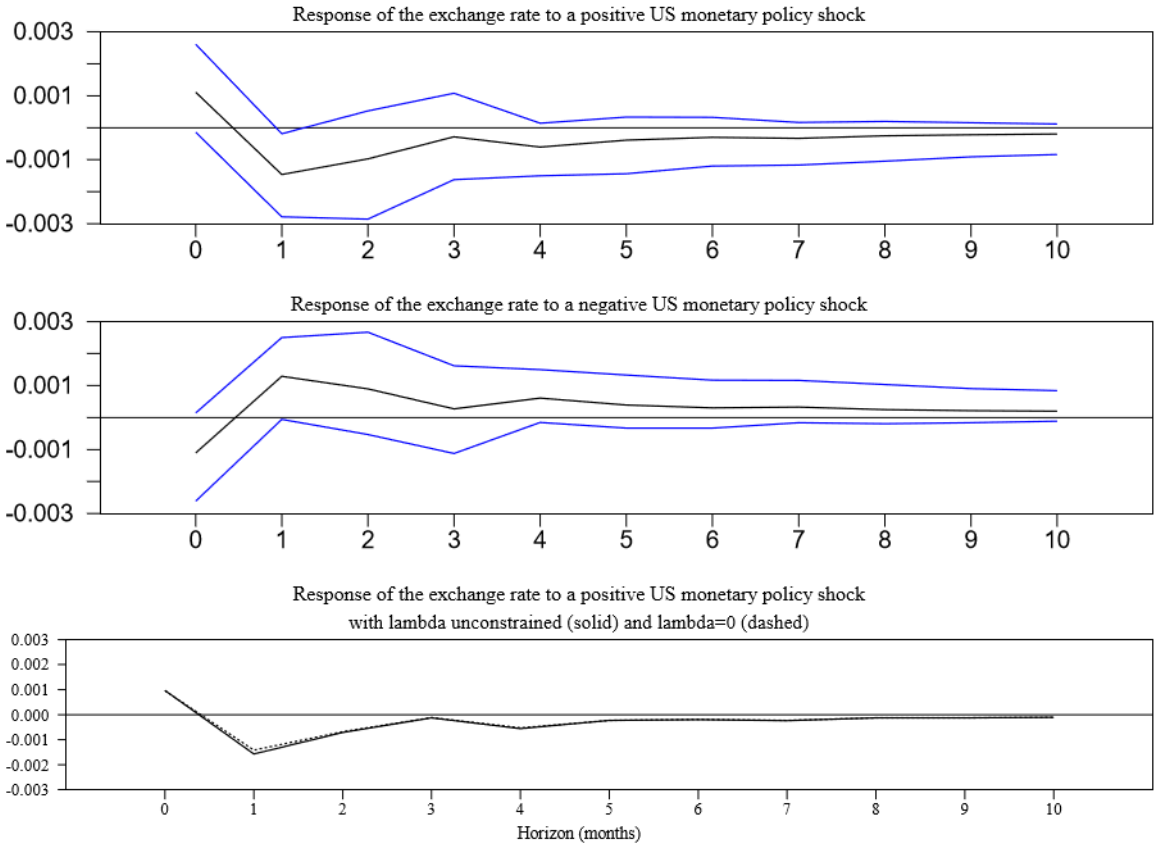

Figure 10. Impulse response functions for Croatia

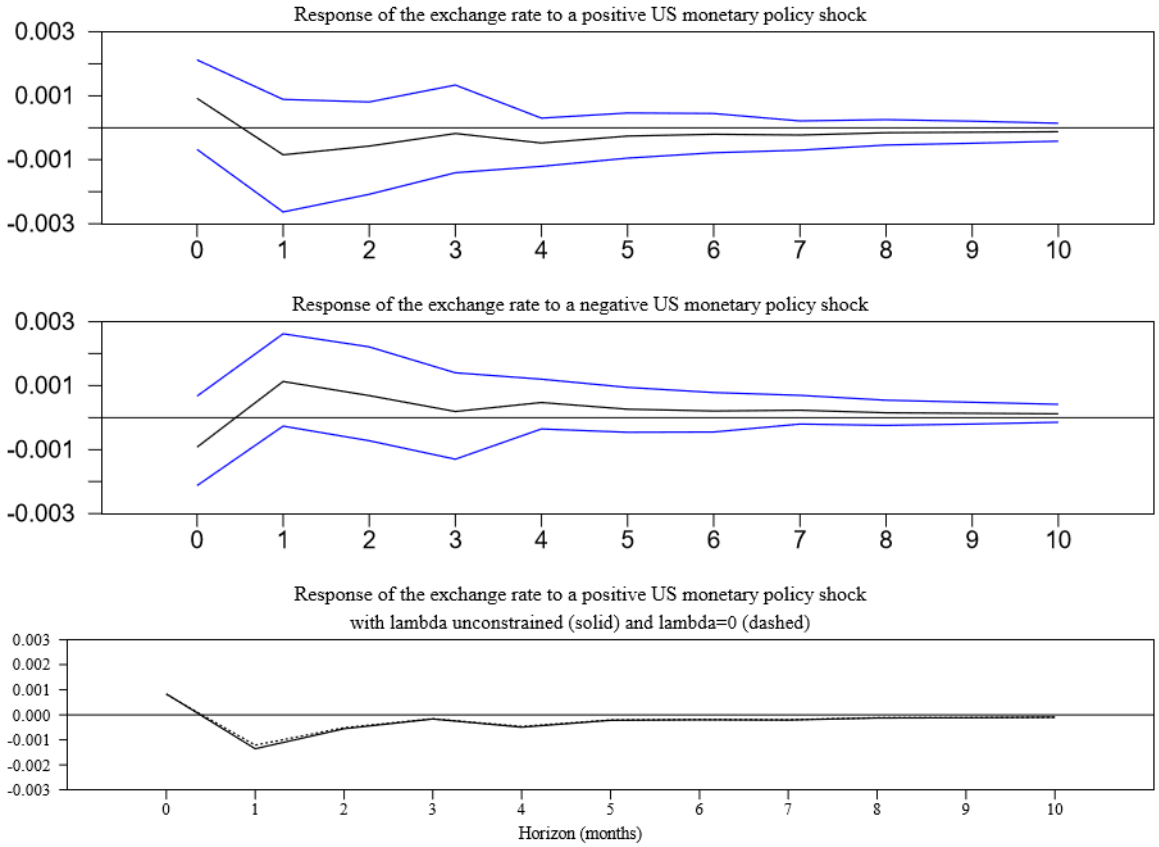

Figure 11. Impulse response functions for Former Yugoslav Republic of Macedonia

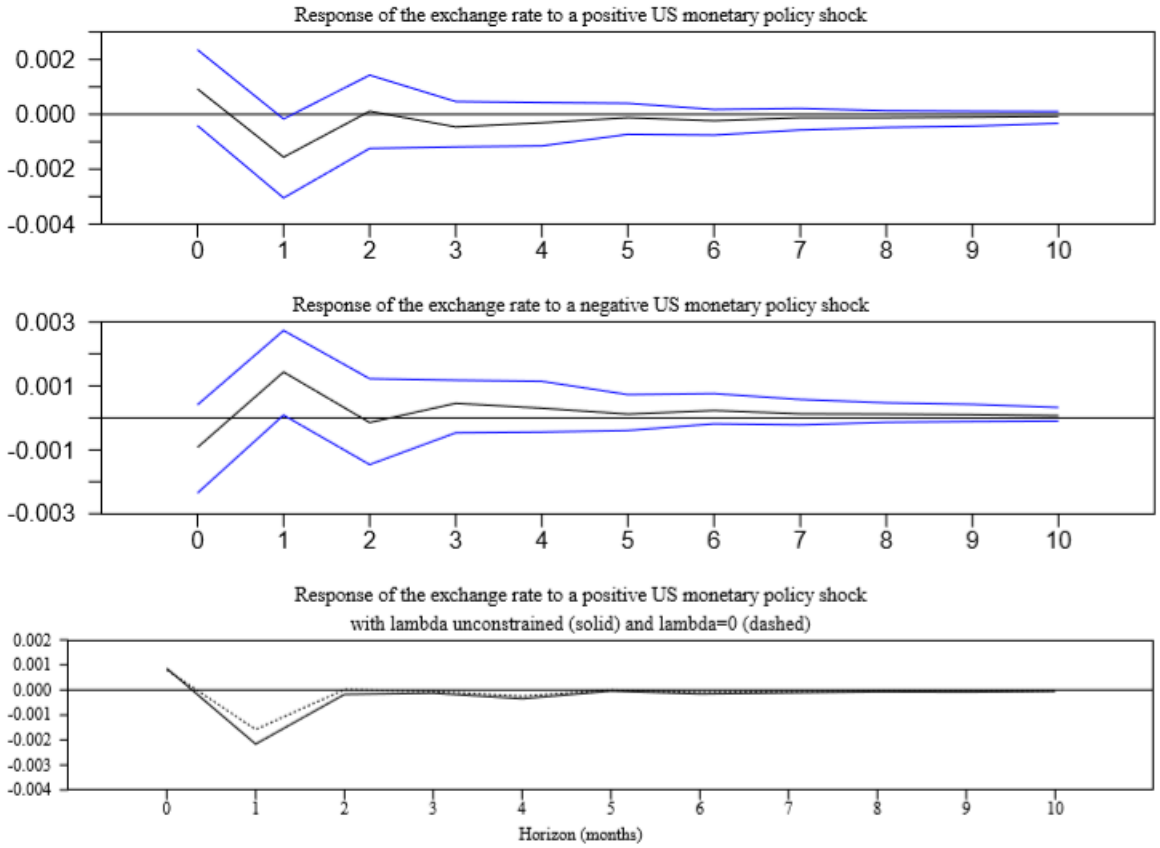

Figure 12. Impulse response functions for Montenegro