On the Interest Channel and the Global Financial Cycle for Emerging Market Economies[1]

Manuel Ramos-Francia
CEMLA

Santiago García-Verdú
CEMLA and
Banco de México

Manuel Sánchez-Martínez
CEMLA and
Banco de México

This draft: January 2019
Do not quote, cite or distribute without the authors' permission.

Abstract

We explore the effects of inflation and the VIX on the term structure of nominal interest rates for a set of emerging market economies. To that end, we estimate affine interest rate models with inflation and the VIX as risk factors. The VIX, in general, affects the long-term interest rate mainly through the term premium component. Joint shocks -on inflation and the VIX- significantly affect long-term interest rates. Thus, the VIX could be hampering their interest rate channels, albeit there is notable heterogeneity across the economies in our database.

Key Words. Global Financial Cycle, Interest Rate Channel, Term Structure of Interest Rate, Term Premium.

JEL Codes. F00, E5, E52, E43.

[1] The opinions in this paper are those of the authors and should not be attributed to those of the Banco de México or CEMLA. We would like to thank Raúl Álvarez-del-Castillo for his comments, and Ana Carolina Garriga for providing us with the central bank independence measures. The remaining errors are our own.

Introduction

There is an important debate on the Global Financial Cycle (GFCy). Some researchers have compellingly argued about its economic implications (Borio, 2014; Forbes and Warnock, 2012; Jordà et al. 2018). Among its possible repercussions, we have that it might affect the traction that local monetary policies have within small open economies (Rey, 2015). In contrast, other scholars have expressed doubts on its bearing (Cerutti, Claessens, and Rose, 2017).

Against this backdrop, we explore how the GFCy might affect the interest rate channel for a set of emerging market economies (EMEs). Specifically, we analyze how shocks on inflation affect the term structure of interest rates compared to the effects brought about *joint* shocks, on inflation and the VIX index.[2] Thus, we use such an index as a proxy for the GFCy (Rey, 2015, Illing and Aaron, 2012, Jordà et al. 2018). While monetary policy (MP) is evidently also transmitted through other channels and the GFCy could also influence them, their consideration is beyond the scope of our paper.

To that end, we estimate affine interest models for a set of emerging market economies (EMEs). As observable risk factors, we precisely use inflation and the VIX index and, as unobservable ones, the principal components of the interest rates.[3] In addition, we interpret the linear models of the short-term interest rates, which are part of the affine interest rate model, as monetary rules. Thus, we examine some of the features between the referred rules and the respective term structures. Our interests though go further. We also explore how changes in the term structure due to inflation shocks measured up against variations in the term structure due to *joint* shocks, on inflation and the VIX. Thus, we assess whether the VIX index could be hampering the response of the term structure of interest rates to inflation shocks. More broadly, we consider whether the global financial cycle could be *adversely* affecting the interest rate channel of EMEs.

[2] The VIX is the implied volatility of options on the Standard and Poor's 500 stock index.

[3] We use the term unobservable variable in the sense that such a variable is not macroeconomic variables or directly obtainable. In the estimation method we use, a variable needs to be readily available. In our case, we use principal components, which we obtain directly from the interest rates. In other words, the estimation method we use does not support the simultaneous estimation of variables (i.e. risk factors), which are sometimes refer to as unobservable.

Anticipating our key results, we have the following remarks. First, the monetary rules' coefficients associated with inflation and the VIX positively relate to the affine model coefficients associated with those same variables. In effect, monetary authorities react to market participants and vice versa. This is, there could be causality in both directions. Second, the responses of long-term interest rates to shocks on the VIX index are, in general, statistically significant. Such responses are mostly due to variations in the term premiums. The responses to shocks on inflation are for the most part due to the expected average short-term interest rates. Third, the responses of the long-term interest rate to *joint* shocks on inflation and the VIX are, in general, statistically significant as well, in which the VIX seems augment the general response. This is indicative of an adverse role of the GFCy on the interest rate channel in EMEs. Having said that, the results depend on the economy in question.

Literature Review

Our paper lies at the intersection of three strands of literature. Accordingly, we organize the following succinct review into three subsections: the global financial cycle (GFCy), term structure of interest rates' models and the monetary policy transmission channels. The implications of the GFCy have been a matter of debate, as mentioned. To begin with, its measurement is challenging as the GFCy manifests itself through several financial variables. A widely used measure of the GFCy is the VIX index (Passari and Rey, 2015, Avdjiev et al., 2016, Bruno and Shin, 2015, and Fratzscher, 2012).[4] Adrian et al. (2017) estimate the price of risk as function of the VIX index. Such price forecasts global financial assets returns. A higher exposure to the referred price correlates to higher output growth and volatility. On their part, Avdjiev et al. (2017) document the importance of the financial channel due to exchange rate fluctuations. Specifically, beyond the garden variety exchange rate channel, variations in the exchange rate affect borrowers' balance sheets and lenders' risk-taking capacity, in the opposite direction

[4] Cerutti et al. (2017a) propose alternative measures, such as volatility indexes analogue to the VIX for other advanced economies, nominal policy interest rates of some advanced economies, rate slopes, GDP growth, real effective exchange rate growth, and M2 growth, among others. One can define the GFCy as "commonality in financial conditions, manifest in capital flows, driven by observable global determinants" (Cerutti et al., 2017a, p. 9).

to that of the exchange rate channel. Baskaya et al. (2017) explore the international spillovers of capital flows on local credit. They argue that capital inflows explain 43% of local credit growth. Reinhart et al. (2017) show that cross border financial flows from financial centers to the periphery are cyclical.

On the other hand, Bekaert and Mehl (2017) propose a measure of financial market integration based on an equity returns' factor. They use this measure to contribute to the debate on whether the classic trilemma has more recently evolved into a dilemma. They find no evidence supporting such a change. Cerutti et al. (2017a) find little quantitative evidence of the GFCy, using direct and indirect measures based on capital flows. They argue that most of the capital flows' variation does not appear to be the result of common shocks. Jorda et al. (2017) argue that fluctuations in the associated risk premiums account for most of the observed equity price synchronization after 1980, but that their effects are muted in floating exchange rate regimes, adding to the debate.[5]

Second, the term structure literature started with interest rate models. Several were parametric and some were constructed based on economic foundations. Quite a few were extended as term structure models (Filipovic, 2000). More recently, affine interest rate models have gained popularity given their tractability (Piazzesi, 2010). The use of affine term structure models for our purposes has several advantages. It allows us to consider the whole term structure, to obtain the decomposition of interest rates into the expected average of the short-term interest rates and term premium, and to incorporate the no-arbitrage condition explicitly in a model. We note that the expected average of the short-term interest rates equals the long-term interest rate under the assumption of risk-neutral agents.

Some researchers have estimated term structure models for emerging market economies (EMEs). For example, Blake et al. (2015) estimate an affine interest rate

[5] Relatedly, Mian et al. (2015) document that an increase in the household debt to GDP ratio predicts a lower GDP growth and higher unemployment. This relationship is stronger for countries with less flexible exchange rates. Hassan et al. (2016) find that a small economy that stabilize its exchange rate, relative to a large economy, increases capital accumulation and wages. Jeanne and Sandri (2017) show that EMEs smooth the impact of the GFCy through the accumulation and de-accumulation of liquid foreign assets.

model to calculate term premiums for a set of Latin American economies. They argue that the adoption of Inflation Targeting has meant that their term premiums, since then, have been smaller.[6] Along a similar line, Ceballos and Romero (2016) decompose the long-term interest rates for EMEs and advanced economies (AEs) into their, respective, risk-neutral interest rates and term premiums. They argue that in EMEs, movements in long-term interest rates are mostly explained by variations in term premiums. In AEs, however, the same movements are explained by changes in both components. On his part, Wright (2011) documents a relationship between the term premium (specifically, decomposing the forward rate into expected short-term interest rates and a term premium) and inflation uncertainty for a set of AEs. He finds that the term premium diminished in economies that reduced their inflation uncertainty by making changes to their monetary frameworks.

Third, the monetary policy transmission channels have been fundamental to the monetary economics literature (Mashkin, 1996, 2001). As is well-known, monetary policy can affect an economy through different channels. For instance, by setting the reference interest rate, the monetary policy stance affects savings, credit, the exchange rate, balance sheets, risk-taking, long-term interest rates, macroeconomic expectations, and inflation expectations. In tandem, these affect the aggregate demand and the inflation level. The interest rate channel entails how changes in the short-term interest rates, or more generally, the monetary policy stance, affect investment and aggregate demand. As investment largely depends on the longer-term interest rates, part of this channel relates to how changes in the short-term interest rates affect the rest of the term structure of interest rates. We have a keen interest in this aspect of such a channel.

Data and Exploratory Statistics

We use the nominal interest rates associated with one-, three-, six-, 12-, 60-, 108- or 120-, and 240-month maturities, for Chile, the Czech Republic, India, Indonesia, Mexico,

[6] We are unsure on why Blake et al. (2015) do not present errors' statistics of their estimations. Those presented are limited to some periods and strike us as relatively large.

Poland, Russia, and South Korea.[7] Our initial set of countries included Brazil, Chile, Colombia, Czech Republic, Hungary, India, Indonesia, Mexico, Poland, Russia, South Africa, South Korea, and Turkey. Nonetheless, if we were unable to obtain a reasonable fit, we did not estimate an affine interest rate model jointly with our macroeconomic variables. For the case of the one-month interest rates, we use the LIBOR-equivalent rate for each economy. We present the respective estimation samples and basic statistics in Table 1. To obtain the complete term structures, for each economy, we use cubic interpolation based on the aforementioned maturities of nominal interest rates. We estimate the affine models with the end-of-the month data for interest rates and VIX time series.

Due to data availability, the starting dates of their samples differ, by four years for Indonesia, three for Russia, and one for Chile. Although some investors tend to bundle emerging markets economies as an asset class, their interest rates' statistics notably differ. Specifically, for instance, long-term interest rates' means are in the 3.1–12.5% range and in 3.1–7.8%, when considering the longest common sample. Their standard deviations are heterogeneous as well, falling in the 0.9–2.7% range, and in 0.8-2.11% when also considering the longest common sample. Their skewnesses tend to be positive, with the exception of India. A positive skewness reflects the possibility of adverse extreme events. Similarly, their kurtoses are positive, except for South Korea's. A positive kurtosis echoes the prospects of extreme events greater than those of a normal distribution.[8]

---

[7] Countries for which we use a 108-month interest rate are: Czech Republic, Hungary, and Poland. Countries for which we use a 120-month interest rate are: Brazil, Chile, Colombia, Czech Republic, India, Indonesia, Mexico, Russia, South Africa, South Korea, and Turkey.

[8] For several economies, the inclusion of inflation and the VIX as risk factors did not lead to reasonable estimation fits. These were Brazil, Colombia, Hungary, South Africa, and Turkey. In every case though, we estimated the model using only the principal components of the corresponding interest rates. We then explored the variables dynamics with a *separate* VAR model. In doing so, we lost some theoretical consistency. Accordingly, we present a summary of the associated results in the appendix. In such cases, we cannot identify whether their differences are due to the modelling approach or to the features of such economies.

	Start	End	Mean			Standard Deviation			Skewness			Excess Kurtosis		
			1y	*5y*	*9 or 10y*	*1y*	*5y*	*9 or 10y*	*1y*	*5y*	*9 or 10y*	*1y*	*5y*	*9 or 10y*
Brazil	27-Mar-07	3-Jul-18	10.95	12.23	12.46	2.35	2.02	1.89	-0.12	0.37	0.59	-0.67	0.47	0.79
Chile	29-Sep-05	3-Jul-18	4.44	5.25	5.60	1.59	1.05	0.92	0.12	0.25	0.24	-0.18	-0.54	-0.73
Colombia	28-Apr-06	3-Jul-18	6.04	7.55	8.22	2.06	1.92	1.72	1.00	0.87	0.74	-0.32	-0.01	0.20
Czech Republic	2-Jan-04	3-Jul-18	1.34	2.31	3.12	1.38	1.55	1.59	0.35	-0.21	-0.33	-0.95	-1.43	-1.15
Hungary	5-Jan-04	3-Jul-18	5.45	6.00	6.25	3.45	2.67	2.11	-0.11	-0.30	-0.36	-1.02	-0.91	-0.80
India	2-Jan-04	3-Jul-18	7.03	7.64	7.85	1.36	0.95	0.90	-0.40	-0.66	-0.77	-0.67	0.41	0.84
Indonesia	2-Jan-08	3-Jul-18	7.61	8.89	9.50	2.37	2.60	2.71	1.21	0.67	0.87	1.76	0.09	2.21
Mexico	2-Jan-04	3-Jul-18	5.76	6.72	7.35	1.80	1.41	1.32	0.19	0.23	0.49	-1.29	-0.94	-0.23
Poland	2-Jan-04	3-Jul-18	3.81	4.50	4.89	1.70	1.53	1.32	0.04	-0.16	-0.30	-0.99	-1.12	-1.17
Russia	4-Jan-07	3-Jul-18	7.41	8.35	8.66	2.19	2.08	2.18	1.10	1.47	1.78	0.85	1.68	3.19
South Africa	2-Jan-04	3-Jul-18	7.31	8.07	8.68	1.37	0.90	0.78	0.51	0.09	0.32	0.57	0.91	0.38
South Korea	26-Jul-04	3-Jul-18	3.24	3.90	4.08	1.25	1.48	1.33	0.22	0.58	-0.26	-1.03	-0.14	-1.27
Turkey	1-Jan-10	3-Jul-18	9.41	9.58	9.67	2.02	1.51	1.29	0.80	0.44	0.32	1.99	2.45	2.62

Table 1. Samples and General Statistics.
Notes: Original data has a daily frequency. The means and standard deviations are in percentages. In a few cases, such as Chile, we substituted data points that were clearly outliers with the last available data points. **Source:** Bloomberg.

Finally, to measure inflation, we use the CPI's year-over-year annual growth, for each economy. Their source is Haver Analytics. As a measure of the Global Financial Cycle (GFCy) dynamics, we use the VIX index, as mentioned. This index is commonly interpreted as a measure of the investors' risk appetite (Forbes and Warnock, 2012). In our context though, for instance, Rey (2015) argues that it is one of the variables that more closely captures the GFCy.

Preliminaries

We briefly go over five features of the EMEs for which their estimations were feasible. Such features are: a concise description of the monetary policy framework for each of their central banks, having as their source the central banks' websites; *de jure* measures of each central bank's independence (Garriga, 2016); the economies' exchange regime classifications (IMF, 2016); a *de jure* measure of financial openness (Chinn-Ito, 2008); and, a measurement of macroprudential monetary stance, based on Cerutti et al. (2017b).

Monetary Policy Frameworks

The Central Bank of Chile is autonomous and has as its purposes to keep inflation low and stable over time. The bank also has to promote the stability of the financial system and the functioning of internal and external payment systems, providing a basis for the economy's growth.

The primary objective of the Czech Central Bank is to maintain price stability. Such an objective is the bank's contribution toward a sustainable economic growth. The bank has to foster financial stability and to oversee the financial system's operation. It also sets macroprudential policy and supports the general economic policies of the Government, and those of the European Union.

The Reserve Bank of India's objectives are, first, to regulate the issue of bank notes and keeping reserves to secure monetary stability and to operate the currency and credit system of India to its advantage. Second, to have a modern MP framework to meet the challenge of an increasingly complex economy. Third, to maintain price stability while keeping the objective of growth in mind.

The Bank Indonesia has the objective of achieving and maintaining stability of the Rupiah's value. This comprises two aspects, one is its stability against goods and services, and the other is the stability of the exchange rate against other currencies.

The main goal of the Bank of Mexico is to preserve the value of its currency in the long term, in order to improve Mexicans' well-being. It bears additional responsibilities such as providing the economy with national currency, promote the healthy development of the financial system and encourage the payment systems operations.

The Central Bank of Poland implements the monetary policy, which is decided by the MP Council. The basic goal of MP is to maintain price stability. This bank has pursued IT since 1998. The central bank strives to maintain a level of interest rates that will maximize the probability of achieving the inflation target.

The Bank of Russia implements MP using an IT framework, and sees price stability as its priority. Such a central bank bases its decisions on the economic outlook and risk assessment to achieve the inflation target over a mid-term horizon, and on possible threats to sustainable economic growth and financial stability.

The Bank of Korea has price stability as the most important objective of MP. It also makes policy efforts to maintain financial stability while pursuing price stability through implementing its MP. Its MP framework aims to achieve its inflation target over a mid-term horizon.

On their independence, we consider the arithmetic average of six measures, specifically, two based on Garriga (2016) and four on Cukierman (2006). These measures are standardized between 0 and 1, where 0 is the least and 1 the most independent. In our data set, they have values from 0.27, in the case of India, to 0.84, in the Polish case, from the year 2012. We note that such measures are more general than the one the discussions surrounding the Trilemma refer to. For instance, while such discussions mostly refer to the positive issues of monetary independence, these measurements also consider political, among other aspects.

On their exchange rate arrangements, most economies maintain either a floating or a free-floating regime. Only the Czech Republic has a stabilized arrangement. For comparison purposes, we have assigned a numeric value to each of the regimes/arrangements. The conventional wisdom is that economies with a free floating regime are in a better position to deal with external shocks. This, however, has been brought to the spotlight.

In essence, all countries in our sample have small open economies. Nonetheless, they differ on their financial openness (Table 2). There are economies, like Chile, the Czech Republic, Mexico, Russia and South Korea, which are relatively open (i.e., they have Chinn-Ito indices greater 0.65 for 2016).

	Exchange Rate Arrangement	**Financial Openness Chinn-Ito**	**Monetary Policy Framework**
Chile	Free Floating	0.69	IT
Czech Republic	Stabilized arrangement	1.00	IT
India	Floating	0.17	IT
Indonesia	Floating	0.42	IT
Mexico	Free Floating	0.70	IT
Poland	Free Floating	0.69	IT
Russia	Free Floating	0.71	IT
South Korea	Floating	0.71	IT

Table 2. Exchange Rate Arrangements, Financial Openness Indices and Monetary Policy Frameworks.
Note: Chinn-Ito indices correspond to 2016. IT stands for inflation targeting.
Source: IMF (2016), Chinn-Ito (2008) and central banks' webpages.

On the other hand, there are those, like Poland, India, and Indonesia, that are relatively closed (i.e., they have Chinn-Ito indices below 0.45 for 2016).[9] In effect, the Chinn-Ito

[9] In 2014, their Chinn–Ito Index, measuring capital account openness, were: Chile (0.69), Czech Republic (1), India (0.17), Indonesia (0.42), Mexico (0.7), Poland (0.45), Russia (0.71), and South Korea (0.71).

index is standardized between 0 and 1, where 0 is the least and 1 the most financially opened. We reemphasize that this index is *de jure* and, thus, should be only seen as an approximation to a *de facto* financial openness measure, in which we are more interested in.

In terms of macroprudential policies, we have that Chile has been the more active economy (Table 4), followed by the Czech Republic, India, Mexico, Poland and South Korea. The economy with less activity in this respect is Indonesia, but it has increased its pace in more recent years. As a caveat, some policies are not necessarily specific to the interest rate transmission channel we are considering, and thus are broad measures.

	Lvau (Garriga)	Lvaw (Garriga)	CEO (Cuk)	Obj (Cuk)	Pol (Cuk)	Limlen (Cuk)	Average
Chile	0.73	0.82	0.58	0.60	0.75	1.00	0.75
Czech Republic	0.75	0.83	0.64	0.60	0.75	1.00	0.76
India	0.26	0.29	0.31	0.40	0.00	0.34	0.27
Indonesia	0.83	0.85	0.64	1.00	0.75	0.91	0.83
Mexico	0.67	0.64	0.77	0.60	0.75	0.56	0.67
Poland	0.83	0.88	0.77	0.60	1.00	0.96	0.84
Russia	0.64	0.70	0.64	0.60	0.53	0.80	0.65
South Korea	0.44	0.41	0.58	0.60	0.27	0.33	0.44

Table 3. Measures of Central Bank Independence 2012
Source: Garriga (2016)

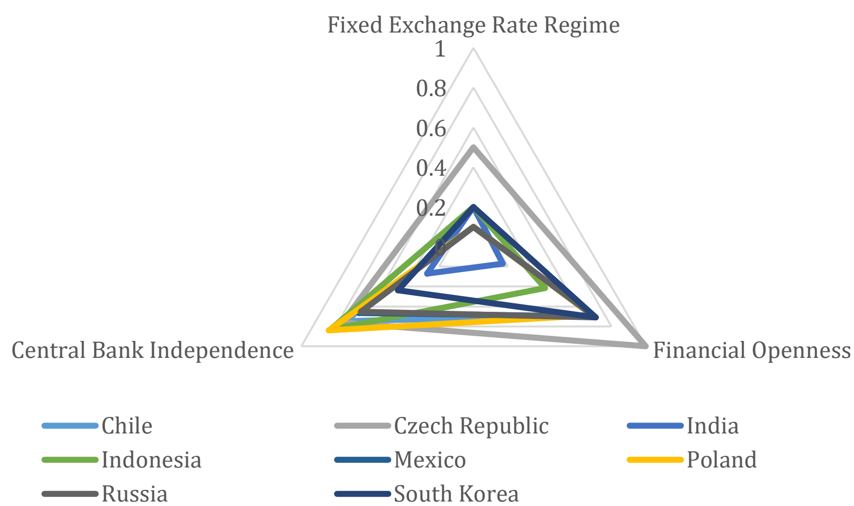


Figure 1. Central Bank Independence, Exchange Rate Regime and Financial Openness.
Source: Own calculations and data from Garriga (2016), Cukierman (2006), IMF (2016), and Chinn and Ito (2016).

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Chile	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	8	7
Czech Republic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	4	5
India	1	1	1	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4
Indonesia	0	0	0	0	0	1	1	1	1	1	1	1	2	2	3	3	4	4
Mexico	0	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4	4	4
Poland	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	4	6
Russian Federation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	4
South Korea	0	0	1	1	1	2	2	3	3	3	3	4	4	4	4	4	5	5

Table 4. Measures of Macroprudential Policy Stance.
Source : Cerutti et al. (2017b).

To sum up, there is little variation on their monetary policy frameworks. In effect, in principle, all such economies use inflation targeting (IT). As for their exchange rate arrangements, there is some variation. The Czech Republic has the one that is closest to being a fixed exchange rate regime. In terms of financial openness and central bank independence, we observe some cross-sectional variation, which allows us to assess their implications more closely. As for macroprudential policies, such economies have implemented macroprudential policies at different intensities, but have more recently become more homogenous.

Model

We estimate affine interest rate models using a set of unobservable risk factors and two observable macroeconomic ones. To obtain the risk factors, we proceed as follows. For each economy, we first orthogonalize the interest rates with respect to our macroeconomic factors. Specifically, we regress each interest rate against inflation and VIX index. We then obtain the principal components of the residuals of the aforementioned regressions.

Our aim is to capture the effects of such macroeconomic factors on the term structure of interest rates as directly as possible. By obtaining the informational content in the interest rates of such macroeconomic factors, we remove potential redundant information. We contend that this procedure misses little pricing information. We note that by only using the principal components from the interest rates and not including the macroeconomics factors leads, in general, to a better fit. But doing so would have made the identification of the effects of such macroeconomic variables more problematic.

On our macroeconomic risk factors, we have some additional comments. First, we did not consider an inflation-based constraint on the SDF. This would have been an addition restriction for the estimation. Instead, we opted to estimate the SDF directly and have inflation as one of the risk factors. Specifically, we use the year-to-year growth of the CPI, as mentioned. Second, we could have the macroeconomic factors as unspanned factors and the principal components as spanned ones. Such an approach would have possibly led to better models' fits. Nonetheless, doing so would have not allowed us to consider how the interest rates priced in such macroeconomic factors, which, in addition, would had been counterintuitive.

Analytically, to obtain the risk factors of the model, we first orthogonalize the interest rates with respect inflation and the VIX index. Thus, we run the following regressions:

$$y_t^{(n)} = \beta_{0,n} + \beta_{1,n}\pi_t + \beta_{2,n}\sigma_t + \epsilon_{t,n} \text{ for } n = 1, 2, 3, \dots, N,$$

where $y_t^{(n)}$ is the zero-coupon interest rate with maturity n (in months), $\beta_{i,n}$ with $i = 0$, 1 or 2, are the regression coefficients, π_t and σ_t are the inflation and VIX index, respectively, and $\epsilon_{t,n}$ are the error terms, at time t. Of course, $\mathbb{cov}[\epsilon_n, \pi\ \sigma] = 0$ for $n = 1, 2, 3, \dots, N$.

Thus, we extract the information interest rates could have on inflation and the VIX index. As a next step, the residuals ϵ_n are subject to a principal analysis decomposition. For the interest rate model, our risk factors are then the first $k - 2$ principal components and the referred index, which we stack in a vector $\boldsymbol{F_t}$. In this manner, we have explicit risk factors.

For the rest of the section, we mostly follow Adrian et al. (2013). One can use a VAR(1) to model the k risk factors, which we have denoted $\boldsymbol{F_t}$, as mentioned.

$$\boldsymbol{F_{t+1}} = \boldsymbol{\theta} + \boldsymbol{\Phi F_t} + \boldsymbol{v_{t+1}}, \quad (1)$$

where $\boldsymbol{\theta}$ is a $k \times 1$ vector, $\boldsymbol{\Phi}$ is a $k \times k$ matrix, $\boldsymbol{v_t}$ is a $k \times 1$ vector of shocks that follow a conditionally normal distribution with parameters $(\boldsymbol{0}, \boldsymbol{\Sigma})$, where $\boldsymbol{0}$ is a $k \times 1$ vector and $\boldsymbol{\Sigma}$ a $k \times k$ variance-covariance matrix, and t is the period.

A natural issue is the determinations of the number of factors. To do so, we solely consider the fit of the model in terms of the interest rates' errors. In this context, a challenge is incorporating explicit macroeconomic variables as risk factors. These typically have errors greater than those models that only uses unobservable or financial risk factors. In general, to obtain reasonable models' fits we needed to augment the number of unobservable risk factors, compared to the case in which we did not incorporate macroeconomic variables.

If there is no arbitrage, there exists a stochastic discount factor M_{t+1}, which prices all financial assets (Duffie, 2001). Consequently, for the case of the government nominal bonds, we have that:

$$P_t^{(n)} = \mathbb{E}_t\left[\boldsymbol{M_{t+1}P_{t+1}^{(n-1)}}\right] \tag{2}$$

where $P_t^{(n)}$ is the price of a zero-coupon bond with maturity n in period t. Equation (2) links the price of the bond with maturity n in period t and $t+1$. Adrian et al. (2013), following Duffee (2002), assume that the SDF has the following functional form:

$$M_{t+1} = \exp\left(-y_t^{(1)} - \frac{\lambda_t'\lambda_t}{2} - \boldsymbol{\lambda_t'\Sigma_t^{-1/2}\nu_{t+1}}\right), \tag{3}$$

in which $y_t^{(1)}$ is the risk-free interest rate and $\boldsymbol{\lambda_t}$ is the market price of risk. The latter is linear with respect to the risk factors.

$$\boldsymbol{\Sigma^{1/2}\lambda_t} = (\boldsymbol{\lambda_0} + \boldsymbol{\lambda_1 F_t})$$

We then denote the log of the excess return for holding a bond with maturity n as $rx_{t+1}^{(n-1)}$ (aka, holding period return).

$$rx_{t+1}^{(n-1)} \equiv \ln P_{t+1}^{(n-1)} - \ln P_t^{(n)} - y_t^{(1)}.$$

One can then rewrite the pricing equation in terms of the excess return:

$$1 = \mathbb{E}_t\left[\exp\left(rx_{t+1}^{(n-1)} - \frac{\boldsymbol{\lambda_t'\lambda_t}}{2} - \boldsymbol{\lambda_t'\Sigma^{-1}\nu_{t+1}}\right)\right]$$

Making some assumptions on the distribution of the return pricing errors, and the shocks (see Adrian et al., 2015, for details), one obtains a linear system to finally estimate $\boldsymbol{\lambda}$, the approach we use.

In affine interest rate models, one can write the logarithm of a bond price as an affine function of the risk factors, as follows.

$$\ln P_t^{(n)} = A_n + \boldsymbol{B_n'F_t} = -n \cdot y_t^{(n)}. \tag{4}$$

The coefficients A_n (a scalar) and $\boldsymbol{B_n}$ (a $k \times 1$ vector) have the following cross-sectional restrictions, a consequence of equations (2) and (4):

$$A_n = A_{n-1} + \boldsymbol{B}'_{\boldsymbol{n-1}}(\boldsymbol{\theta} - \boldsymbol{\lambda_0}) + \frac{1}{2}(\boldsymbol{B}'_{\boldsymbol{n-1}}\boldsymbol{\Sigma}\boldsymbol{B}_{\boldsymbol{n-1}} + \sigma^2) - \delta_0;$$

$$A_0 = 0;$$

$$\boldsymbol{B}'_{\boldsymbol{n}} = \boldsymbol{B}'_{\boldsymbol{n-1}}(\boldsymbol{\Phi} - \boldsymbol{\lambda_1}) - \boldsymbol{\delta_1};$$

$$\boldsymbol{B_0} = \boldsymbol{0}; \text{ for } n = 1, \dots, N.$$

One can estimate $y_t^{(1)} = \delta_0 + \boldsymbol{\delta}'_{\boldsymbol{1}}\boldsymbol{F_t}$ with OLS. We interpret this linear relationship as a monetary rule, in a positive sense.

If $\boldsymbol{\lambda_0}$ and $\boldsymbol{\lambda_1}$ are set equal to zero, then there are no risks compensations. One can then obtain the associated interest rates and bond prices under the assumption of risk-neutral agents *implied* by the model,

$$\ln P_t^{(n),*} = A_n^* + (\boldsymbol{B}_{\boldsymbol{n}}^*)'\boldsymbol{F_t},$$

where we have used an asterisk to differentiate them from the usual interest rates. Similarly, A_n^* is a scalar and $\boldsymbol{B}_{\boldsymbol{n}}^*$ is $k \times 1$ vector, for each maturity n. One can derive such coefficients from the following recursive relations:

$$A_n^* = A_{n-1}^* + (\boldsymbol{B}_{\boldsymbol{n-1}}^*)'\boldsymbol{\theta} + \frac{1}{2}((\boldsymbol{B}_{\boldsymbol{n-1}}^*)'\boldsymbol{\Sigma}(\boldsymbol{B}_{\boldsymbol{n}}^* + \sigma^2) - \delta_0;$$

$$A_0^* = 0.$$

$$(\boldsymbol{B}_{\boldsymbol{n}}^*)' = (\boldsymbol{B}_{\boldsymbol{n-1}}^*)'\boldsymbol{\Phi} - \boldsymbol{\delta_1};$$

$$\boldsymbol{B}_{\boldsymbol{0}}^* = \boldsymbol{0}; \text{ for } n = 1, \dots, N.$$

In this model, the distribution of the short-term interest rates is independent of the values of $\boldsymbol{\lambda_0}$ and $\boldsymbol{\lambda_1}$. We then note that:

$$y_t^{(n,*)} = \mathbb{E}_t\left[y_t^{(1)} + y_{t+1}^{(1)} + \cdots y_{t+n-1}^{(1)}\right]n^{-1}$$

$$y_t^{(n)} = \mathbb{E}_t\left[y_t^{(1)} + y_{t+1}^{(1)} + \cdots y_{t+n-1}^{(1)}\right]n^{-1} + TP_t^{(n)} = y_t^{(n,*)} + TP_t^{(n)}$$

As a result, we have that

$$y_t^{(n)} = y_t^{(n,*)} + TP_t^{(n)}.$$

where $TP_t^{(n)}$ is the term premium.

The conventional interpretation for the term premium is that of a compensation for an investor who instead of rolling over short-term nominal bonds, she buys a long-term bond. There is, however, a broader interpretation for which the first component is the long-term nominal rate under the assumption of risk-neutral agents. Thus, the second component is the risk-compensations for all risks, including inflation and liquidity risks. Such an interpretation is quite useful in several contexts.

Estimation Results

We present the interest rates' mean absolute errors (Table 5). We selected the number of factors based on the models' fit, as mentioned. Such errors are sensible, particularly so, considering we have used macroeconomic variables as risk factors. Having said that, we have three comments. First, some models are not very successful in capturing the short-end of the term structure. Second, in the estimation of term premiums, their levels are difficult to identify. However, our interest focuses in their dynamics. Third, Mexico's model has a relatively large mean absolute error in its long-end. This does not seem to be an issue that pervades to all other maturities. But we will keep these issues in mind when interpreting our results.

	Mean Absolute Errors (basis points)					
	Horizon					
	1y	*2y*	*4y*	*6y*	*8y*	*10y*
Chile	2.1	0.5	0.8	0.7	1.3	1.1
Czech Republic	10.3	2.4	5.3	0.6	2.1	2.1
India	1.6	0.5	0.7	0.8	1.2	3.2
Indonesia	2.7	2.2	1.8	2.7	1.3	3.0
Mexico	1.6	1.5	3.6	9.7	8.5	17.9
Poland	0.9	2.3	1.6	2.1	1.7	2.2
Russia	4.8	1.2	4.9	3.0	4.1	2.7
South Korea	3.5	0.9	2.1	1.6	0.8	3.5

Table 5. Interest Rates' Mean Absolute Error

Notes: Each datum is the mean absolute error, $T^{-1}\sum\left|y_{t,data}^{(n)} - y_{t,model}^{(n)}\right|$, for each economy (row) and maturity (column), units are basis points.

We next consider the coefficients associated with the short-term interest rate as a function of the risk factors, denoted as $\boldsymbol{\delta}$ (Table 6).

	Chile	**Czech Republic**	**India**	**Indonesia**	**Mexico**	**Poland**	**Russia**	**South Korea**
δ_0	2.16	-0.13	6.38	2.90	2.27	2.27	5.26	1.70
PC1	0.07	0.05	0.15	0.05	0.11	0.08	0.11	0.06
PC2	0.22	0.14	0.32	0.11	0.18	0.23	0.26	0.17
PC3	0.26	0.11	0.34	0.33	0.23	0.29	-0.13	0.18
PC4	0.14	-0.08	0.81	0.72	0.35	0.12	0.88	0.34
PC5	0.86	0.52	-0.17	0.53	0.50	0.79	-0.18	0.51
PC6	-0.22	0.77	-0.07	-0.11	.	-0.35	-0.12	0.63
PC7	0.06	-0.09	0.07	.	.	-0.02	0.04	-0.20
π	0.57	0.47	0.19	0.34	0.92	0.65	0.39	0.68
VIX	-0.02	0.03	-0.02	0.02	-0.03	-0.001	-0.01	-0.02

Table 6. Estimates for $\boldsymbol{\delta}$: $\boldsymbol{y_t^{(1)}} = \delta_0 + \boldsymbol{\delta}_1'\boldsymbol{X_t}$.

Notes: All coefficients are statistically significant at the 99% confidence level.

We note that the principal components we have used could not necessarily have the common interpretation, of 'level', 'slope' and 'curvature', for two reasons. Such an interpretation might not necessarily apply to all economies. In addition, we have obtained such components only after making the interest rates orthogonal to the macroeconomic variables, as we previously explained.

On their estimates (Table 6), we have the following remarks. The coefficients are statistically significant at the 99% confidence level. The coefficients associated with inflation are positive in all cases. In effect, a monetary authority typically tightens (loosens) its stance when inflation increases (decreases).

On their part, the coefficients associated with the VIX index are, in most cases, negative. The Czech Republic and Indonesia, being exceptions, have positive coefficients. We have no priors on their signs. Whether the VIX affects monetary policy depends on several aspects. For example, given a positive shock on inflation and a negative conditional covariance between inflation and the VIX, one would observe, on average, a decrease in the VIX. Thus, if the coefficient associated to the VIX is negative, then one would expect to see a rise in the short-term interest rate, consistent with a rise in inflation.

The conditional covariances for inflation and the VIX are presented in Table 7. The estimates for Mexico, Poland, and Russia are in line with the example just described. On their part, Chile, Indonesia and South Korea, have relatively small conditional covariances. Thus, they do not seem to be facing a distortion in this respect. In the case of India, it has a positive conditional covariance and the coefficient associated with the VIX is negative.[10] In the Czech case, it has a negative conditional covariance and the coefficient associated with the VIX is positive. Thus, these two economies could be facing a distortion in this respect. Having said that, the intertemporal interactions of the aforementioned variables could involve richer dynamics.

[10] Specifically, the coefficients are negative for all expect the Czech Republic. The conditional covariances are positive for Chile, Korea, Indonesia and India, but, small for the first three. Such covariances are negative for the Czech Republic, Mexico, Poland, and Russia.

On a related matter, the unconditional correlations of inflation and the VIX index seem important. There is some heterogeneity across economies, their sample correlations range from 0.23, for Mexico, to 0.47, for South Korea.

Finally, we report the estimated coefficients of the market prices of risk (i.e. $\boldsymbol{\lambda}$ in equation (3)), in the appendix. For all economies and all risk factors, there exists at least one coefficient in $\boldsymbol{\lambda}$ that is statistically significant at the 90% confidence level. This underscores the statistical relevance of each risk factor towards the bonds' pricing dynamics.

	Conditional Covariance VIX, Inflation	Unconditional Correlation VIX, Inflation
Chile	0.02	0.31
Czech Republic	-0.04	0.24
India	0.16	0.48
Indonesia	0.01	0.42
Mexico	-0.03	0.23
Poland	-0.07	0.40
Russia	-0.05	0.42
South Korea	0.01	0.47

Table 7. Conditional Covariance and Unconditional Correlation Between the VIX index and inflation.
Source: Own estimation with data from Haver Analytics and Yahoo Finance.

In what follows, first, we explore the coefficients of the affine interest rate models associated with inflation and the VIX. Afterwards, we focus on the 10-year nominal interest rates given its relevance as an economic indicator and financial benchmark.[11] Second, we study the relationship between the monetary rules' characteristics and those of the term structure of interest rates.[12] Such a relationship might entail bi-directional causal effects, as monetary authorities react to market participants and vice versa. Third, we examine the coefficients associated with the expected short-term interest rates and the term premium, which allows us to weigh the market responses as a function of the expected path of monetary policy and the risk compensation to holders of nominal bonds. Finally, we analyze the impulse-response functions of long-term interest rates to *joint* shocks, i.e., on inflation and the VIX index.

[11] Naturally, similar analyses could be done for other maturities, which might point to other aspects of the interactions between the interest rates and the macroeconomic variables.
[12] Such a relationship could be due to the underlying structure of the economy.

Affine Interest Rate Models' Coefficients

We next examine the coefficients of the affine interest rates models associated with inflation and the VIX index (Figure 2). We have that, given a rise in inflation, short-term interest rates increase in all economies. Analyzing the coefficients associated to the interest rates, there are two main types of coefficients though. There are those that are close to being 'parallel' along the maturities: India, Indonesia, Poland, Russia, and South Korea. There are others for which their short-term rates' coefficients are greater than those of the long-term ones, namely, Chile, Czech Republic, and Mexico.

Given an increase in inflation, the risk-neutral interest rates increase in all economies, albeit, the specific reactions are heterogeneous. Their associated coefficients decrease as their maturity increases. The effect of the expected change in interest rate diminishes as inflation converges to its long-term mean.[13] Given a rise in inflation, the term premiums tend to increase. In effect, as the inflation risk premium is part of the term premium, an increase in inflation should affect it. Moreover, in general, risk premiums tend to increase with the investment horizon. The exception to this is Chile. Its associated coefficients form an inverted U-shape.

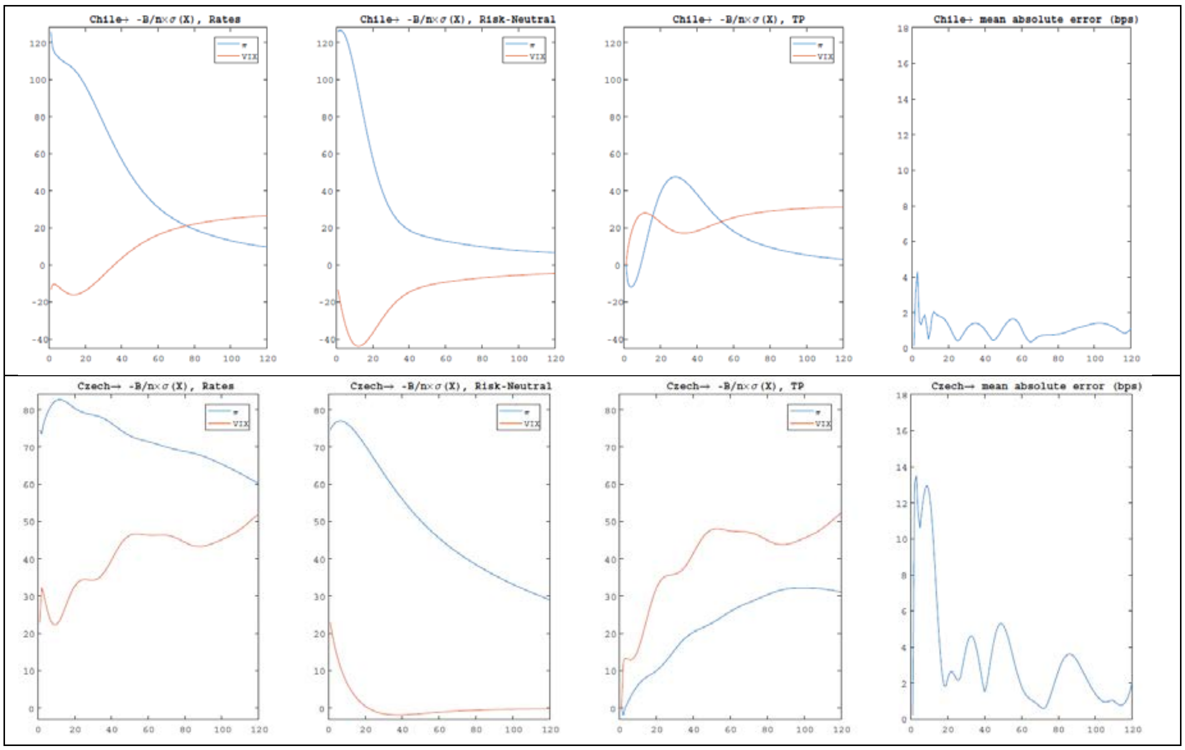
On its part, given an increase in the VIX index, a pattern in the model coefficients is not as direct. Having said that, the Czech Republic, Indonesia, and Poland's interest rates increase. In the Czech case, such an increment is greater for the long-end of the term structure. Moreover, India, Mexico, and Russia's coefficients decrease, although those of Mexico and Russia are close to zero. Chile and South Korea's dynamics are somewhat more involved, as their short-end coefficients decrease and their long-end ones increase.

Given a rise in the VIX index, there seem to be two kinds of coefficients associated with the risk-neutral interest rates. On the one hand, the Czech Republic and Indonesia's increase in the short-end. On the other hand, the rest of the economies' are relatively close to zero. In theory, given variations in risk, there should be no changes in the risk-neutral interest rates. Empirically, the VIX does necessarily match to *the* risk

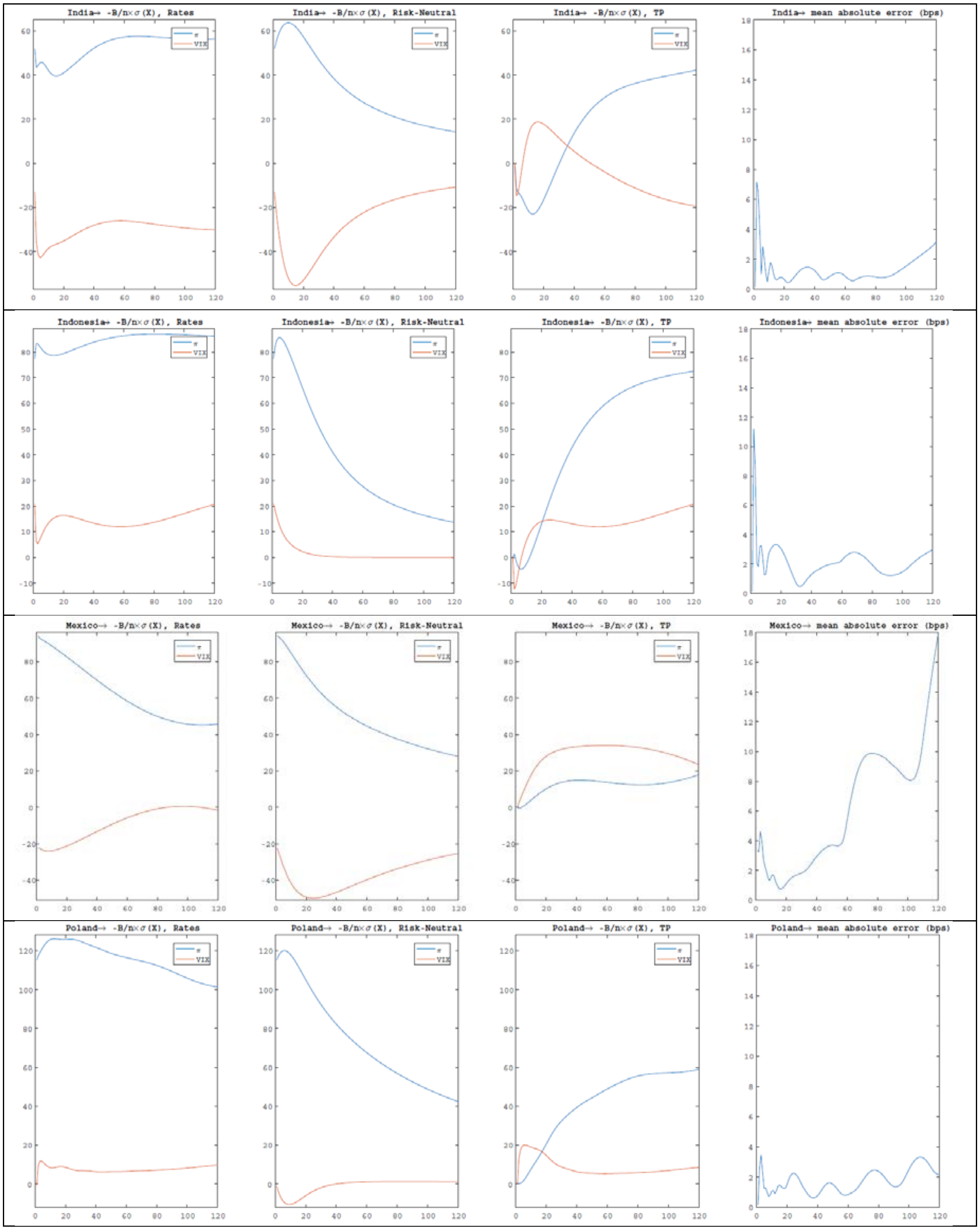
[13] Recall that the risk-neutral interest rate equals the expected average of short-term interest rates.

of each economy. Given a rise in the VIX index, all term premiums tend to increase, in general. Their exact shifts somewhat differ. Chile, the Czech Republic, Indonesia, Poland, Mexico and Russia's shifts are 'quasi-parallel.' Korea's increases but its shift is an inverted u-shape. India's, in contrast, increases in the short-end but decreases in the long-end.

There is a caveat to some of these results, specifically, with respect to the short-end of Russia and South Korea, and the long-end of Mexico. The measurement errors are notable relative to some of their effects. Having said that, in all cases, note that relatively close maturities tend to reduce their mean absolute errors.[14]



[14] One could consider a higher number of unobservable factors to account for this caveat. For instance, using nine principal components of the interest rates significantly improves the model's fit in the case of Mexico. Nonetheless, we prefer not running the risk of overfitting such a model.


India→ -B/n×σ(X), Rates
India→ -B/n×σ(X), Risk-Neutral
India→ -B/n×σ(X), TP
India→ mean absolute error (bps)
Indonesia→ -B/n×σ(X), Rates
Indonesia→ -B/n×σ(X), Risk-Neutral
Indonesia→ -B/n×σ(X), TP
Indonesia→ mean absolute error (bps)
Mexico→ -B/n×σ(X), Rates
Mexico→ -B/n×σ(X), Risk-Neutral
Mexico→ -B/n×σ(X), TP
Mexico→ mean absolute error (bps)
Poland→ -B/n×σ(X), Rates
Poland→ -B/n×σ(X), Risk-Neutral
Poland→ -B/n×σ(X), TP
Poland→ mean absolute error (bps)
π
VIX

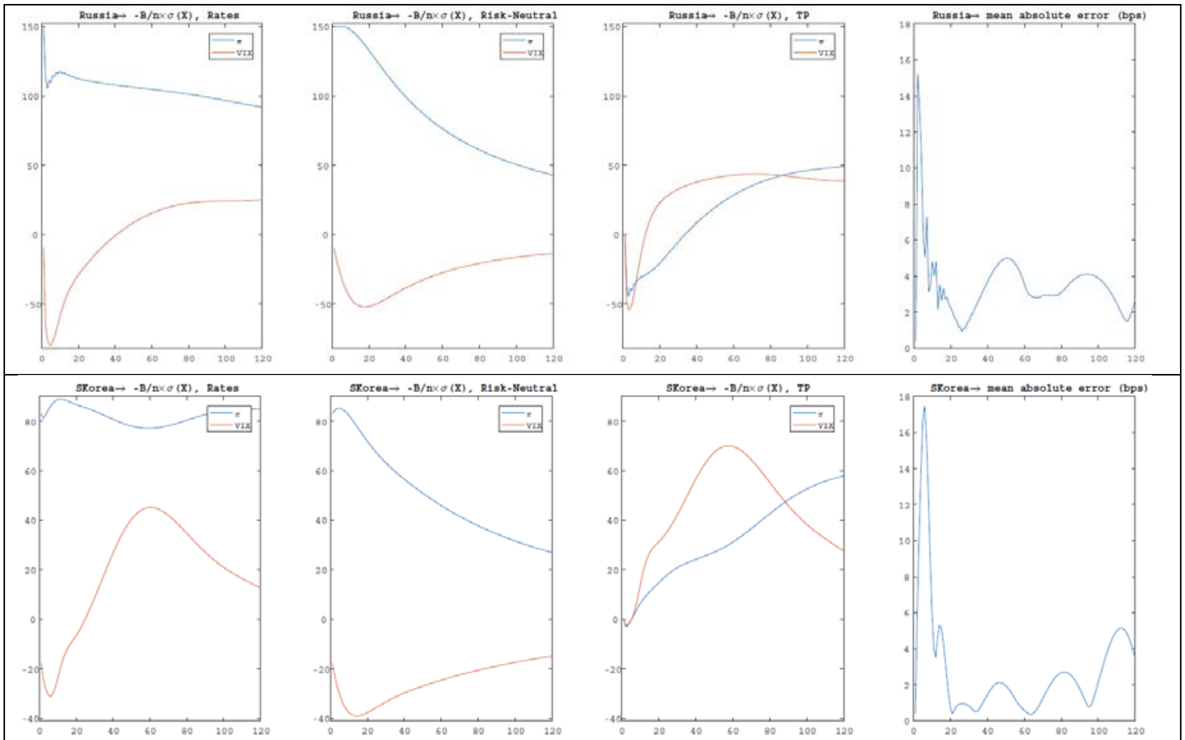


Figure 2. Affine Model Coefficients.
Notes: We present the coefficients associated with Inflation and the VIX index for the interest rates and their two components, the risk-neutral and the term premium. The horizontal axis are the bonds maturities, which are in months.

In sum, first, a rise in inflation affects the risk-neutral interest rates positively and the effect diminishes as the maturity increases. Changes in inflation affect the expected short-term interest rates as monetary authorities react to them or are expected to do so. In effect, the expected average of short-term interest rates is equal to the risk-neutral interest rate. Second, a change in the VIX affects the risk-neutral interest rates quantitatively much less than inflation does. In theory, risk-neutral investors are not compensated for risks, including those associated with the VIX. Third, a rise in inflation or in the VIX increases the term premium. This holds true in general except for the short-end in some economies. This is intuitive, the term premium compensates for risks in general. Finally, a rise in inflation tends to affect interest rates positively across all maturities. The effect on the interest rates of a change in the VIX is less direct.

Monetary Rules and Affine Interest Rates Models' Coefficients

We next compare some of the features of the monetary rules with those of the interest rate term structure. Our presumption is that these monetary rules are, in a positive sense, reasonable models. We conjecture that they might have a bearing on the respective term structures. Thus, in Table 8 we compare the coefficients of the short-term rates associated with inflation and volatility index ($\boldsymbol{\delta}$), with those from the affine model associated with those same variables related to the 10-year horizon ($\boldsymbol{B}(\boldsymbol{n})$).

	Affine Model Maturity	π	VIX	PC's
Chile	1-month (Monetary Rule)	0.57	-0.02	...
	10-year	0.04	0.03	...
Czech Republic	1-month (Monetary Rule)	0.47	0.03	...
	10-year	0.38	0.06	...
India	1-month (Monetary Rule)	0.19	-0.02	...
	10-year	0.21	-0.04	...
Indonesia	1-month (Monetary Rule)	0.34	0.02	...
	10-year	0.21	-0.04	...
Mexico	1-month (Monetary Rule)	0.92	-0.03	...
	10-year	0.45	-0.002	...
Poland	1-month (Monetary Rule)	0.65	-0.001	...
	10-year	0.57	0.01	...
Russia	1-month (Monetary Rule)	0.39	-0.01	...
	10-year	0.24	0.03	...
South Korea	1-month (Monetary Rule)	0.68	-0.02	...
	10-year	0.70	0.02	...

Table 8. Monetary Rule vs. Affine Model Coefficients
Note: We have not included the coefficients associated with the principal components.
Source: Own estimations.

In general, we find a positive relation between the coefficients associated with the monetary rules and those with the long-term interest rates. For instance, for inflation, the smallest two coefficients for 1-month horizon belong to India and Indonesia, while the smallest two coefficients for 10-year horizon belong, precisely, to those same economies. As for the VIX index, the greatest two coefficients for 1-month horizon are from South Korea and Mexico, while the greatest two coefficients for 10-year horizon are from South Korea and, yet Poland. In effect, monetary authorities could be reacting more strongly to inflation shocks knowing that long-term interest rates are more sensitive to such shocks. In tandem, such sensitivity might also be the product of the authorities' policy reaction functions.

It is worth mentioning that the relation between the monetary rules and the affine model coefficients does not have to be direct. As one can deduct from the affine interest rate model, the monetary rule coefficients are determined by the coefficients in $\boldsymbol{\delta}$, and the affine coefficients (i.e., $A(n)$ and $\boldsymbol{B}(\boldsymbol{n})$) are a function of $\boldsymbol{\delta}$ but also of other parameters such as $\boldsymbol{\lambda}$.

The aforementioned results are suggestive. Yet, it is worth emphasizing that we have a small cross-sectional sample. In addition, these are statistic comparisons. Consequently, we will next explore some results based on IRFs, which account for their dynamics.

Impulse Response Functions

We consider three identification schemes for the impulse response functions (IRFs). For the first one, we assume uncorrelated shocks as a benchmark exercise. In this case, we only consider shocks on inflation and, *separately*, on the VIX. For the second and third schemes, we use short-run restrictions' identification. We assume that shocks, on any variable, do not affect inflation contemporaneously. This could be rationalized by the presence of nominal frictions in prices. Similarly, for the principal component factors, we assume that shocks on one component contemporaneously affect the next component, and so on.

The key difference between the second and third schemes is the relative order of the VIX index and the principal components. In the second scheme, we assume that the VIX responds to shocks to any risk factor, akin to the identification scheme used in Rey (2015). In the third scheme, we assume that the principal components can respond to shocks on the VIX index but not the other way around. In due course, we discuss the relative merits of these identification strategies.

On our identification assumptions, we have some additional remarks. On our second scheme, we are assuming that the principal components can, contemporaneously, affect the VIX but that the VIX cannot affect the principal components. With this last restriction, we are bending over backwards the possibility of finding an effect of a shock on the VIX. If such an effect is found, this provides added support to the financial global cycle relevance.

On the third scheme, we are assuming that the VIX can, contemporaneously, affect the principal components but that the principal components cannot affect the VIX. In terms of the small open economy feature of every country in our database, this last assumption seems intuitive. Nonetheless, one could argue that the second scheme is preferable in that it is the less favorable to the main hypothesis.

We stop short of using sign restrictions, long-run restrictions, and structural VARs for the following reasons. Arguably, there are no solid priors on the signs of the risk factors we use, except possibly for inflation and the VIX index. Moreover, we think that there are no natural long-run restrictions between the variables we use. For its part, to estimate a structural VAR, we would need a model with implications on the shocks' dynamics. To the best of our knowledge, there is no formal model on the global financial cycle that could provide us with some specific identification restrictions.

We first consider the IRFs to shocks on inflation and, separately, on the VIX index (Figure A4.1, in the appendix). Both exercises assume uncorrelated shocks, the simplest identification assumption possible, which we use as a point of reference. On these IRFs, we have the following comments.[15] The Chile's long-term interest rate and term premium responses to shocks on the VIX are statistically significant and last for about 4 months. They share similar dynamics, which implies a small response by the risk-neutral interest rates. On the other hand, the response to VIX's shocks tend to be small and short-lived.

The Czech long-term interest rate and term premium's responses to shocks on the VIX index are statistically significant. On their part, the responses to shocks on inflation are also statistically significant and quite persistent, lasting for about 12 months.

As for India, its long-term interest rate and term premium's responses to shocks on the VIX index are quite different from those of the other economies, because they are negative. Their responses from shocks on inflation can be considered expected, as they are positive.

In the case of Indonesia, its long-term interest rate and term premium's responses to a shock on the VIX are positive and statistically significant, yet short-lived. In the case of the responses to a shock on inflation, they are positive, statistically significant, and persistent, lasting for about 8 months.

---

[15] It is important to use a benchmark to provide some context in terms of the economic significance of the changes in the long-term interest rates. The standard deviations of movements of the long-term interest rates of each country are as follows (in basis points): Chile – 28, Czech Republic – 25, India – 34, Indonesia – 34, Mexico – 34, Poland – 27, Russia – 72, and South Korea – 24; using their respective samples.

The Mexican long-term interest rate's response to a shock on the VIX is not statistically significant. Nonetheless, the term premium's response to the same shock is positive and statistically significant. As for their responses to an inflationary shock, they are positive and statistically significant as well, but that of the long-term interest rate is quantitatively more important.

The Polish long-term interest rate and term premium's responses to shocks on the VIX and inflation, respectively, are positive, statistically significant, but quantitatively small. Their responses to shocks on inflation have positive and statistically significant, and the response of the long-term interest rate is, on impact, almost twice the magnitude of that of the term premium.

The Russian long-term interest rate and term premium's responses to shocks on the VIX are positive and statistically significant. Although relatively short-lived, they seem quantitatively important. As for the responses to shocks on inflation, they are positive and statistically significant. Although they lose statistically significance rapidly, they seem persistent.

Finally, for South Korea, its long-term interest rate and term premium's responses to shocks on the VIX are positive, statistically significant, albeit short-lived. That of the term premium seems quantitatively more important. As for their responses to shocks on inflation, they are positive, statistically significant, and quite persistent. As in other economies, the interest rate's response is greater than that of the term premium.

Altogether, we see the following general patterns. First, long-term interest rates and term premium's responses to the VIX's shocks are, in general, positive, and those of the term premium tend to be greater. This is intuitive, as risk appetite decreases (i.e., the VIX increases), investors reduce their demand for risky assets, including long-term EMEs nominal bonds. Thus, as their prices drop, their associated interest rates rise.[16]

Second, long-term interest rates and term premium's responses to inflationary shocks are, in general, positive, and those of the long-term interests rate greater than those of their term premiums. In effect, inflation shock should affect the risk-neutral

[16] A related interpretation is that the demand for risky assets drops as their volatility increases, in line with Merton's (1969) portfolio model. This assumes that the VIX index links with the volatility of each bond.

interest rate via the short-term interest rates, and the term premium via the inflation risk premium.

Third, on their risk-neutral interest rates, several of their responses tend to be small in magnitude. As we have argued, this is intuitive in the case of the VIX, as risk-neutral agents are not compensated for risks. As explained, the long-term interest rate equals the risk-neutral interest rate plus the term premium.

Complementarily, some relatively recent events could have a bearing on the global financial markets. Albeit in principle idiosyncratic events, they could have led to some contagion. In the appendix, we present a summary of event study exercises considering key recent events surrounding Argentina and Turkey. Anticipating these results, we find statistically significant effects related to the referred events.

Joint Shocks on Inflation and the VIX

A natural exercise is to compare the responses of the long-term interest rates to shocks on inflation, versus the responses to *joint* shocks on inflation and the VIX. Our aim is to explore the role of the VIX in the implementation of the EME's monetary policy. More generally, our aim is to explore whether the presence of shocks on the VIX has implications for the dynamics derived from shocks on inflation. From this point on, we focus on the second and third identifications.

On the results based on the second identification, we have the following remarks. The Chilean long-term interest rate response to a joint shock on inflation and VIX is positive and statistically significant. This seems to be due to the role of the VIX, as the individual responses to an inflation shock are not statistically significant.

Similarly, the Czech long-term interest rate response to a joint shock is positive and statistically significant. The presence of the VIX appears to be key to obtain such a response. In effect, the interest rate's response to an inflationary shock is not statistically different from zero.

India's long-term interest rate response to a joint shock is negative but short-lived. Interestingly enough, it seems that the presence of the VIX partially staves off the inflationary shock. Its response to the VIX is negative, in contrast to the typical response from other economies.

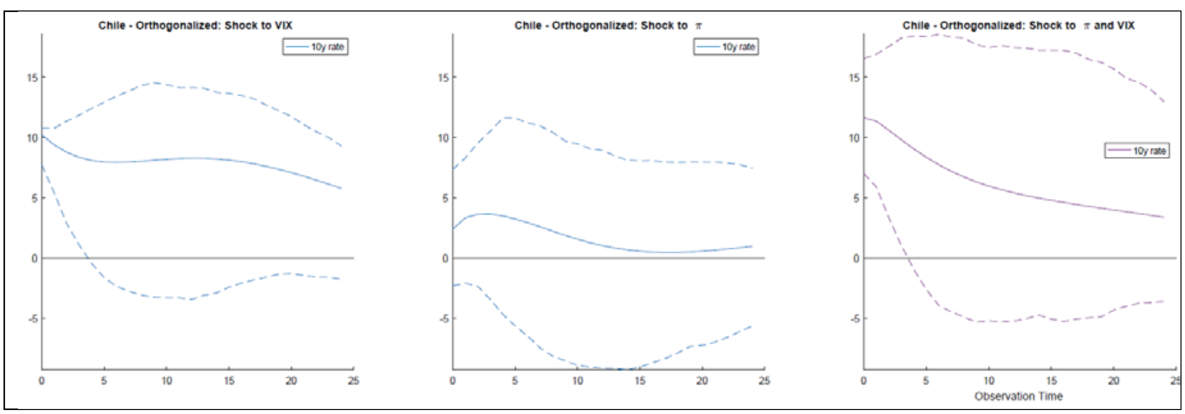
As for Indonesia, its long-term interest rate response to a joint shock is positive and statistically significant. Comparing it to its response to an inflationary shock, they are not statistically different from each other. Nonetheless, the former appears to be less persistent.

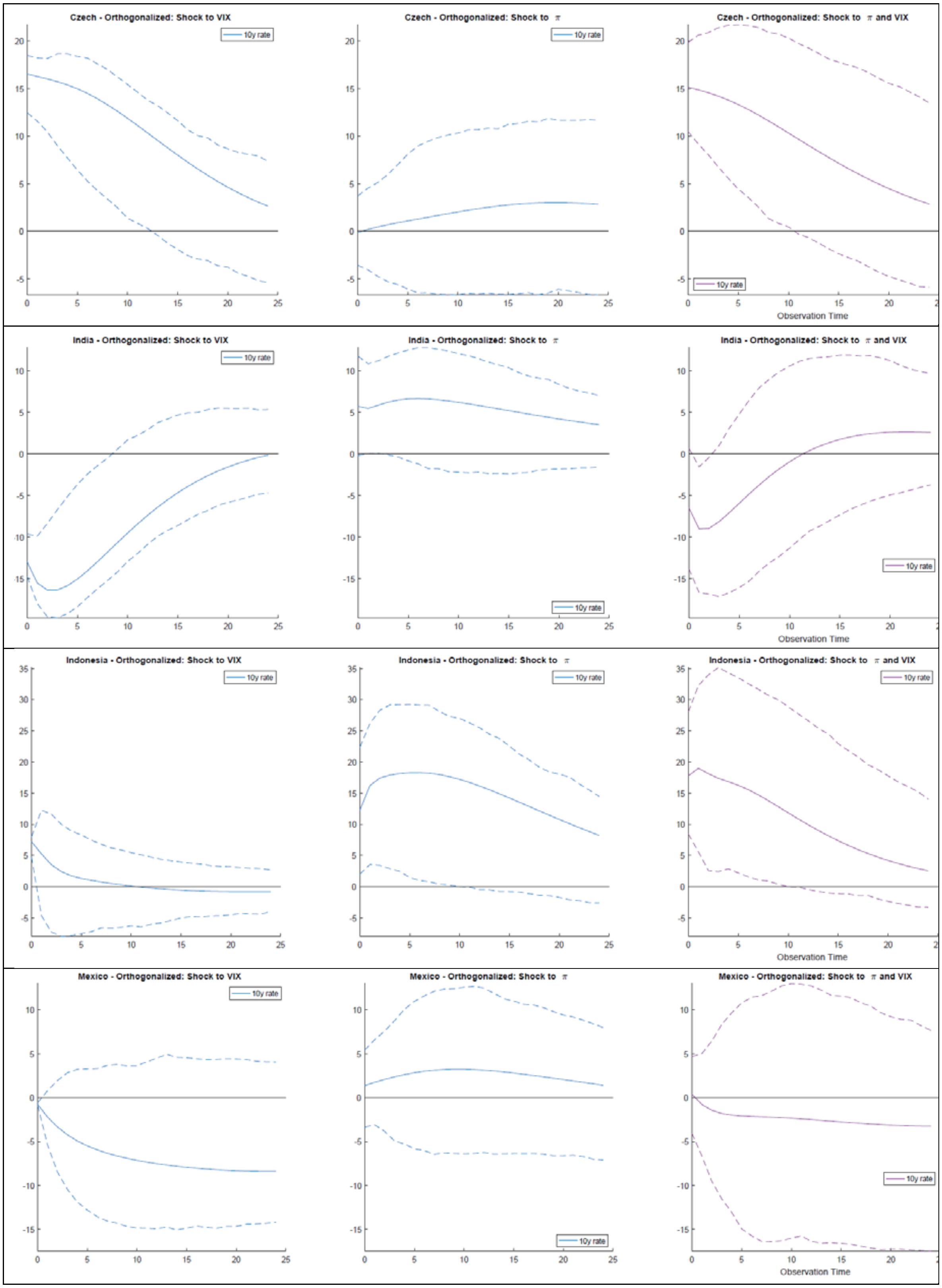
The Mexican long-term interest rate response to a joint shock is not statistically significant. This contrasts with most of those from the economies in our data set.

The Polish long-term interest rate response to a joint shock is positive and statistically significant. In line with this, its response to a shock on the VIX is positive and statistically significant, albeit its response to an inflationary shock is (marginally) significant.

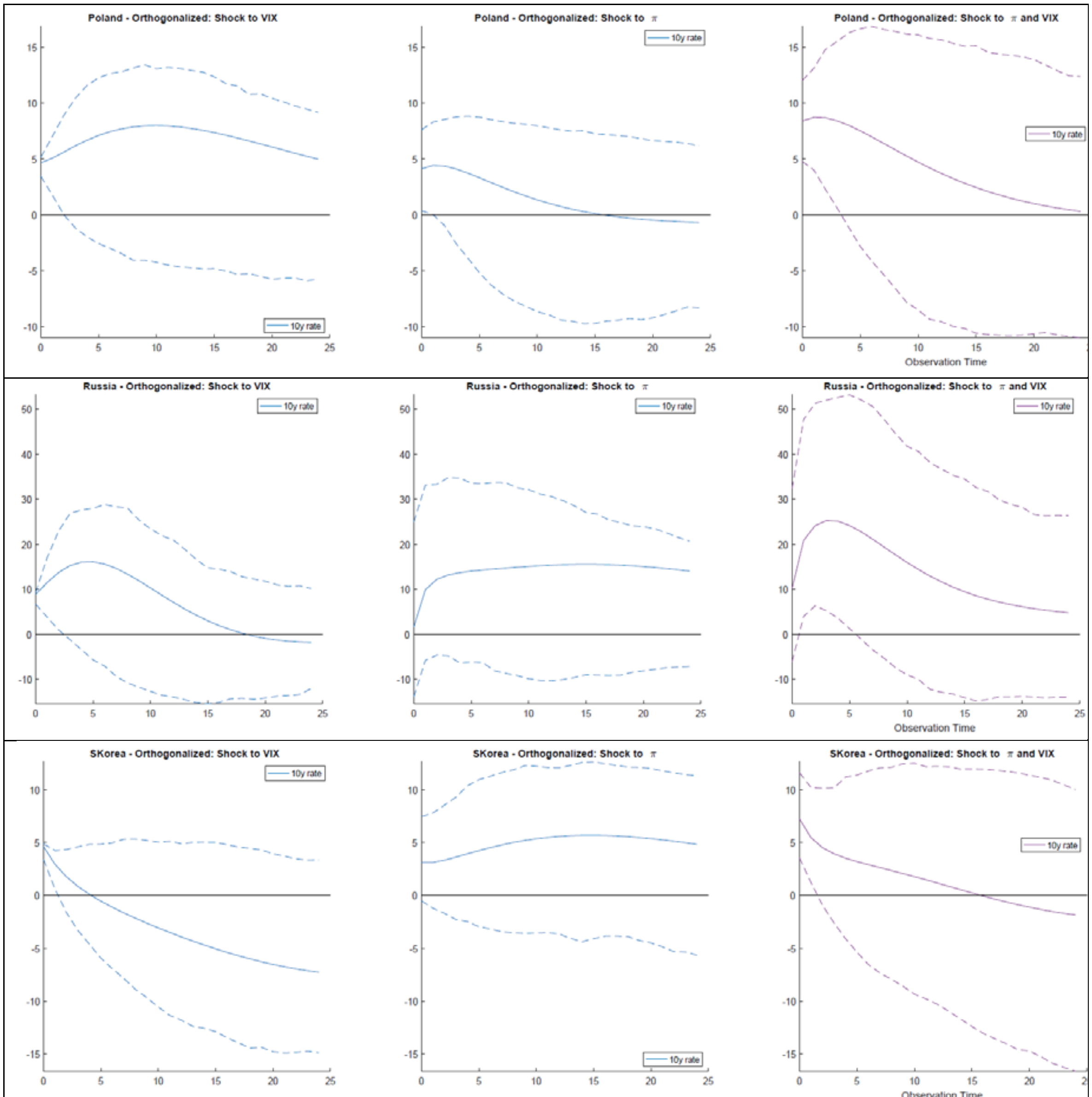
In the Russian case, the response of its long-term interest rate to a joint shock is positive and statistically significant. Its response to a shock on VIX shares similar features. In contrast, its response to an inflationary shock is not statistically different from zero.

Finally, the Korean long-term interest rate response to a joint shock is positive and statistically significant, but short-lived. Although its response to a shock on inflation is not statistically significant, the presence of the VIX seems to augment inflationary shocks.





Czech - Orthogonalized: Shock to VIX
10y rate
Czech - Orthogonalized: Shock to π
10y rate
Czech - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
India - Orthogonalized: Shock to VIX
10y rate
India - Orthogonalized: Shock to π
10y rate
India - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
Indonesia - Orthogonalized: Shock to VIX
10y rate
Indonesia - Orthogonalized: Shock to π
10y rate
Indonesia - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
Mexico - Orthogonalized: Shock to VIX
10y rate
Mexico - Orthogonalized: Shock to π
10y rate
Mexico - Orthogonalized: Shock to π and VIX
10y rate
Observation Time



Figures 3. Impulse Response Functions.
Notes: Impulse Response Functions to a shock of one standard deviation on the respective variable. The vertical axis is presented in basis points. Order is VIX (fastest), Principal Components and Inflation (slowest).

On our results based on the third identification, we have the following remarks. For Chile, the long-term interest rates respond little to VIX or inflation shocks. Thus, under a joint shock, the long-term interest response is not statistically different from zero.

Similarly, the Czech long-term interest rate response to a joint shock is not statistically significant.

India seems to be the exception to several of our results. Its interest rate response to joint shocks on the VIX and inflation is not statistically significant. This happens although its response to an individual inflationary shock is positive and marginally significant. As in the previous exercise, the shock on the VIX seems in, some way, to stave off the inflationary one.

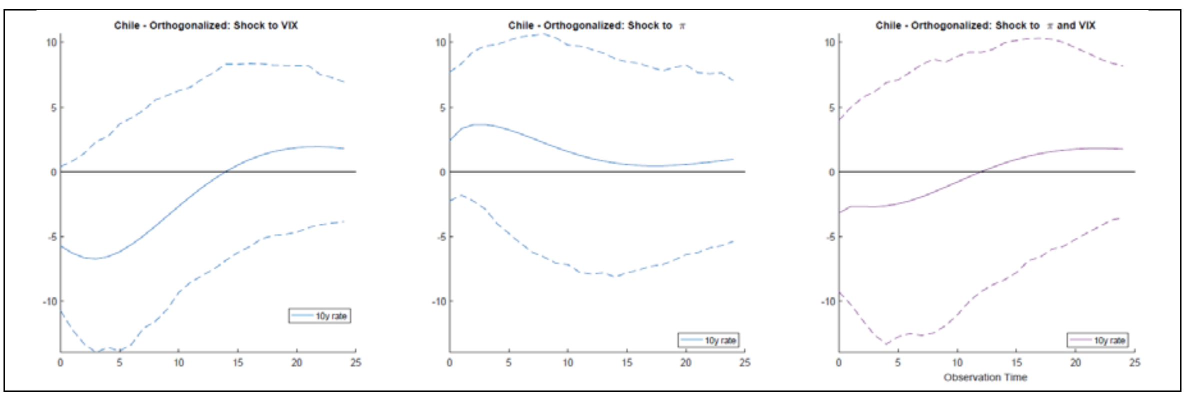
The Indonesian long-term interest rate response to a joint shock is positive and statistically significant. While this appears to be mainly due to the dynamics of inflation, the presence of the VIX shock is possibly increasing the level of its response.

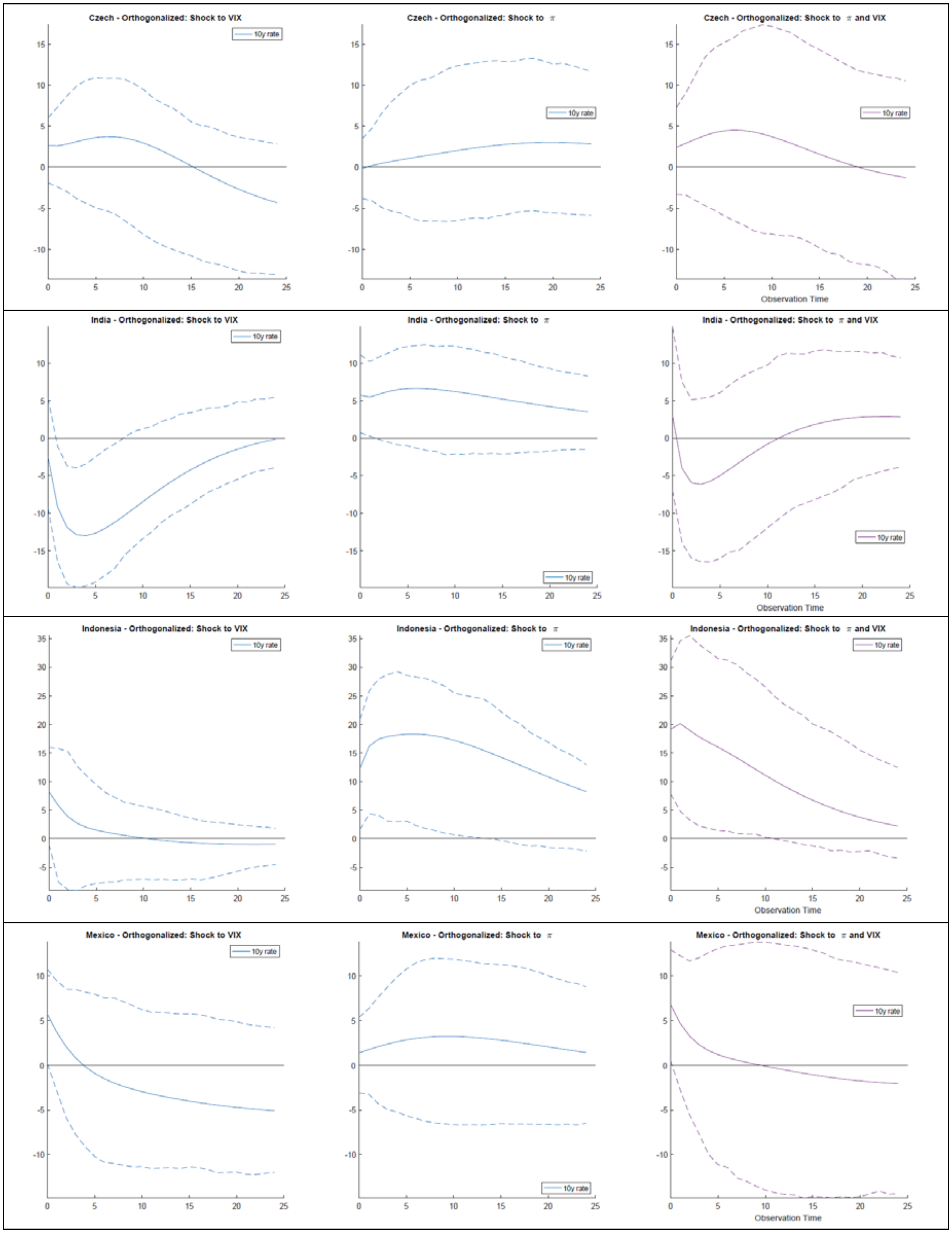
Mexico's interest rate response to joint shocks is marginally significant. Based on its response to the individual shocks, we would not have expected a significant response. Still, while marginal, it seems that the variables' interaction augments the response of the long-term interest rate.

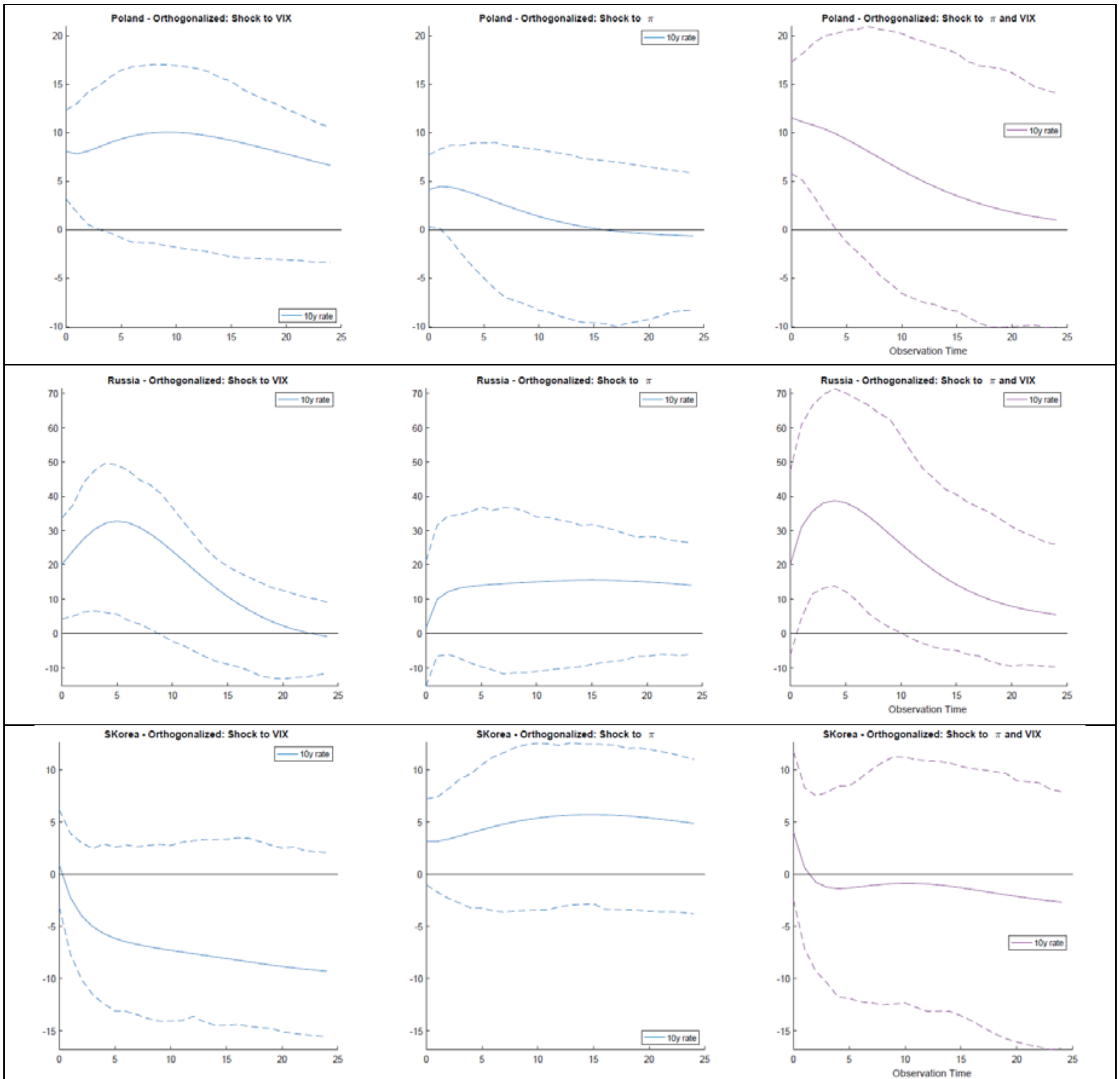
The Polish interest rate response to a joint shock is positive and statistically significant. It is the interaction of both shocks that seems to lead to such a response. Compared to its response to an inflationary shock, it is greater and more persistent.

Russia's interest rate response to a joint shock seems greater than the response to only an individual shock on the VIX. This happens although its response to an inflationary shock is not statistically significant.

For South Korea, we have the long-term interest rate response to joint shock is not statistically significant. This is explained by its individual responses.




Czech - Orthogonalized: Shock to VIX
10y rate
Czech - Orthogonalized: Shock to π
10y rate
Czech - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
India - Orthogonalized: Shock to VIX
10y rate
India - Orthogonalized: Shock to π
10y rate
India - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
Indonesia - Orthogonalized: Shock to VIX
10y rate
Indonesia - Orthogonalized: Shock to π
10y rate
Indonesia - Orthogonalized: Shock to π and VIX
10y rate
Observation Time
Mexico - Orthogonalized: Shock to VIX
10y rate
Mexico - Orthogonalized: Shock to π
10y rate
Mexico - Orthogonalized: Shock to π and VIX
10y rate
Observation Time



Figures 4. Impulse Response Functions.
Notes: Impulse Response Functions to a shock of one standard deviation on the respective variable. The vertical axis is presented in basis points. Variables' order: Principal Components (fastest), VIX, inflation (slowest).

In terms of their exchange rate regimes, central bank independence and financial openness, Chile, Mexico, Poland, and Russia can be grouped together. Nonetheless, under the second identification scheme, the responses of their long-term interests to a joint shock have some differences. Those of Chile, Poland, and Russia are similar, although Russia's is notably greater.[17] We note that those of Mexico are not statistically significant, albeit we suspect that this could partly be due to its model's fit.

Indonesia's economy shares several features with those economies above, except that it is relatively more financially closed. In line with this, we have that the long-term interest rate's response to a shock on the VIX is not statistically significant for the third identification.[18] Still, its response under the second identification is statistically significant. In both schemes, its response to a joint shock appears to be greater than that to only an inflation shock, although not significant.

A broader comparison is the Czech Republic vis-à-vis India, as, in the former, the economy is financially opened, has an independent central bank and has a stabilized arrangement regime. On the other hand, India is financially more closed, its central bank is the least independent among those in our database, and it has a floating exchange rate regime. Accordingly, when it comes to a joint shock, the Czech interest rates response is positive and statistically significant. In stark contrast, India's interest rate response is small and not statistically significant.

In terms of macroprudential policies, Chile and Russia are a good comparison in that they are similar except for such policies. Our evidence is supportive of a statistical significant response to joint shocks in both economies. Nonetheless, that of Russia is quantitatively more important. Having said that, the Russian long-term interest rate presents a higher variability, which is indicative of other factors being at play in its determination.

Concluding Remarks

We have documented that the monetary rule's coefficients relate to those of the long-end of the affine interest rates. In effect, monetary authorities react to financial markets

[17] Mexico and Chile differ in, at least, one feature. The interest rate of the former responds (little) to shocks on the VIX (inflation). The interest rate of the latter responds (little) to shocks on inflation (the VIX). Yet, their interest rates response similarly to joint shocks. A plausible explanation is that Chile has been more active in implementing macroprudential policies (Cerutti et al., 2017b).

[18] South Korea differs from Chile, Mexico and Russia in that its central bank is not as independent. Such a characteristic does not seem to make a difference in terms of the interest rates' response to joint shocks.

and the associated markets react to the authorities' policies. We have seen how, in general, shocks on the VIX are mostly taken by the term premium component of the long-term interest rate, while shocks on inflation are mostly absorbed by the risk-neutral interest rate.

We have provided evidence that some EMEs could be facing distortions in two related ways. First, in terms of their monetary rule, shocks on the VIX could be hampering with what the rule might be indicating as a function of inflation. In effect, such a hinder might involve that an implied rule's monetary policy description is in the opposite direction or a shock on the VIX might lead to changes in monetary policy that are not necessarily warranted by the current inflation dynamics. Second, the long-term interest rate dynamics might involve some distortions in terms of how a joint shock might lead to responses that would not be statistically significant under the absence of a VIX shock. Thus, central banks might be facing additional difficulties on the stability and thus determination of their long-term interest rate under shocks to the VIX.

Moreover, we have generally considered shocks that are usual in that they have the size of a standard deviation. Our results suggest that under financial stress episodes in which shocks on the VIX might notably increase, the responses we have found would become more of a concern and those that were not relevant in our estimation might become so.

In terms of policy, a given EMEs would be in a better position to face the GFCy by reducing the term premium component of the long-term interest rate. This would involve reducing risks that are priced in by the term premium and that the authorities are in a position to modify. Some of those risks might be of a more longstanding nature, such as the development of financial markets. Thus, their modifications might entail extended implementation efforts.

References

1. **Adrian, T., R. K. Crump, and E. Moench. 2013.** "Pricing the Term Structure with Linear Regressions." Journal of Financial Economics 110(1): 110–38.
2. **Adrian, T., Fleming, M., Shachar, O., and Vogt, E. (2017).** Market liquidity after the financial crisis. *Annual Review of Financial Economics*, 9, 43-83.

3. **Avdjiev, S., Gambacorta, L., Goldberg, L., and Schiaffi, S. (2016).** The shifting drivers of international capital flows. Unpublished manuscript.
4. **Baskaya, Y. S., Giovanni, J. D., Kalemli-Ozcan, S., and Ulu, M. F. (2017).** International spillovers and local credit cycles (No. w23149). National Bureau of Economic Research.
5. **Bekaert, G., and A. Mehl (2017). "**On the Global Financial Market Integration "Swoosh" and the Trilemma". No. w23124, National Bureau of Economic Research.
6. **Blake, A. P., G. R. Rule, and O. J. Rummel. 2015.** "Inflation Targeting and Term Premia Estimates for Latin America." Latin American Economic Review 24(1): 1–21.
7. **Borio, C. (2014),** "The financial cycle and macroeconomics: What have we learnt?", Journal of Banking and Finance 45(395): 182–98.
8. **Bruno, V. and H. S. Shin (2015),** "Cross-Border Banking and Global Liquidity", Review of Economic Studies 82, 535-564.
9. **Ceballos, L., A. Naudon, and D. Romero. 2015.** "Nominal Term Structure and Term Premia: Evidence from Chile." Working Paper 752, Central Bank of Chile, Santiago.
10. **Cerutti, E., S. Claessens and A. K. Rose (2017a),** "How Important is the Global Financial Cycle? Evidence from Capital Flows", CEPR discussion paper 12075.
11. **Cerutti, E., Claessens, S., and Laeven, L. (2017b).** "The use and effectiveness of macroprudential policies: New evidence." Journal of Financial Stability, Vol. 28, 203-224.
12. **Chinn, M. D., and Ito, H. (2008).** A new measure of financial openness. Journal of comparative policy analysis, 10(3), 309-322.
13. **Cukierman, A. (2006).** Central Bank Independence and Monetary Policymaking Institutions: Past, Present, and Future. Documentos de Trabajo (Banco Central de Chile), (360), 1.
14. **Duffee, G. (2002).** "Term premia and interest rate forecasts in affine models. Journal of Finance. 57, 1, 405-443.
15. **Filipovic, D. (2000).** Exponential-polynomial families and the term structure of interest rates. Bernoulli, 6(6), 1081-1107.
16. **Forbes, K. J. and F. E. Warnock (2012),** "Capital Flow Waves: Surges, Stops, Flight, and Retrenchment", Journal of International Economics 88: 235-251.
17. **"**crisis. Journal of International Economics, 88(2), 341-356.
18. **Garriga, A. C. (2016).** Central bank independence in the world: a new data set. International Interactions, 42(5), 849-868.
19. **Hassan, T. A., Mertens, T. M., and Zhang, T. (2016).** Currency manipulation (No. w22790). National Bureau of Economic Research.
20. **Illing, M., and M. Aaron (2005).** A brief survey of risk-appetite indexes. In Bank of Canada Financial System Review.
21. **IMF (2016).** "Annual Report on Exchange Arrangements and Exchange Restrictions" IMF
22. **Jeanne, O., and Sandri, D. (2017).** Global financial cycle and liquidity management. Working Paper, John Hopkins.
23. **Jordà, O., M. Schularick, A. M. Taylor, and F. Ward. 2018.** "Global financial cycles and risk premiums", CEPR Discussion Paper 12969.

24. **Merton, R. C. (1969).** Lifetime portfolio selection under uncertainty: The continuous-time case. The review of Economics and Statistics, 247-257.
25. **Mian, A., Sufi, A., and Trebbi, F. (2015).** Foreclosures, house prices, and the real economy. The Journal of Finance, 70(6), 2587-2634.
26. **Mishkin, F. S. (1996).** The channels of monetary transmission: lessons for monetary policy (No. w5464). National Bureau of Economic Research.
27. **Mishkin, F. S. (2001).** The transmission mechanism and the role of asset prices in monetary policy (No. w8617). National bureau of economic research.
28. **Passari, E., and Rey, H. (2015).** Financial flows and the international monetary system. The Economic Journal, 125(584), 675-698.
29. **Piazzesi, M. (2010).** Affine term structure models. Handbook of financial econometrics, 1, 691-766.
30. **Rey, H. (2013),** "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence", in Proceedings of the 2013 Federal Reserve Bank of Kansas City Economic Symposium at Jackson Hole: 285-333.
31. **Rey, H. (2015),** "International Channels of Transmission of Monetary Policy and the Mundellian Trilemma", Mundell Fleming lecture, IMF Economic Review 64(1): 6–35.
32. **Reinhart, C., Reinhart, V., and Trebesch, C. (2017).** Capital Flow Cycles: A Long, Global View. In IMF Jacques Polak Annual Research Conference, November (pp. 2-3).
33. **Wright, J. H. 2011.** "Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset." American Economic Review 101(4): 1514–34.

Appendices

Appendix A1. Event Studies

We explore whether some recent episodes of two EMEs, Argentina and Turkey, have affected the 10-year interest rates and their term premiums, of the EMEs in our data set. We use a daily frequency, thus, we follow the Adrian et al. (2013) methodology, estimating affine term structure models and their corresponding term premium for Brazil, Chile, Colombia, the Czech Republic, Hungary, India, Indonesia, Mexico, Poland, Russia, South Africa, South Korea, and Turkey. In contrast with the models in the main text, we only use the principal components of the interest rates of each economy as risk factors; i.e., we do not include the VIX index nor inflation.

Then, for each country, we implement event studies using 11-day windows around the specific day of the event at hand, using as controls the first three principal components of the interest rates, and the VIX index as a proxy of the possible effects of external information. We focus on three specific events:

- **April 26, 2018.** The Argentinian Central Bank announces the use of 60,000 million of USD of international reserves in an attempt to stabilize the Argentinian Peso/USD exchange rate (which we named Arg_1).
- **May 4, 2018.** The Argentinian Central Bank announces a high increase in its interest rate, stating it in 40% (which we named Arg_2).
- **May 23, 2018.** The Central Bank of Turkey raised interest rates at an emergency meeting (which we named Turk_1).

Specifically, we proceed to estimate the following model for each economy i, and event j:

$$y_{i,t}^{(10)} = \alpha_i + \boldsymbol{\beta}_i' \boldsymbol{X}_{i,t} + \delta_j D_{j,t} + \varepsilon_{i,j,t}$$

where $\boldsymbol{X}_{i,t}$ is a vector that contains the control variables, i.e., the first three principal components of the interest rates of the economy i, and the VIX index; $D_{j,t}$ is the dummy variable for event j, which is equal to 1 if $t = \tau \pm 5$, where τ is the event date, and equal to 0 otherwise; and $\varepsilon_{i,j,t}$ is the error term. Similarly, we estimate the same model, but using the 10-year term premium of economy i as the dependent variable. We do not report the associated estimations.

We find that the Arg_1 event seems to produce a statistically significant effect on the 10-year interest rate of Chile, Colombia, Indonesia, and South Africa. It is worth mentioning that, for this countries, the responses of the 10-year interest rate to this event are positive, except for Colombia. The effects in the cases of Chile, and Indonesia are statistically significant in their respective term premiums.

For its part, for the Arg_2 event, the exercise provides evidence that the 10-year interest rates of Chile and Colombia are affected by it. Similarly, the sign of the effect on the Colombian interest rate is negative, contrary to an expected positive sign for Chile. In addition, the effect on the Chile long-term interest rate is mostly one due the impact on its term premium.

Finally, the Turk_1 event produces a statistically significant effect on the 10-year interest rate of Brazil, Chile, Colombia, Hungary, Indonesia, and, expectedly, Turkey. In the case of Colombia, interest rate responds negatively to the event, in contrast to the positive responses of the other economies. Notably, the main effect on the 10-year interest rate of Chile, Hungary, Indonesia, and Turkey is more notable in their respective term premiums. Nonetheless, the effect on the Turkish term premium is, expectedly, negative.

Appendix A2. Market prices of risk

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	0.01	-0.20*	-0.33	0.20	5.81*	0.36	-1.23	-25.88*	-0.53	0.11
PC2	-0.04*	-0.11*	0.21	0.47	0.39	3.70*	3.80*	-8.09*	0.51*	-0.062
PC3	-0.001	-0.02*	-0.01	-0.80*	0.64*	0.41*	1.67*	-0.70	-0.05	0.02*
PC4	0.002	0.00	-0.05*	0.14*	-0.54*	0.03	-0.01	-0.69	-0.05	0.01
PC5	-0.01*	-0.03*	0.05*	-0.13*	0.34*	0.74*	0.51	-1.38*	0.05	-0.003
PC6	-0.0003	-0.01*	-0.01	0.12*	0.04	0.04	-0.60*	-0.74*	-0.01	0.005*
PC7	-0.0001	-0.003	-0.004	-0.10*	0.11*	0.08	0.25*	-0.41	-0.01	0.001
π	0.01	0.07*	0.01	0.15	-1.94*	-0.70	-1.63	7.17*	0.06	-0.04
VIX	-0.13*	-0.04	1.53*	0.84	-10.50*	11.07*	15.49*	20.46	2.81*	-0.55*

Chile

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	-0.17*	1.16*	-2.13*	5.86*	30.06*	110.07*	-82.24*	20.33	-4.67*	2.09*
PC2	-0.04*	0.07	0.27	1.50*	-3.81	-10.41	-4.97	-6.46	0.63	0.01
PC3	-0.002	0.02*	-0.06*	-0.05	0.46*	1.85*	-1.00*	-0.02	-0.05*	0.03*
PC4	0.001*	-0.01*	0.003	-0.05*	-0.39*	-0.52*	0.33*	-0.03	0.02*	-0.01*
PC5	0.004	0.004	-0.07*	-0.17*	0.82*	2.87*	-0.47	0.38	-0.14*	0.03*
PC6	-0.001	-0.02	0.06	-0.07	-1.00*	-2.30	0.43	-2.26*	0.14*	-0.03*
PC7	0.0004	0.003	-0.01	-0.04	0.35*	0.92*	-0.20	-0.01	-0.04*	0.01*
π	0.05*	-0.11*	-0.22	-1.47*	2.39	6.41	7.49*	3.86	-0.44	-0.09
VIX	-0.12	-1.21	5.85*	1.58	-75.76*	-249.09*	83.93*	-69.97	12.35*	-3.01*

Czech Republic

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	0.01	0.01	-0.42	2.35*	-4.02*	-4.63*	26.95*	-12.77*	-0.93*	0.24*
PC2	0.001	0.01	0.15	-0.43	2.30*	0.33	-10.33*	1.80	0.34*	-0.07*
PC3	-0.003*	0.01	0.09*	-0.37*	0.51*	-0.21	2.09*	0.20	-0.02	0.05*
PC4	-0.01*	0.02*	0.10*	-0.21*	0.47*	-0.24	-0.77	1.11	0.06*	0.05*
PC5	-0.002*	0.004	-0.02	0.05	-0.28*	-0.43*	1.36*	-0.97*	-0.02	0.01*
PC6	0.0003	0.0003	0.02*	0.003	0.11*	-0.12*	-0.62*	-0.47*	-0.01*	0.005*
PC7	-0.0001	0.004*	-0.001	0.03*	-0.12*	0.01	0.21	-0.33*	-0.004	-0.001
π	0.01*	-0.05*	0.21*	-0.63*	2.12*	0.48	-10.44*	2.13	0.25*	-0.13*
VIX	0.05*	-0.05	-0.45	3.05*	-0.49	-10.13*	21.63*	-12.99	-1.31*	0.12

India

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	-0.02	-0.16*	-0.23	0.59	1.02	3.11*	-5.03	0.03	0.06
PC2	-0.01*	-0.02*	-0.41*	0.14	0.45*	0.05	0.27	-0.002	0.05
PC3	-0.02*	-0.04*	-0.05	-0.56*	0.70*	0.92*	-0.98*	-0.002	0.03
PC4	-0.02*	-0.04*	-0.05	0.03	0.35*	0.92*	-0.84*	-0.02	0.02
PC5	-0.01*	-0.03*	-0.08*	0.10	0.41*	0.16	-0.12	-0.01	-0.0001
PC6	-0.002*	-0.005*	-0.004	-0.01	0.12*	0.14*	-0.27*	-0.01	0.003
π	-0.001	-0.002	0.003	-0.003	-0.25	-0.62*	1.26	0.03	-0.01
VIX	0.04	0.09	0.80*	-5.68*	3.34*	-1.41	-18.07*	-0.15	-0.09

Indonesia

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	-0.05	0.07*	0.56*	1.42*	-3.62	-1.20	1.48*	-0.17
PC2	0.03	0.02	-0.44*	0.61*	3.81*	-3.14*	-0.71	0.13*
PC3	-0.0004	0.001	-0.01	-0.19*	0.17	0.02	-0.02	0.01
PC4	-0.01*	0.001	0.08*	0.003	-0.94*	1.09*	0.14	-0.02
PC5	-0.003*	0.001	0.02	0.001	-0.15	-0.01	0.05	-0.005
π	0.02*	-0.01*	-0.18*	-0.07	1.68*	-0.29	-0.41*	0.05*
VIX	0.44*	-0.10	-5.94*	5.85	57.44*	-26.11	-10.63*	1.84*

Mexico

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	0.22*	0.08	0.70	-4.02*	-7.98*	26.67*	-57.86*	-48.85*	0.20	-0.78*
PC2	-0.001	-0.01	-0.02	0.19	0.26	0.54	-1.71	0.98	0.05	-0.01
PC3	0.01*	-0.001	-0.004	-0.34*	-0.51*	1.65*	-2.49*	-0.90	-0.01	-0.04
PC4	0.002*	-0.01*	0.05*	0.01	-0.33*	0.34*	-0.46	-0.16	0.01	-0.01*
PC5	0.01*	-0.01*	0.11*	0.01	-0.12	0.93*	-1.93*	-1.23*	0.02	-0.03*
PC6	-0.001	0.002	-0.05*	-0.01	-0.07	-0.23	0.49	0.94*	-0.01	0.01*
PC7	0.001*	0.001	-0.002	-0.05*	-0.06*	0.19*	-0.16	-0.45*	-0.002	-0.004
π	-0.03*	-0.01	-0.16	0.56*	1.02*	-3.92*	9.19*	6.91*	-0.07	0.12*
VIX	0.02	-0.14	4.56*	-0.97	5.28	13.69	-64.13*	-59.02*	1.53*	-0.91*

Poland

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	-0.08*	-0.03	-0.09	-2.97*	3.12*	-2.25	-9.02*	12.86	0.20	0.73*
PC2	-0.13	0.22	5.38	-2.15	5.53	-10.08	3.20	15.25	3.03	-0.36
PC3	-0.05	0.09	2.00	-1.04	1.82	-2.63	2.35	4.86	1.12	-0.17
PC4	0.01	-0.01	-0.89	0.01	-0.30	1.10	-2.21	-2.57	-0.32	0.18
PC5	-0.01	0.01	0.24	-0.07	0.25	-0.93*	1.01*	0.28	0.10	-0.01
PC6	-0.001	-0.001	-0.05	-0.03	0.04	0.01	-0.002	-0.62*	-0.02	0.02
PC7	0.001	-0.001	-0.03	0.03*	-0.01	0.08	-0.17*	-0.90*	-0.01	-0.001
π	0.03*	-0.02	-0.08	0.90*	-1.09*	0.74	2.42*	-6.66*	-0.20	-0.19*
VIX	-0.36	0.62	16.29	-6.24	14.02	-27.38	15.98	37.76	8.90	-1.39

Russia

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$	$\lambda_{1,PC6}$	$\lambda_{1,PC7}$	$\lambda_{1,\pi}$	$\lambda_{1,VIX}$
PC1	0.02	-0.36*	6.92*	-2.11	0.73	7.94	30.67	2.10	3.94*	-0.78*
PC2	0.08	-0.05	-1.79	-2.53	4.90	1.87	-48.01	-76.71	-1.13	0.51
PC3	0.02	-0.01	-0.39	-0.43	1.08	-0.04	-10.36	-14.13	-0.21	0.09
PC4	-0.003*	-0.01*	0.09*	0.04	-0.46*	0.77*	1.91*	0.70	0.08*	-0.01
PC5	-0.003*	0.00004	0.08*	0.03	-0.08	0.11	1.77*	1.13	0.08*	-0.01
PC6	-0.003*	0.003	0.06	0.05	-0.09	0.26*	1.18	0.86	0.07*	-0.002
PC7	0.0005	-0.001	-0.02	-0.003	0.03	-0.04	-0.35	-0.49	-0.02*	0.001
π	-0.01*	0.05*	-0.58*	0.60*	-0.57	-1.06*	2.88	10.27*	-0.29*	0.01
VIX	0.28	-0.05	-9.42	-7.80	16.84	-1.29	-194.18	-278.28	-5.26	2.19

South Korea

Tables A2.1. Market Prices of Risk $\boldsymbol{\lambda_0}$ and $\boldsymbol{\lambda_1}$.

Notes: An asterisk indicates significance at least as the 90% level.

Appendix A3. About the Term Premium Estimate for the Non-Selected Countries

	Error (basis points)					
	1y	*2y*	*4y*	*6y*	*8y*	*10y*
Brazil	25.3	6.8	5.6	5.1	2.9	2.7
Colombia	20.6	2.6	3.6	1.3	2.6	2.1
Hungary	34.8	3.8	2.9	4.5	4.5	4.6
South Africa	7.1	7.8	2.8	1.7	2.6	3.5
Turkey	17.5	5.4	3.4	2.7	2.2	3.7

Table A3.1. Interest Rates Mean Absolute Errors.
Units: Basis Points**.**

$$mean_t\left(\left|y_{t,model}^{(n)} - y_{t,interp}^{(n)}\right|\right)$$

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$
PC1	-0.01	-0.07*	0.31*	-0.77*	-1.70*	-0.45
PC2	-0.001	0.01	-0.10*	0.37*	-0.23	0.61
PC3	-0.0001	0.001	0.03*	-0.07	0.54*	-0.24
PC4	-0.001	-0.002	0.04*	0.22*	-0.56*	0.50*
PC5	-0.001*	0.001	0.02*	-0.01	-0.04	-0.12*

Brazil

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$
PC1	-0.01*	-0.02	0.16*	-0.01	-1.00*	0.13
PC2	-0.001	0.0003	-0.05	0.06	0.22	0.18
PC3	0.001	-0.00005	0.003	-0.18*	0.31*	0.33*
PC4	0.0002	-0.005*	0.01	0.12*	-0.47*	0.89*
PC5	-0.001*	-0.005*	0.02*	0.11*	-0.25*	0.30*

Colombia

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$
PC1	-0.01*	-0.01	0.23*	-0.18	-0.55	1.71
PC2	-0.00001	-0.003	-0.10*	0.23	0.24	0.05
PC3	0.0003	-0.0001	0.02*	-0.18*	0.37*	0.13
PC4	-0.0001	0.01*	0.04*	-0.003	-0.51*	0.45*
PC5	-0.0004	0.01*	0.02*	-0.11*	-0.01	-0.43*

Hungary

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$
PC1	-0.005*	-0.05*	0.24*	0.12	0.76*	1.25*
PC2	0.0001	0.02*	-0.06*	0.05	0.18	0.40
PC3	-0.002*	0.012*	0.09*	0.40*	0.51*	0.53*
PC4	-0.001*	-0.0003	0.05*	0.13*	0.02	0.09
PC5	-0.001*	-0.0004	0.02*	-0.03	0.04	-0.13*

South Africa

Risk-Factor	λ_0	$\lambda_{1,PC1}$	$\lambda_{1,PC21}$	$\lambda_{1,PC3}$	$\lambda_{1,PC4}$	$\lambda_{1,PC5}$
PC1	0.01	0.01	0.27	0.79	-1.07	1.15
PC2	0.002	0.0001	-0.15*	0.33	0.96*	-0.45
PC3	0.0001	-0.02*	-0.001	-0.29*	0.41*	-0.32*
PC4	-0.001*	-0.03*	-0.06*	0.17*	-0.05	-0.98*
PC5	0.001*	0.02*	0.04*	-0.03	0.02	0.13

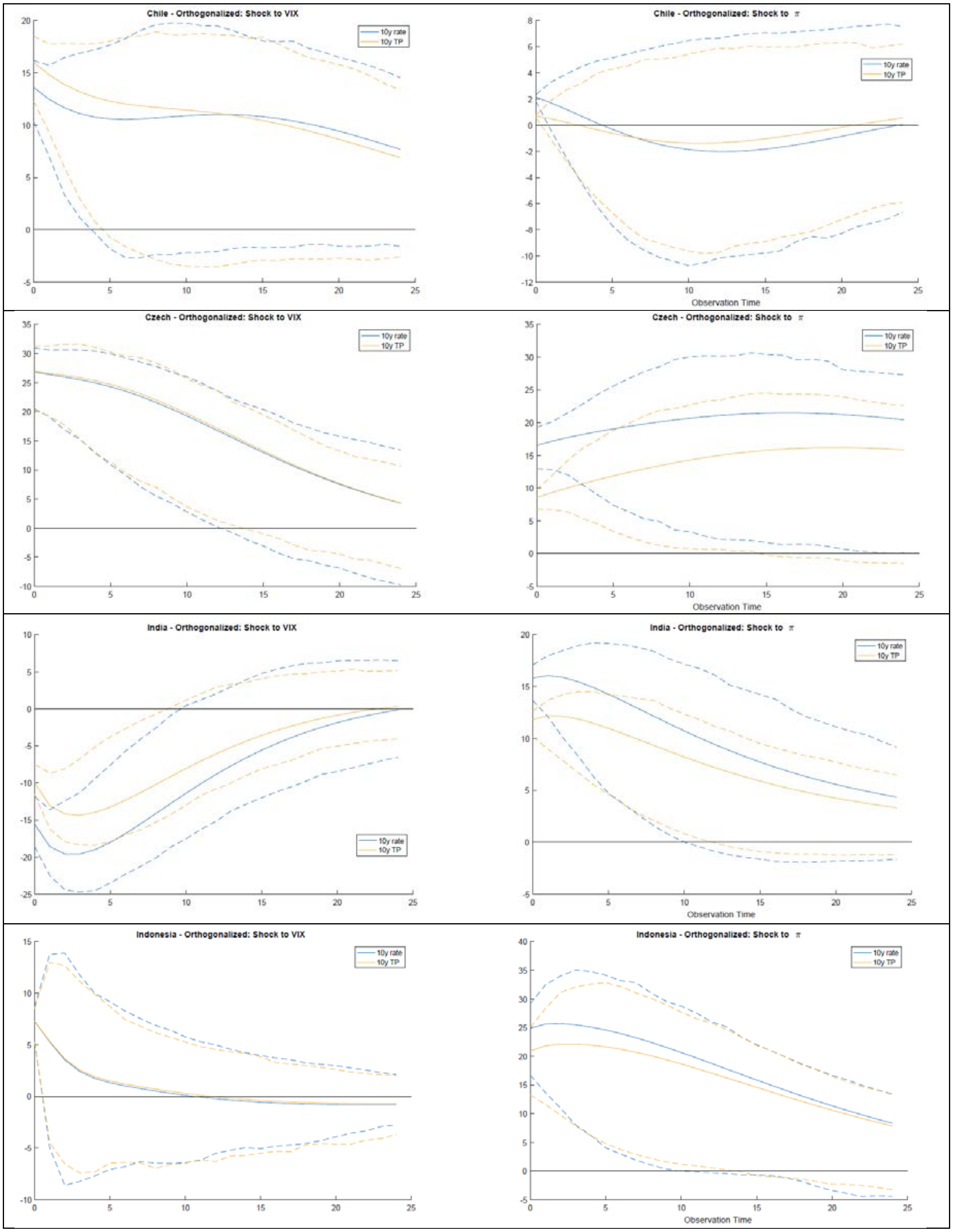
Turkey

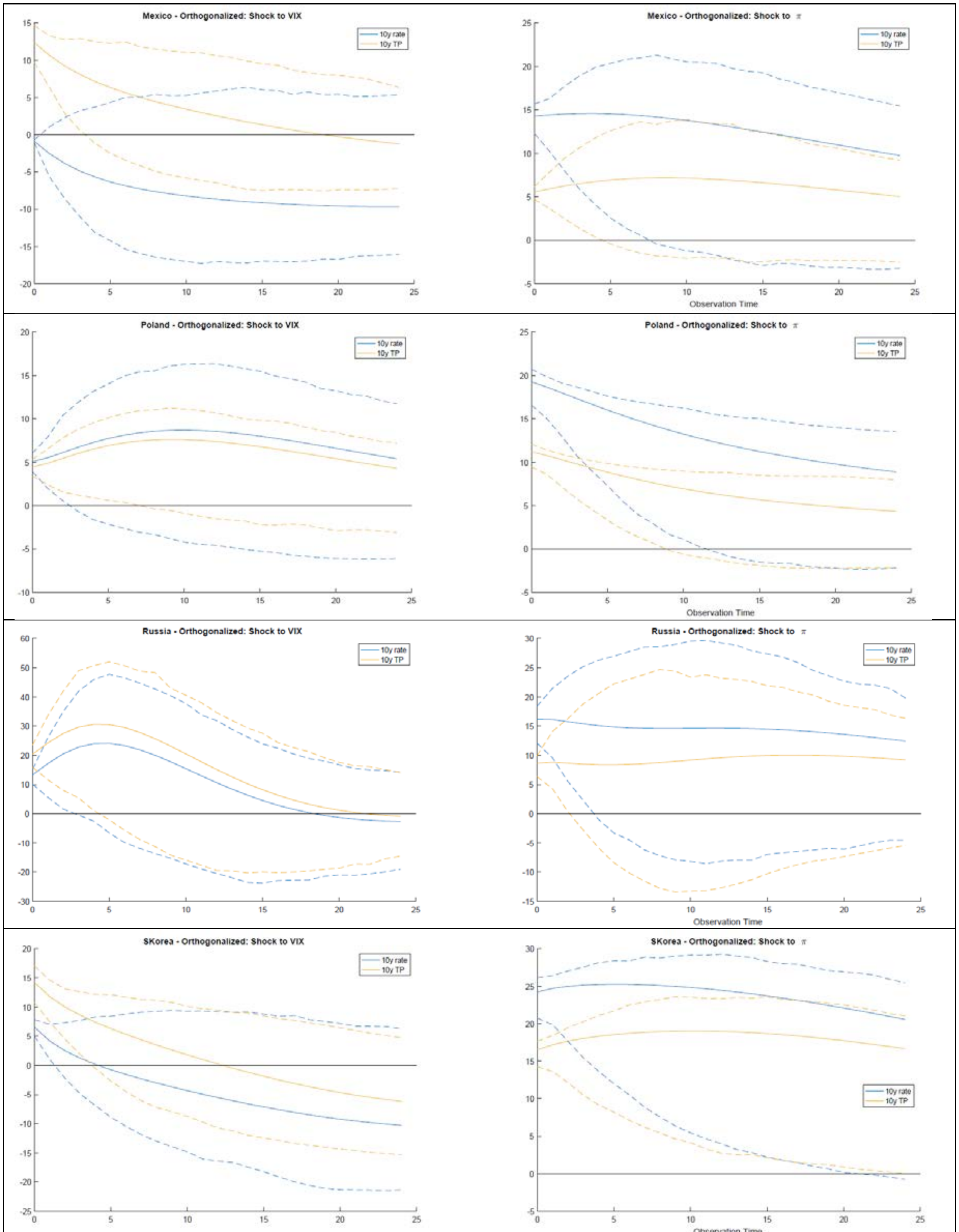
Tables A3.2. Market Prices of Risk $\boldsymbol{\lambda_0}$ and $\boldsymbol{\lambda_1}$.
Notes: An asterisk indicates significance at least as the 90% level.

	Brazil		Colombia		Hungary		South Africa		Turkey	
	OLS (1m)	Affine Model (10y)	OLS (1m)	Affine Model (10y)	OLS (1m)	Affine Model (10y)	OLS (1m)	Affine Model (10y)	OLS (1m)	Affine Model (10y)
α	10.84	12.44	5.53	8.19	5.34	6.25	7.08	8.65	9.84	9.68
PC1	0.07	0.08	0.09	0.08	0.11	0.07	0.13	0.06	0.13	0.07
PC2	0.23	-0.09	0.21	-0.08	0.19	-0.11	0.21	-0.12	0.30	-0.10
PC3	0.43	0.09	0.22	0.15	0.38	0.09	0.75	0.06	0.34	0.11
PC4	0.38	-0.10	0.60	-0.07	0.52	-0.10	0.42	-0.12	0.74	-0.05
PC5	0.50	0.05	0.67	0.03	0.63	0.04	0.32	0.06	-0.37	-0.06

Table A3.3. Monetary Rule vs. Affine Model Coefficients – Not selected economies.
Source: Own Estimations

Appendix A4. Impulse Response Functions - Diagonal Identification



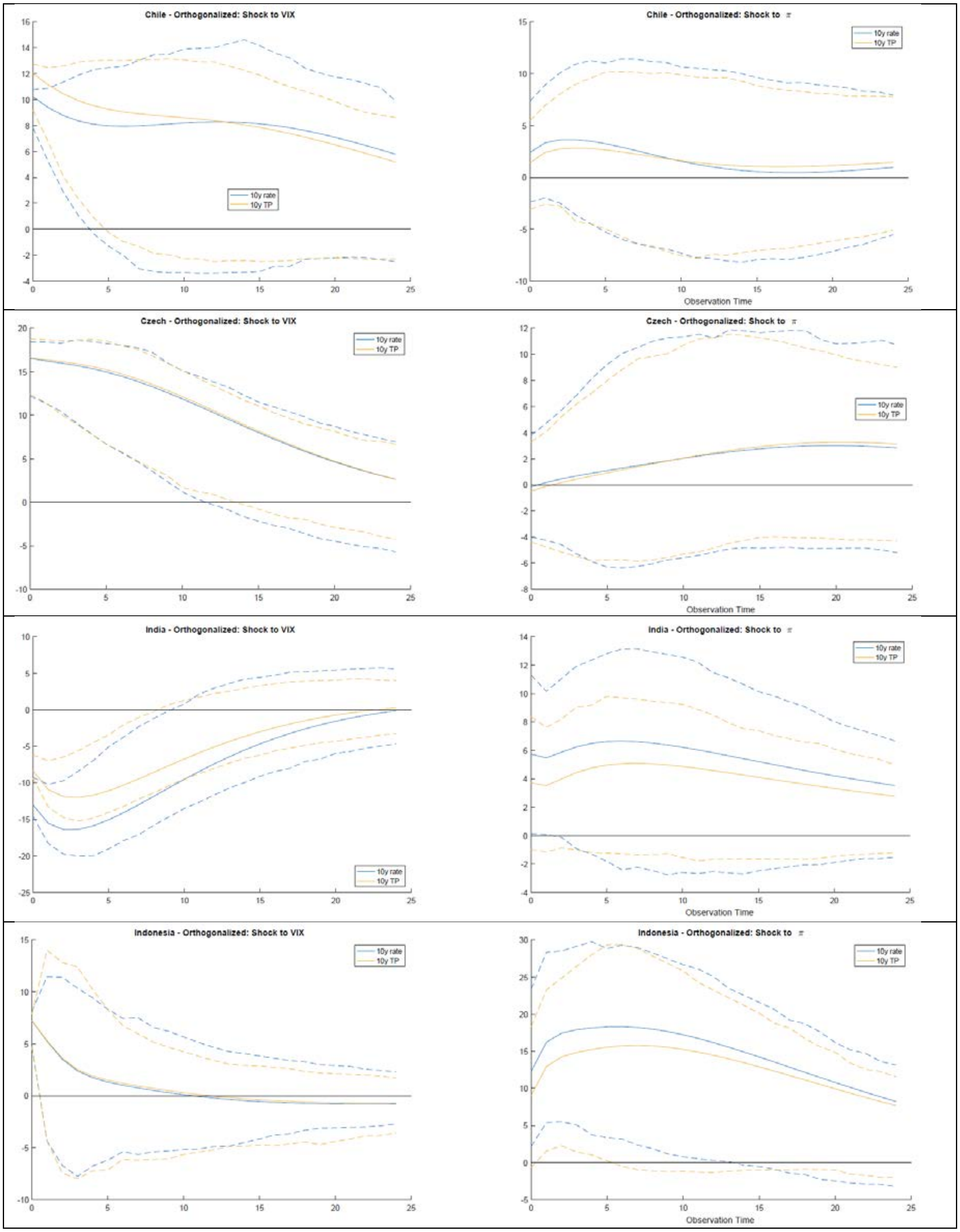


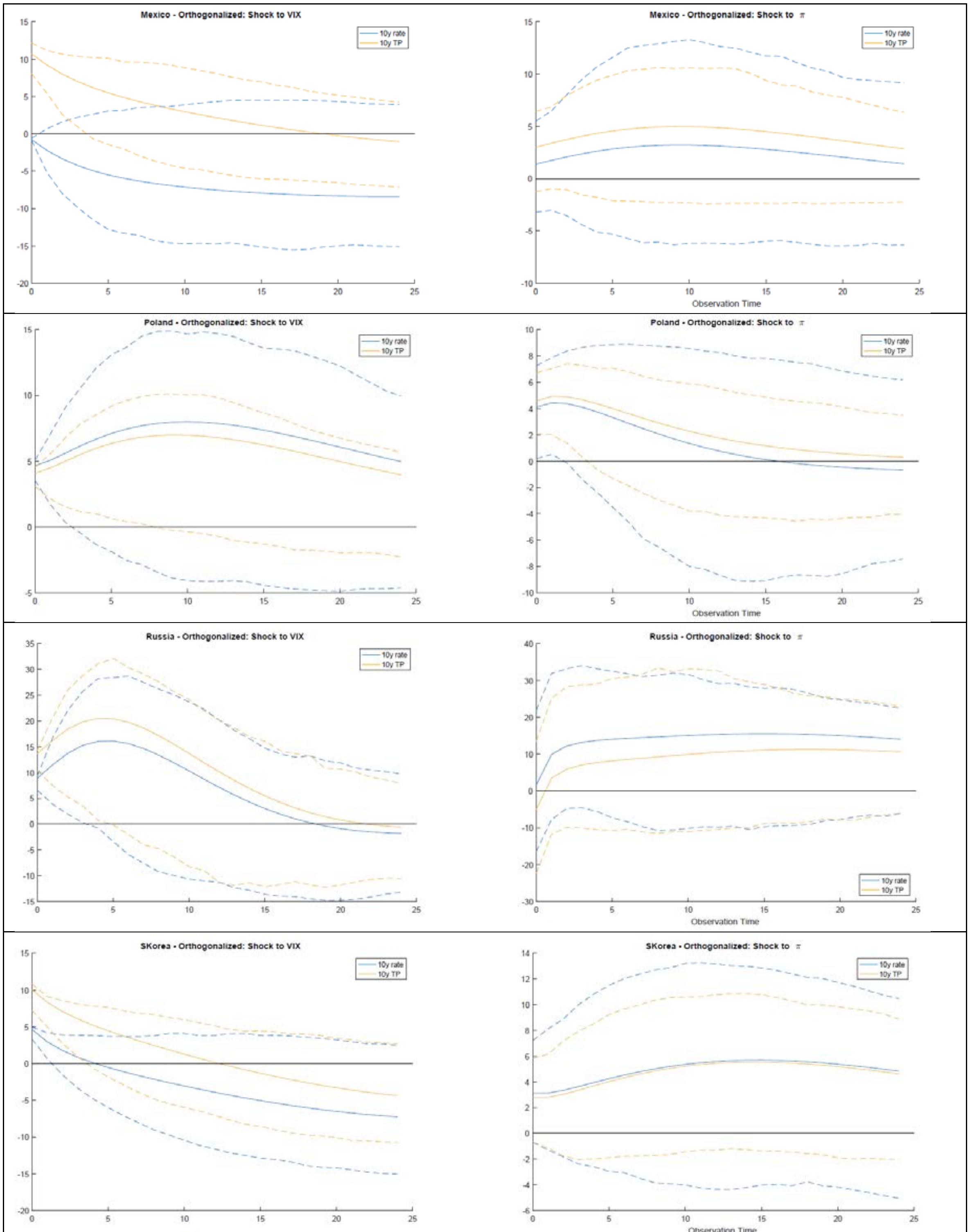
Figures A4.1. Impulse Response Functions

Notes: These are the response functions of the interest rates, and term premiums to shocks on inflation and the VIX index. The identification assumption is diagonal variance-covariance matrix.

Source: Own estimations with data from Bloomberg.

Appendix A5. Impulse Response Functions Decomposed – Identification: VIX-Rate-Inflation



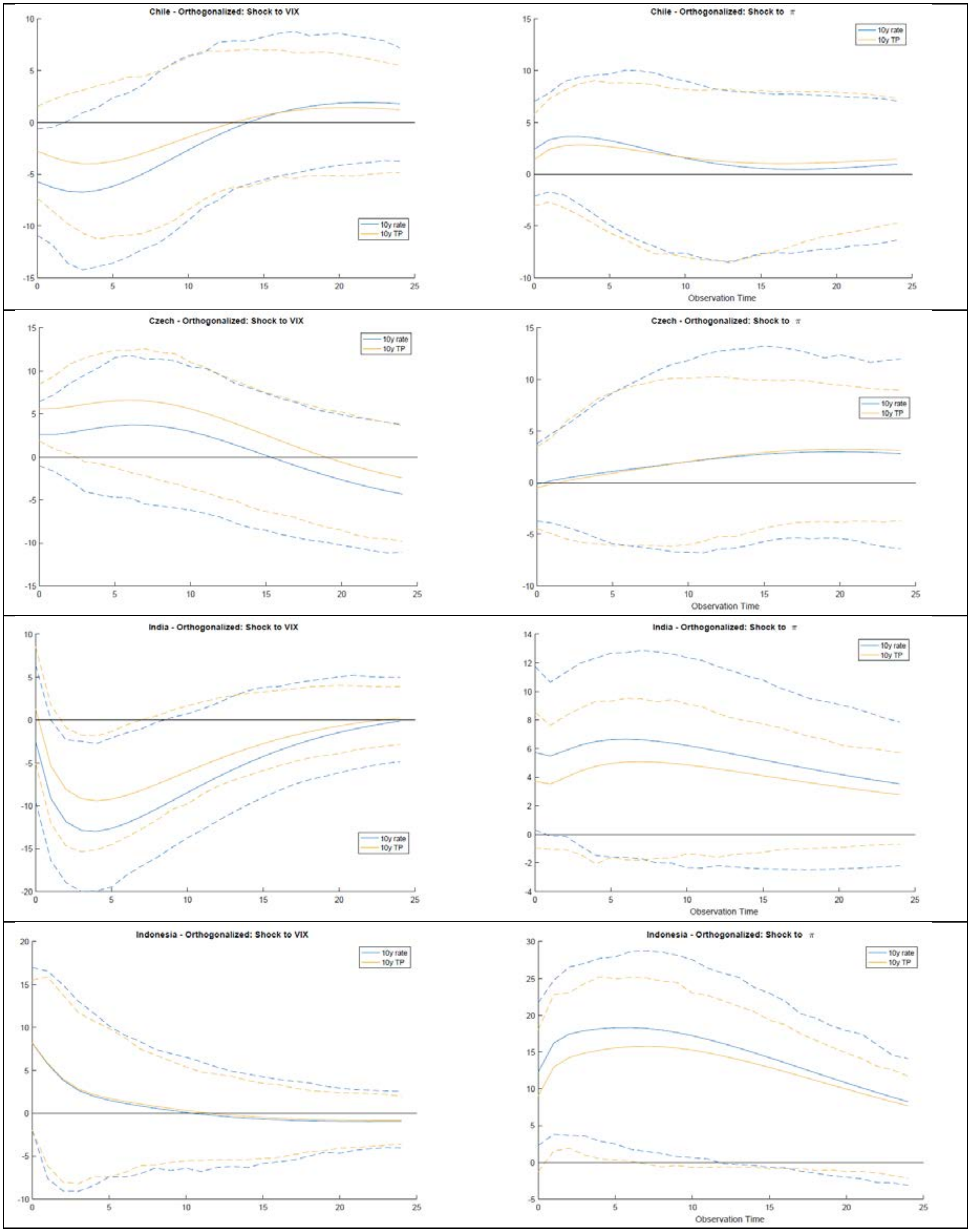


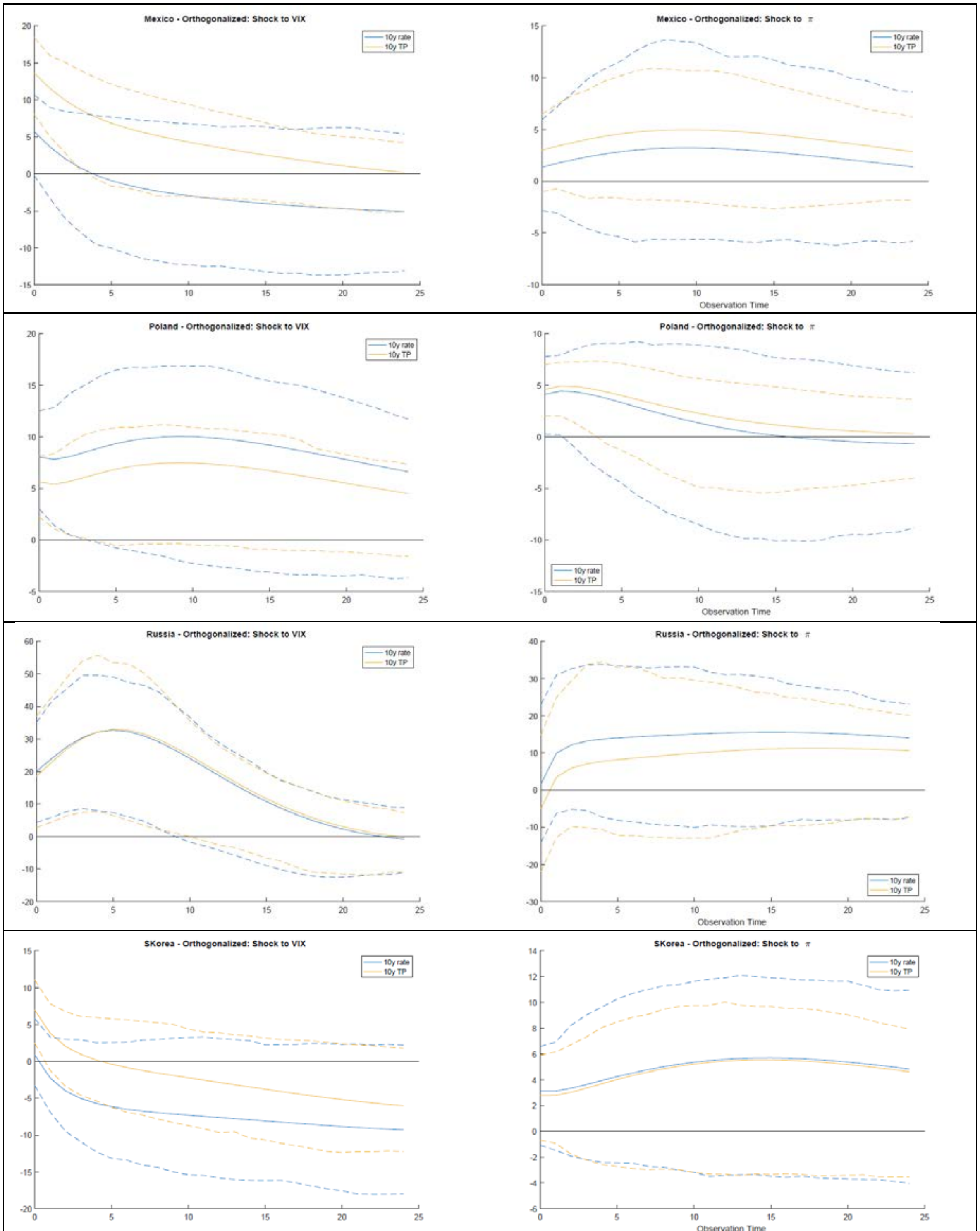
Figures A5.1. Impulse Response Functions.

Notes: We use short run identification restrictions. We assume that unobservable factors are the fastest, followed by the VIX and inflation is the slowest.

Source: Own estimations with data from Bloomberg and Central Banks.

Appendix A6. Impulse Response Functions Decomposed – Identification: Rate-VIX-Inflation





Figures A6.1. Impulse Response Functions.
Notes: We use short run identification restrictions. We assume that unobservable factors are the fastest, followed by the VIX and inflation is the slowest.
Source: Own estimations with data from Bloomberg and Central Banks.

Appendix A7. Impulse Response Functions for the not selected countries.

A7.1 On the Impulse Response Functions by Component

For the countries for which we did not find a satisfactory fit in the estimation of an affine model of interest rates using inflation and the VIX index as risk factors, namely, Brazil, Colombia, Hungary, South Africa, and Turkey, we proceeded to estimate the term premium using the first five principal components of the interest rates, and, separately, implementing a VAR model between the 10-year interest rate or the 10-year term premium, inflation and the VIX index. About its impulse response functions, we have the following comments.

We note that, independently of the short-run identification, all the initial responses are positive and statistically significant, or statistically not different from zero. Moreover, the shocks on the VIX index tend to affect directly the term premium. In a similar way, shocks to inflation tend to be absorbed by the expected path of the short-term rate (the difference between the long-term rate and its term premium). This results are in line with the ones fund in the main text for the economies where we were able to estimate a joint affine model.

Specifically, when the short-run identification assumed is that where the VIX index is the fastest variable, and inflation is the lowest one, by construction only shocks in the VIX index have an initial effect on the VIX index different from zero. In contrast, in the specification where the 10-year rate or the 10-year term premium is the fastest variable, we find that all the selected economies have a positive and statistically significant response to a shock on the VIX index.

A7.2 On the Impulse Response Functions – Joint shocks.

Similar to the economies presented in the main document, we next compare the individual impulse response functions of the 10-year rate under a shock on inflation and, separately, on the VIX index, and those of a joint shock on this two variables.

We focus the discussion on the identification that assume that the 10-year rate is the fastest of the variables; in the other case, where the VIX index is the fastest variable, the initial response of the long-term rate to a shock on the VIX is zero by construction. Thus, we note that, in general, a joint shock on the VIX index and inflation produces a higher impulse response function of the long-term rate. Even though, they are not statistically different to those of a shock on inflation alone. Therefore, we do not find evidence that a shock in the VIX index produces a significantly different response in the long-term rate, under this specifications.