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Is there a carry trade channel of monetary policy in emerging countries?*

(Létezik-e a monetáris politika carry trade csatornája a feltörekvő országokban?)

Written by: Kornél Kisgergely

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Contents

Abstract

This paper empirically tests whether monetary policy can have a perverse effect on aggregate demand in emerging economies, because of short-term speculative inflows. For this purpose, a bayesian VAR is estimated on a panel of six major emerging countries. Monetary and risk shocks are identified by imposing only very mild restrictions. It is found that a positive interest rate shock results in a persistent decline in production and inflation. The net foreign asset position even improves in most of the countries. Thus no large net inflows are observed and there is no sign of a perverse effect on aggregate demand. More interestingly, central banks loosen interest rate policy significantly and persistently in the face of a capital inflow shock, possibly to dampen the immediate disinflationary effect of the appreciation and/or to protect balance sheets from exchange rate volatility. In some specifications this results in overheating (positive industrial production gap and inflation) in the medium-term. Thus central banks might amplify the effect of risk premium shocks by cutting interest rates—rather than raising them—when capital flows in.

JEL: C11, C33, C54,E44, E58, F32.
Keywords: carry trade, monetary policy, emerging markets.

Összefoglalás

Ez a tanulmány az első empirikus tesztje annak a hipotézisnek, miszerint a monetáris politika fordítottan működhet a feltörekvő országokban a rövid távú, spekulatív tőkeáramlások miatt. Erre a célra egy Bayes-i VAR modellt becsültem egy hat országot magában foglaló panelen. Monetáris és kockázatiprémium-sokkokat identifikáltam minimális megkötések segítségével. Eredményeim szerint egy pozitív kamatsokk hatására a termelés és az infláció tartósan csökken. A nettó külső adósság mutató még javul is a legtöbb ország esetében. Azaz, nem figyelhető meg nagy tőkebeáramlás a szigorú monetáris politika hatására, és semmi nyoma a fordított összefüggésnek a kamatpolitika és az aggregált kereslet között. További érdekes eredmény, hogy a jegybankok tartósan és érdemben lazítják a monetáris politikájukat nagy tőkebeáramlások hatására; valószínűleg azért, hogy tompítsák az azonnali dezinflációs hatását az árfolyamerősödésnek és/vagy, hogy védjék a gazdasági szereplők mérlegkitettségeit az árfolyam-volatilitástól. Bizonyos specifikációkban ez a viselkedés középtávon túlfűtöttséghez (pozitív termelési és inflációs réshez) vezet. Ezek szerint a jegybankok valóban felnagyítják a kockázati prémiumsokkok hatását azáltal, hogy kamatot vágnak – és nem kamatot emelnek – tőkebeáramlások idején.

1 Introduction

The relationship between domestic monetary policy and capital flows is again at the top of the policy agenda in emerging countries. After normalisation of the capital markets in 2009, demand for some EM assets increased significantly, and many central bankers fear that, against the backdrop of capital inflows, raising interest rates may have a perverse effect on aggregate demand. This is, because the wider interest rate spread induces more speculative inflows, which are manifested in even higher consumption and investment activity. As De Gregorio (2009) described the dilemma:

> ”…if capital inflows generate a boom of activity, without inflationary consequences due to the appreciation of the currency, there could be the temptation to tighten monetary policy, aggravating the problem of massive inflows.”

Behind this logic, there is the empirically well-documented carry trade (CT) phenomenon. Nominal interest rate differentials are correlated with expected returns on unhedged long positions in high-yielding currencies. If there is an arbitrage opportunity, many investors crowd in. As De Gregorio continues:

> ”the perverse dynamics are as follows: high interest rate differentials induce capital inflows to arbitrage those differences (…) the incentives for inflows increase as not only the interest rate differential is large, but also the expectations of appreciation; finally, the appreciation takes place, which validates the expectations of arbitrageurs. (…) In this process there are ”excess” inflows and ”excess appreciation”, and the issue is how to avoid those excesses.”

Indeed there are several possible explanations to the CT puzzle, but few of these provide a direct explanation about the relationship of CT and domestic monetary policy.

1.1 THE CARRY TRADE PUZZLE

Since the seminal paper of Fama (1984) was first published on the empirical failure of the UIP, a vast body of literature has emerged about the long term profitability of CT. For example Burnside et al. (2006), Burnside, Eichenbaum, and Rebelo (2007), Brunnermeier, Nagel, and Pedersen (2008) and Hochradl and Wagner (2010) documented that this simple trading strategy is just as profitable—or maybe even more so—than the US equity market, even after taking into account all kinds of risks.

The most cogent explanation argues that the CT puzzle is not caused by the interest rate differential per se, but by the risk premium of the high yielding currency. When the central bank of a country with high interest rate currency reacts to risk premium shocks systematically, the increased interest rate differential points towards appreciation, even though the strengthening of the currency was not caused by the interest rate but by the unobserved risk premium shock. This explanation was first put forth by McCallum (1994). High interest rate currencies appreciate because their risk premia are higher.[1]

[1] To put it more accurately, the high interest rate differential might signal a strengthening of the exchange rate when the risk premium has a positive correlation with the interest rate spread and it has higher variance. These are the criteria formulated by Fama.

In emerging market countries, risk premia can be explained by sovereign risk. Volatility of the sovereign risk premium may be caused by investors' incomplete or imperfect information about the the probability of default or devaluation. This situation can lead to herding in the manner of Bacchetta and Wincoop (1998) and Chari and Kehoe (2003).

A recent explanation of the CT puzzle based on a representative agent is provided by Verdelhan (2010). In countries with similar levels of sovereign risk, the positive risk premium attached to high interest rate currency assets may be caused by different stages in the business cycle. The risk aversion of economic agents in the low interest rate country in recession is higher than that in a booming country with a corresponding high interest rate and therefore the low interest rate country demands a higher expected return when buying instruments of the high interest rate country.

However, the risk aversion of representative agents in different countries is not sufficient to fully explain the CT puzzle. These models are not able to generate such an exchange rate risk premium, which can be accommodated quantitatively with the data and which could produce currency collapses endogenously. Backus (2001) demonstrated as well that affine yield curve models demanding a minimum level of restrictions cannot generate any appropriate level of risk premium.

Other theories suggest that persistently high returns on CT may be caused by the fact that too few agents invest in high interest rate currencies. Explanations built on financial market frictions assume that most investors do not actively trade in international instruments, and therefore such instruments are notoriously undervalued. According to this explanation, CT will approximate exchange rates to their fundamental value. Carry traders are nearly risk neutral institutional investors who will take the largest possible position in underpriced instruments when they see an arbitrage opportunity. Due to the problem of asymmetric information, they can take positions only up to a limited extent, and therefore mispricing can persist. According to this line of thought, the risk premium can be explained mostly by the financing constraints of the institutional investors active in the CT business. This kind of liquidity risk is taken into account by professional investors in their decision-making, which may be a partial explanation for the persistence of long-term high yields. According to calculations by Farhi et al. (2009), the risk associated with a sudden, severe fall in the exchange rate can explain about one fourth of CT yields.

Irrational expectations can also explain the UIP anomaly and the profitability of CT, as shown in Gourinchas and Tornell (2004) and Bacchetta and Wincoop (2006). In practice, at least based on polls of market participants, market expectations cannot be regarded as undistorted estimates of actual exchange rate movements. An explanation for this may be that investors systematically underestimate the persistence of monetary shocks. Thus the interest rate differential does not diminish as expected after the initial shock, and this impacts markets as a series of further positive interest rate shocks. If these quasi-shocks are large enough, delayed overshooting and persistent high returns are reproduced.

A similar story is outlined by Benczúr (2003), focusing on interest rate based disinflation periods. In his model, distorted expectations of the exchange rate are formed through parameter learning caused by the altered monetary regime. If actual disinflation is slower than the original expectations of investors, sustained appreciation can be realised under rational expectations.

The most common explanation for CT is that speculators push the high interest rate currency higher and higher with their own purchases. In other words, CT causes a kind of exchange rate bubble as described by Plantin and Shin (2011) In such a case the exchange rate diverts from its fundamental path as a result of CT inflows. The bubble will burst at a point in time which cannot be foreseen. These episodes happen when too many investors suddenly realize the mispricing or hit by the same shock. Empirical evidence for this hypothesis is provided by Jorda and Taylor (2009), who found that the profitability of CT diminishes with the strengthening of the real exchange rate. This suggests that an initially undervalued, high interest currency attracts speculators, who strengthen the exchange rate by their buying pressure. The more overvalued a currency, the greater the probability of a correction. Finally the bubble bursts, the exchange rate becomes undervalued, and the whole cycle begins again.

1.2 CARRY TRADE AND MONETARY POLICY

As we have seen there are many hypotheses for the CT puzzle. None of them, however offer a clear picture about the interaction of domestic monetary policy and CT. Even if we accept the bubble hypothesis, it is not clear how the bubble—together with the higher interest rate—affects domestic aggregate demand. Why would domestic agents be willing to take on more home currency debt, despite its rising cost, to buy more home products, despite their rising relative price?

Unfortunately there are few empirical papers related to this topic.[2] A number of researchers have studied the monetary transmission mechanism in small open economies. A recent example is Jarociński (2010), who found that a positive interest rate shock is similarly contractionary and even more disinflationary in emerging than developed European countries. According to Catao and Pagan (2010) credit growth slows in response to a hike in domestic interest rates both in Chile and Brazil. Brzoza-Brzezina, Chmielewski, and NiedźwiedziAńska (2010) showed that monetary tightening leads to a substitution in the currency denomination of debt in Central European countries, although the overall loan flow decreases. Canova (2005) studied the transmission of US shocks to Latin America. He found that after an exogenous increase in the spread between US and Latin American interest rates the trade balance of the emerging countries improves (i.e. a net outflow of capital is observed, which is in sharp contrast with the carry trade channel hypothesis).

This paper aims to test empirically the effect of monetary policy on capital flows on a large set of emerging countries. A VAR is estimated in a bayesian hierarchical panel of six major EM countries (Brazil, Chile, Hungary, Israel, South Africa, and Thailand). Monetary and domestic risk shocks are identified via zero restrictions. The analysis focuses on how these shocks affect the net foreign asset (NFA) position of the home countries. It is also of interest how monetary policy reacts to risk shock (i.e. an exogenous change in the demand for its assets). Whether or not monetary policy really attempts to counteract the effect of cheaper foreign financing in these countries. It is found that after a positive interest rate shock, both inflation and industrial production declines, while the net foreign asset position improves in most countries. Several robustness checks are conducted. In almost all cases strict monetary policy is contarctionary, disinflationary and does not deteriorates persistently—or even improves—the NFA position. Thus there is no sign of a perverse effect of monetary policy among these countries. In addition a robust finding is that after a favorable domestic risk shock monetary policy loosens significantly in all countries, possibly to counteract the immediate disinflationary consequence of the exchange rate appreciation. In turn (in some cases at least), the lower domestic interest rate and lower country risk premia creates an inflationary problem in the medium-term. This finding is similar to that of Gómez (2006), in which a capital outflow situation is analysed in a structural model and an exchange rate defence by monetary authorities causes a recession. Thus there might be a monetary policy dilemma with capital flow volatility, but it is totally consistent with the standard view of the monetary transmission mechanism.

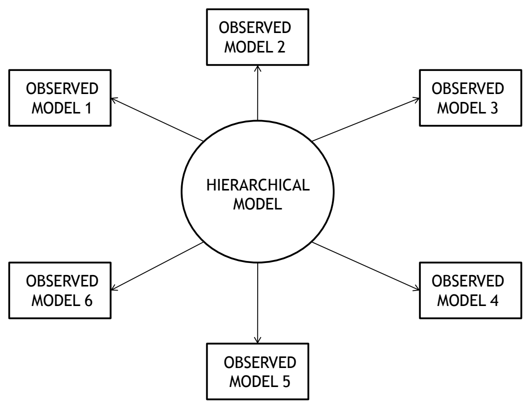
The rest of the paper is organised as follows. The next section presents the empirical model. Section 3. describes the data. Section 4. discusses result from the baseline model. In section 5. the robustness of these results are tested. Section 6. concludes. In the Appendix the conditional posterior distributions are derived and exact data sources are shown.

[2] There is a vast body of literature on how home and foreign variables affect vulnerabilities, but in the former case these tell nothing about causality, and thus cannot be used for policy purposes.

2 The empirical model

In emerging markets, economic time series are often short, noisy and disturbed by structural breaks. This situation calls for bayesian techniques. The methodology used in this paper is a slightly modified version of Jarociński (2010). The basic idea of the model is that parameters of EM economies are similar, but not identical. Thus an informative prior is imposed. Hyperparameters across the panel are different realisations of the same distribution as illustrated in Figure 2. The econometrician can use the whole panel when estimating posterior distributions. On the other hand she does not have to go so far as to assume that these distributions are identical across the panel. The resulting posteriors are weighted averages of the fully pooled and country specific estimators.

Figure 1
The hierarchical structure



The estimated equations are the following. Let $\mathbf{x}_k \in \mathbb{R}^N$ be a vector of endogenous variables for country k, $\mathbf{z} \in \mathbb{R}^M$ is a vector of common exogenous variables, and $\mathbf{w} \in \mathbb{R}^{P+N}$ are another group of exogenous variables including N country specific constants. With

$$\begin{aligned}
\mathbf{Z} &= [\mathbf{z}_1, \ldots, \mathbf{z}_{T_k}]' \in \mathbb{R}^{T_k \times M}, \\
\mathbf{W} &= [\mathbf{w}_1, \ldots, \mathbf{w}_{T_k}]' \in \mathbb{R}^{T_k \times P+N} \\
\mathbf{Y}_k &= \mathbf{Y}_{k,T_k} = [\mathbf{x}_{k,1}, \ldots, \mathbf{x}_{k,T_k}]' \in \mathbb{R}^{T_k \times N}, \\
\mathbf{X}_k &= [\mathbf{Y}_{k,T_k-1}, \mathbf{Y}_{k,T_k-2}, \ldots, \mathbf{Y}_{k,T_k-L}, \mathbf{Z}] \in \mathbb{R}^{T_k \times (LN+M)}, \\
\mathbf{E}_k &= [\varepsilon_{k,ti}] \in \mathbb{R}^{T_k \times N} \quad where \quad \varepsilon_{k,t} \sim \mathcal{N}(0, \Sigma_k),
\end{aligned} \tag{1}$$

the VAR can be written in the regression form:

$$\mathbf{Y}_k = \mathbf{X}_k \mathbf{B}_k + \mathbf{W}\mathbf{F}_k + \mathbf{E}_k, \tag{2}$$

where $\mathbf{B}_k \in \mathbb{R}^{(LN+M) \times N}$, $\mathbf{F}_k \in \mathbb{R}^{(P+N) \times N}$.

2.1 PRIORS

For country-specific parameters, conditionally conjugate prior distributions were chosen. Flat priors were imposed on the hierarchical part.

$$\begin{aligned} f(\mathbf{b}_k \mid \bar{\mathbf{b}}, \Lambda_k) &= \mathcal{N}(\bar{\mathbf{b}}, \Lambda_k) \\ f(\Sigma_k) &= \mathcal{W}(\rho, \mathbf{R}) \\ f(\mathbf{R}) &\propto 1 \\ f(\bar{\mathbf{b}}) &\propto 1 \\ f(\mathbf{f}_k) &\propto 1 \end{aligned} \tag{3}$$

where $\mathbf{b}_k = \mathrm{vec}(\mathbf{B}_k)$, $\mathbf{f}_k = \mathrm{vec}(\mathbf{F}_k)$. Observe that the prior mean of the VAR coefficients and the covariance matrix of the residuals are the same and are equal to the fully pooled panel estimate. How the country-specific coefficients ($\mathbf{b}_k$ and Σ_k) can deviate from their means hinges on the parameters Λ and ρ. Λ_k is defined similarly as in the Minnesota prior:

$$\begin{aligned} \mathrm{E}[\mathbf{B}_k^2(n1, n2)] &= \lambda \frac{\hat{\sigma}_{kn2}^2}{\hat{\sigma}_{kn1}^2} \\ \mathrm{E}[\mathbf{B}_k(n1, n2)\mathbf{B}_k(n3, n4)] &= 0 \quad if \quad (n1, n2) \neq (n3, n4), \end{aligned} \tag{4}$$

where $\mathbf{B}_k(n1, n2)$ denotes the coefficient of variable $n1$ in equation $n2$ of country k, $\hat{\sigma}_{kn1}$ is the estimated standard error in an univariate L-th order autoregression for variable $n1$ in country k, $\hat{\sigma}_{kn2}$ is defined similarly for the left hand side variable in equation $n2$ in country k. $\lambda = 0$ corresponds to the fully pooled panel estimation. As λ grows, more and more weight is given for the country-by-country individual estimates.

ρ plays a similar role in the estimation of the residual's covariance matrices. The posterior mean of k country's residual covariance matrix is related to the hyperparameter ρ in the following way:

$$\mathbf{E}(\Sigma_k) = \frac{\left(\sum_{i=1}^{K} \Sigma_i^{-1}\right)^{-1} (K\rho + n + 1) + E_k E_k'}{n + \rho + T + 1}. \tag{5}$$

When $\rho = T_i$, $\mathbf{E}(\Sigma_i)$ is some kind of equally weighted average of the country-specific and the hierarchical mean.

This setup is very similar to Jarociński (2010) with two distinctions. In Jaroćinski's model λ was a parameter with an inverse gamma distribution. In my setup, λ is a hyperparameter. I experienced with an inverse gamma distribution as well, but its posterior distribution was not greatly affected by the data. In the baseline model, I used the posterior mean of Jarociński. A possible more important difference is that here the hierarchical structure is applied to the residual covariance matrices as well. Jaroćinski uses flat priors for these matrices. In my setup, information contained in the whole panel is used also when estimating the residual's covariance structure, not just in the case of the VAR parameters. This seems to be more consistent with the treatment of lagged relationships. If it is assumed that effects of lagged parameters are similar across the panel, than contemporaneous relationships must be similar too.

The conditional posterior distributions can be found in the Appendix with derivations. These are either normal or Wishart distributions. A sample from the full posterior was acquired from the Gibbs-sampler.

2.2 IDENTIFICATION

Monetary and risk shocks are identified by zero restrictions, as shown in Figure 1. REER stands for real exchange rate and EMBI is the sovereign spread (more on these in the data section). Both monetary and risk shocks are considered as financial shocks, meaning that they emanate from financial markets and do not affect real variables within a month.[3] In both

[3] Since these countries operate inflation-targeting regimes money demand shocks are accommodated automatically, so interest rate shocks and monetary shocks are used interchangeably throughout the text.

cases, there are zero restrictions in the lines of industrial production and inflation, which aimed to distinguish these shocks from supply or demand shocks. However, the relationships among financial variables are evidently contemporaneous. To distinguish monetary from risk shocks, it is assumed that the former do not affect sovereign spreads contemporaneously (i.e. an unexpected change in the monetary stance does not affect the probability of default or the price of risk). No restrictions were put on the capital flow line, as this is our key variable of interest. Also there are no restrictions on interest rates in the case of risk premium shocks. How monetary policy reacts to these shocks is an open question. On one hand there is a ”temptation to tighten” to counteract the stimulating effect of cheaper foreign financing. On the other hand, the risk shock appreciates the exchange rate, which has a direct negative effect on inflation that points to the other direction. This policy situation is nontrivial as pointed out by Caputo, Medina, and Soto (2010).

Table 1
Contemporaneous restrictions

	Monetary policy	Risk premium
Net capital flow		
Inflation	0	0
Industrial prod.	0	0
Interest rate		
REER		
EMBI	0	

The real exchange rate and industrial production enter as log deviations from the trend. This specification poses long-term restrictions on these variables too. Since the VAR is stable, they both revert to the trend after the shock. Thus, implicitly it is also assumed that monetary and risk shocks do not affect real variables in the long run.

3 Data

The sample consists of a monthly time series of six emerging economies as shown in Table 2. The criteria used in choosing these countries were: to represent all major EM regions; to have a relatively freely floating exchange rate, liberalised capital markets and independent monetary policy; and to be able to follow these for a relatively long period. The sample is dominated by the Latin American and the Europe, Middle East and Africa (EMEA) regions, while Asia—where floating exchange rates are less prevalent—has only a 10 percent weight.[4]

Table 2
The sample

	Sample	Observations
Brazil	1999M01-2010M07	138
Chile	1999M07-2010M07	133
Hungary	2001M06-2010M07	110
Israel	2004M06-2010M07	74
South Africa	2000M01-2010M07	127
Thailand	2004M03-2010M07	77
$\sum$		659

The variables chosen were the net foreign asset position as a percentage of GDP (NFA, which is our key variable), month on month inflation (INF), 1 month interbank interest rate (INT, the policy rate in case of Chile), EMBI spread[5] (CDS in the cases of Israel and Thailand), industrial production index (IPO), and real effective exchange rates (REER). The last two are measured as log deviations from HP-filtered trends. Monthly GDP (to standardise NFA) was approximated with a simple linear trend from the quarterly data. This is admittedly a very rough measure, but the overwhelming majority of the variance in the resulting NFA per GDP variable comes from the former part. All nonfinancial variables are seasonally adjusted.

Business cycle stylised facts show similarities across these countries,[6] however, the structure of their economies, export profiles, and trading partners can be very different. To capture these differences a wide array of exogenous variables were added to the model, all with flat prior coefficients. These were: short interest rates in the EMU, US and Japan, the VIX[7] index, industrial production in Germany and the US, and commodity indices from S&P (agriculture, copper, energy, gold and precious metals). The exact data sources can be found in the Appendix.

Standard deviations and contemporaneous correlations are displayed in Figure 3 and 4. The highest volatility can be found in Brazil and Hungary with both experiencing crises in the sample. Israel seems to be the calmest of these economies.

There is a fairly strong negative correlation between exchange rates and sovereign spreads, which suggests that this type of risk contributes significantly to exchange rate volatility. Again Israel is an exception. In some cases, there is also strong

[4] There is a technical reason why not to choose all countries from one region. When calculating the likelihood function of the model, it is convenient to assume that residuals across the panel are uncorrelated, and thus the full function can be written as a product of the individual countries' likelihoods. My experience is that within a region these residuals are strongly correlated even after conditioning for possible common exogenous factors. These spillover effects cannot be accounted for in this setup.

[5] This index is provided by J.P. Morgan and measures the spread on a dollar denominated sovereign bond yield relative to US Treasuries.

[6] See for example Agénor, McDermott, and Prasad (2000) and Benczúr and Rátfai (2005).

[7] Measures the implied volatility of S&P index options, which is considered as a good proxy for the risk taking capacity of financial firms. For example see Brunnermeier, Nagel, and Pedersen (2008).

Table 3
Standard deviations

(%)

	BRA	CHL	HUN	ISR	SAF	THL
Net capital flow	5.80	9.30	13.99	8.93	10.62	7.70
Inflation	0.41	0.42	0.28	0.31	0.44	0.58
Industrial prod.	3.76	2.04	5.10	3.15	3.59	5.57
Interest rate	4.66	2.07	1.91	1.52	2.16	1.41
REER	8.08	4.10	4.21	2.61	8.03	2.49
EMBI	4.27	0.72	1.23	0.56	1.15	0.66

comovement between the sovereign spread and domestic interest rates. This suggests a systematic reaction to risk shocks by central banks.

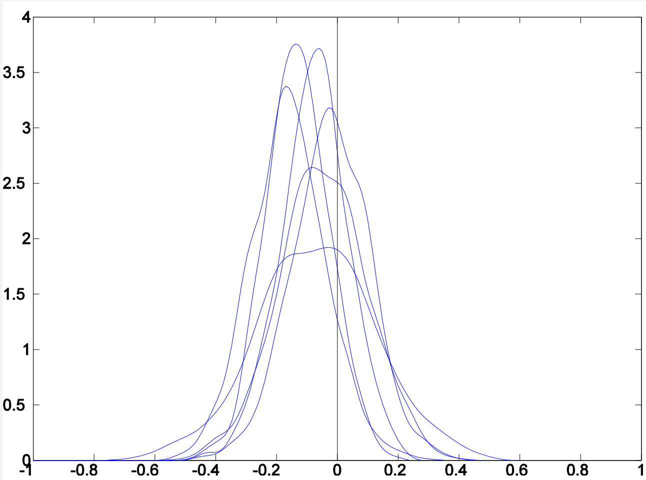
Table 4
Correlations

	Brazil					Chile				
	IPO	EMBI	R1M	REER	NCF	IPO	EMBI	R1M	REER	NCF
INF	0.0	0.2	0.3	−0.1	−0.2	0.1	−0.2	0.3	0.1	0.1
IPO		−0.1	−0.3	0.4	0.2		−0.2	0.0	0.2	0.1
EMBI			0.6	−0.4	−0.3			0.4	−0.3	0.1
R1M				−0.4	−0.1				−0.0	0.2
REER					0.1					0.0
	Hungary					Israel				
INF	0.1	−0.1	0.1	−0.2	0.0	−0.0	0.1	−0.2	−0.2	−0.0
IPO		−0.2	−0.1	0.1	−0.2		−0.3	0.2	0.3	−0.1
EMBI			−0.0	−0.3	−0.0			−0.8	0.2	0.3
R1M				−0.1	−0.0				0.1	−0.2
REER					0.1					−0.1
	South Africa					Thailand				
INF	0.2	0.0	0.3	−0.4	0.0	0.2	−0.3	−0.0	0.0	0.1
IPO		−0.3	0.3	−0.1	0.1		−0.5	0.1	0.3	−0.2
EMBI			0.5	−0.3	−0.0			−0.2	−0.2	0.2
R1M				−0.4	0.0				−0.3	0.1
REER					−0.0					0.0

4 Results

In the baseline model, λ was set to 0.0001 (somewhat higher than Jarociński's posterior mean) and $\rho_k = T_k$. This results in a relatively strong pooling, but interesting differences still emerge, and robustness checks with looser priors are shown later.

Figure 2
Posterior densities of the correlation coefficient between the residuals of the exchange rate and domestic interest rate



Looking at the posterior distributions of the correlation between the real exchange rate's and interest rate's error terms in Figure 2. gives some insight into the relative importance of risk shocks. Monetary, technology or demand shocks move interest rates and the exchange rate in the same direction (here a rise in the exchange rate is an appreciation); however, in all cases the posterior mean of this correlation is negative. This might be explained by the endogenous reaction of monetary policy to exchange rate shocks, and it stresses the need to properly distinguish monetary shocks from risk shocks when analysing monetary transmission in emerging economies.

Three lags are included in the VAR (both for the endogenous and exogenous variables). Specifications were estimated with up to nine lags, but those results were qualitatively the same, though much noisier.

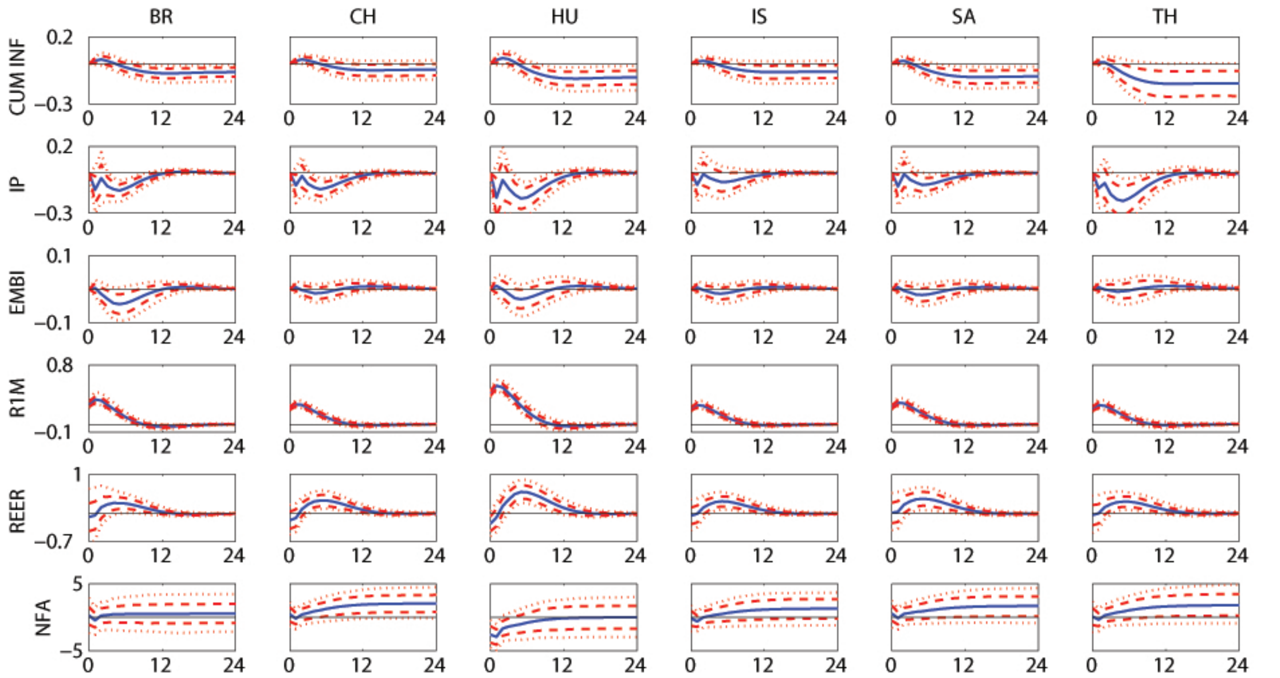
Appearing in the following graphs are inflation (CUM INF) cumulatively (i.e. the log of CPI), industrial production (IP) and real effective exchange rate (REER) as the deviation from HP-trend, sovereign spread (EMBI), interest rates (R1M) in levels and net foreign asset (NFA) as a percentage of GDP.

4.1 MONETARY SHOCKS

Responses for a monetary shock in the baseline model are plotted in Figure 3. These are approximately 25 basis points of unexpected hikes in the interest rate and last about nine months. There is a price puzzle in most of the countries as inflation is above steady state for 1-2 months after a positive interest rate shock, but subsequently inflation declines and brings CPI significantly under its initial value. The industrial production gap is negative, between $t+3$ to $t+12$. For the

Figure 3
Monetary policy shock

(%, baseline model, 5, 16, 50, 84, 95 percentiles)



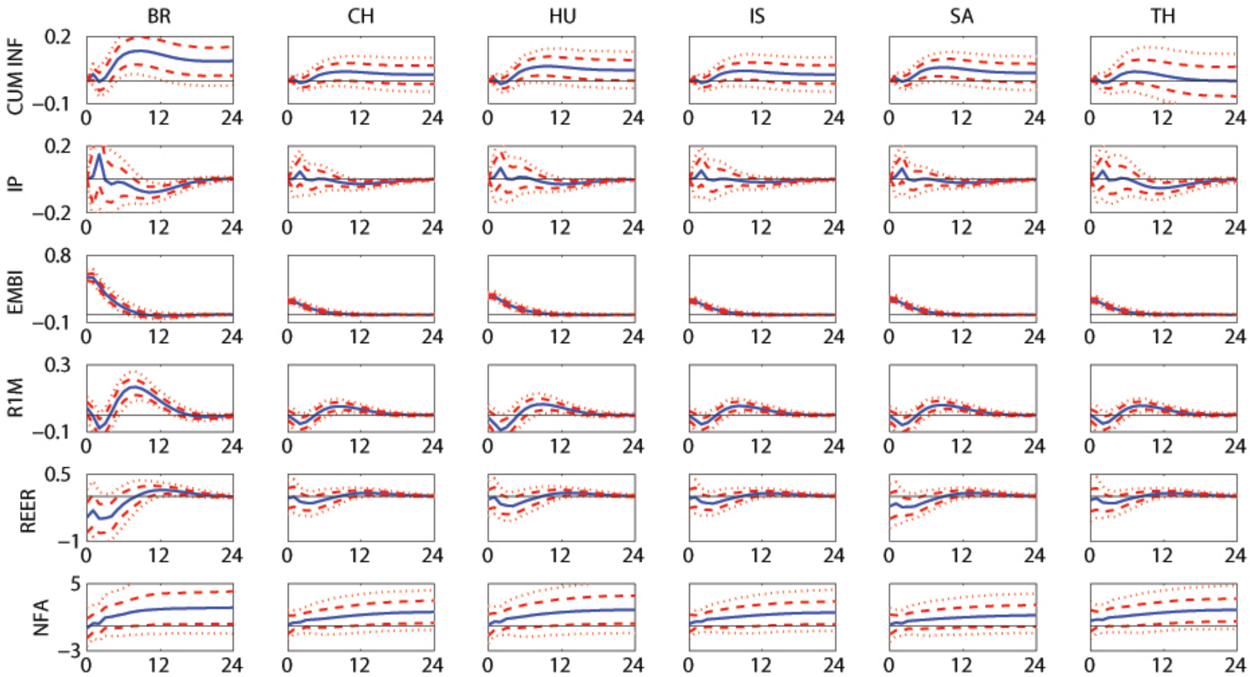
most important variables, there appear to be no contradictions in these findings with the mainstream view of the monetary transmission mechanism. A positive interest rate shock is disinflationary and contractionary. The only notable difference from the seminal VAR findings of advanced economies is that the transmission is found to be much faster. The interest rate shock exerts all of its effects in a year. This finding is not uncommon in SME samples (for example, see Cushman and Zha (1997) and Jarociński (2010)). The sovereign spread declines somewhat in most countries, but rarely significantly. This is consistent with my assumption that this variable is not affected by monetary shocks. Contrary to economic theory there is no immediate appreciation in countries either, and in some cases (Chile and Hungary) the exchange rate even depreciates on impact. However, there is a significant appreciation later on, before the CPI starts to decline, meaning that the nominal exchange rate appreciates as well. This delayed overshooting takes 3-6 months, and then the exchange rate starts depreciating towards steady state. The net foreign asset position improves in four countries, is practically unaffected in Brazil, and worsens for a short period only in Hungary. Overall the hypothesis that high interest rates result in more net capital inflows is barely supported by the data. Adding to this the negative industrial production gap and disinflation, these results are clearly at odds with the carry trade channel hypothesis.

4.2 RISK SHOCKS

In Figure 4. impulse responses to a unfavourable risk shock are shown. It manifests in a 50 basis point increase in the EMBI spread in Brazil and around 10 in other countries. In all cases, NFA improves persistently, which is consistent with theory. As foreign financing becomes more expensive, domestic agents want less of it. Surprisingly, the exchange rate does not depreciate on impact (with the exception of Brazil). For about a year after, the real exchange rate's point estimates are below the zero line (meaning a depreciation), but barely significantly so. Monetary policy's reaction to these shocks is of particular importance. For about three months, there is a small decline in interest rates, and then central banks clearly and persistently tighten and hike interest rates. This might be the reason why exchange rates do not depreciate materially. Thus rather than trying to counteract the contractionary (stimulating) effect of capital outflows (inflows) by cutting (raising) interest rates, central banks seem to smooth the exchange rate, or focus on short term inflation. This shock does not have an effect in industrial production for about nine months. Probably this is a result of contradicting

Figure 4
Domestic risk shock

(%, baseline model, 5, 16, 50, 84, 95 percentiles)



forces: the weaker real exchange rate increases foreign demand, while higher financing costs harms production. After nine months production starts to decline. With the normalisation of the exchange rate only the negative forces prevail: both foreign (the original shock) and domestic financing (central bank's reaction) have become more expensive. Finally, the very same pattern emerges when looking at inflation dynamics. After three months, the weaker exchange rate passes through to domestic prices. Later on—with the shrinking of domestic demand due to interest rate hikes—CPI declines. This disinflation is most striking in Brazil and Thailand.

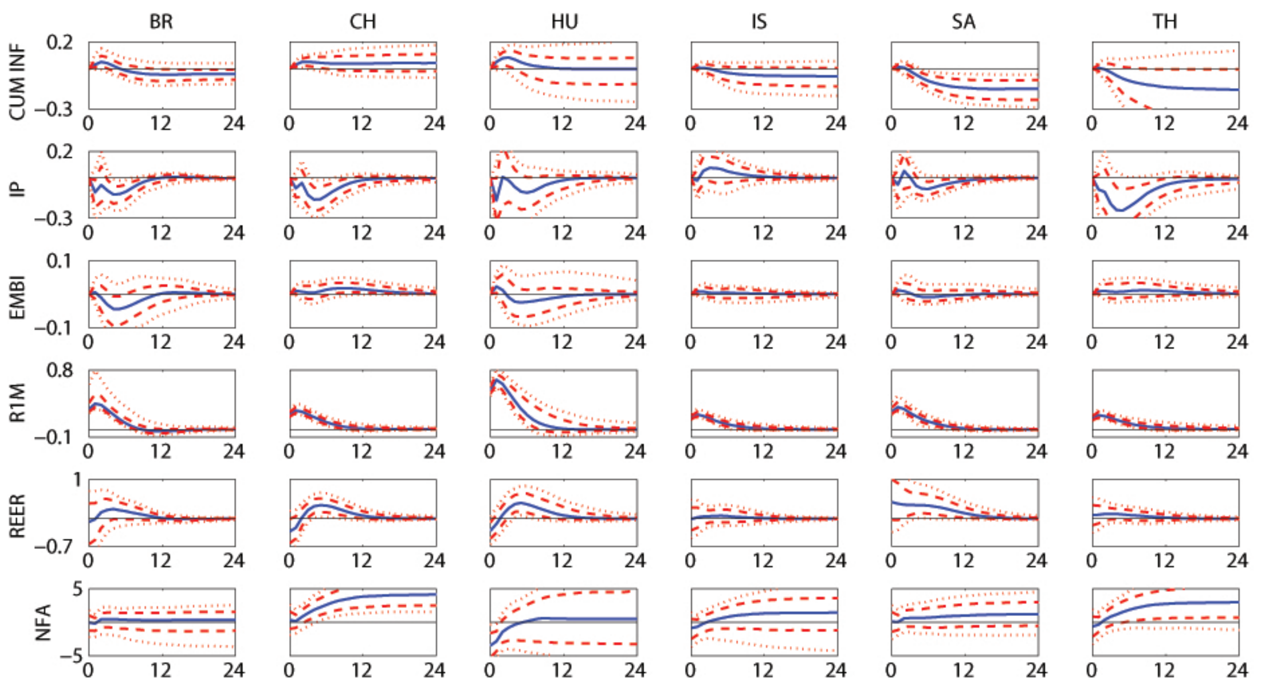
5 Robustness checks

In this section, two alternative specifications are presented. One obvious robustness check is to loosen the priors of the parameters. Here the prior variance of the VAR parameters are ten times larger than in the baseline model and the weight of the hierarchical part in the mean of the posterior residual covariance matrices is cut in half. A second deviation from the baseline model is a restricted panel, leaving Israel out of the estimation. The reason behind this is that in the first robustness check, Israel proved to be an outlier. Perhaps this is because it is more of a developed than an emerging economy.

5.1 LOOSER PRIORS

Figure 5
Monetary policy shock

(%, loose priors, 5, 16, 50, 84, 95 percentiles)

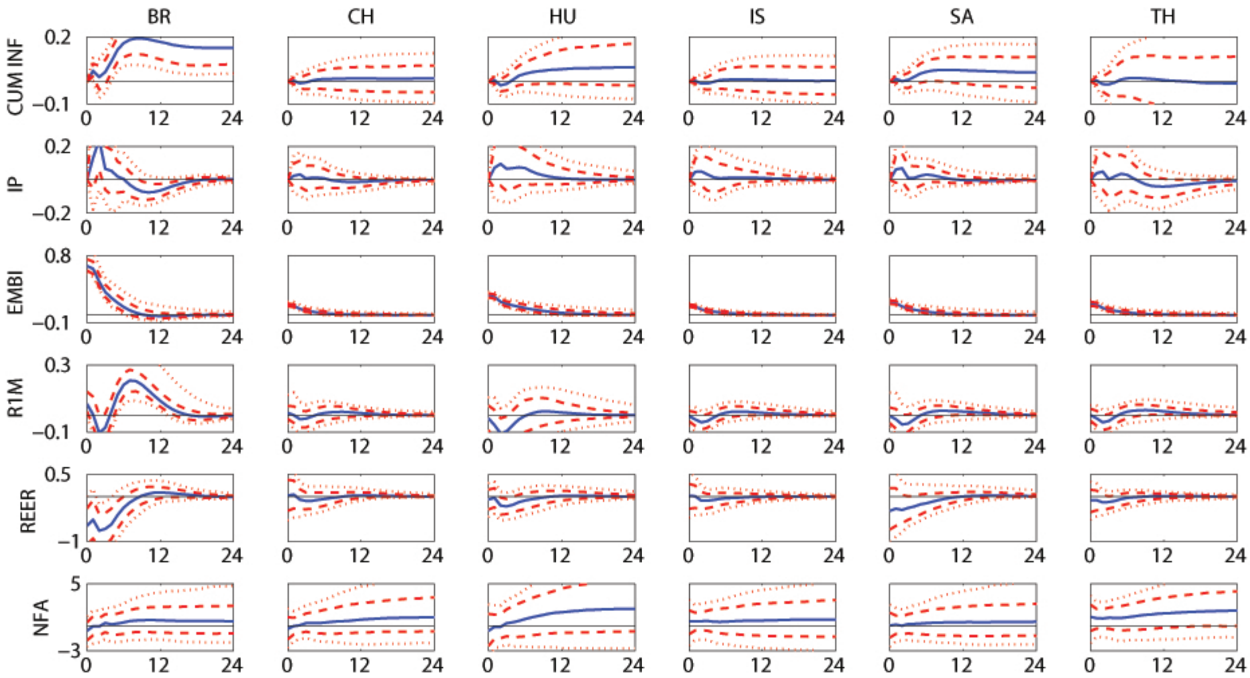


When the model is estimated with less weight given to the hierarchical prior, naturally country-specific differences are magnified. IRFs of an interest rate shock are shown in Figure 5. Most notable differences emerge in Chile, Hungary and Israel. In the former two cases, monetary shocks do not decrease—or even increase—the price level and depreciate the real exchange rate on impact. However the carry trade channel hypothesis is not supported in these cases either, as there are capital outflows (increases in the NFA variable) when the real exchange rates start appreciating and real activity also shrinks. In Israel, no endogenous variables react significantly to monetary shocks.

Risk premium shocks shown in Figure 6 are not well identified in this specification, except in Brazil. There it leads to a depreciation of the exchange rate, an interest rate defence from the central bank, inflation in the short run and below

Figure 6
Domestic risk shock

(%, loose priors, 5, 16, 50, 84, 95 percentiles)



average inflation in the medium-term. Industrial production improves, possibly due to real depreciation, but later slows as a result of tighter credit conditions. There is some—though not significant—capital outflow. In the other countries, almost no IRF is significant at any standard level.

5.2 5 COUNTRY SAMPLE

In the previous subsection, Israel proved to be an outlier as practically none of its impulse responses were significant at any point of time. This might be explained by the fact that it is the most developed of all the examined countries, and perhaps the monetary transmission and propagation of risk shocks are materially different than in the rest of the panel. As this might have distorted our estimates in the baseline model, it was reestimated only using data from the remaining five countries. As can be seen in Figure 5.2, error bands are thinner. There is still some price puzzle and delayed overshooting in the case of monetary shocks. The following capital outflow is now significant in Chile and marginally so in South Africa and Thailand. The capital inflow disappears quickly in Hungary.

There is much more deviation from the baseline results in the case of risk shocks. Now we see significant depreciations in all countries. The cost of the exchange rate defence shown in Figure 8 is very clear. After an unfavourable risk shock, monetary policy tightens in all cases. This leads to below potential output and undershooting of the inflation target a year after the shock. This policy dilemma was emphasised by Gómez (2006), too.

Correspondingly, after a favourable risk shock (multiplying all IRFs by −1 on the graph), the central banks amplify overheating by cutting and not by raising interest rates. It seems that the price of exchange rate smoothing, the protection of the balance sheets, and a lower decline in the short run inflation is a medium-term overheating problem. It is the quite the opposite of the carry trade channel hypothesis: in the face of capital inflows, central banks seem to loosen—not tighten—monetary policy, which worsen the overheating through traditional channels.

Figure 7
Monetary policy shock

(%, 5 country sample, 5, 16, 50, 84, 95 percentiles)

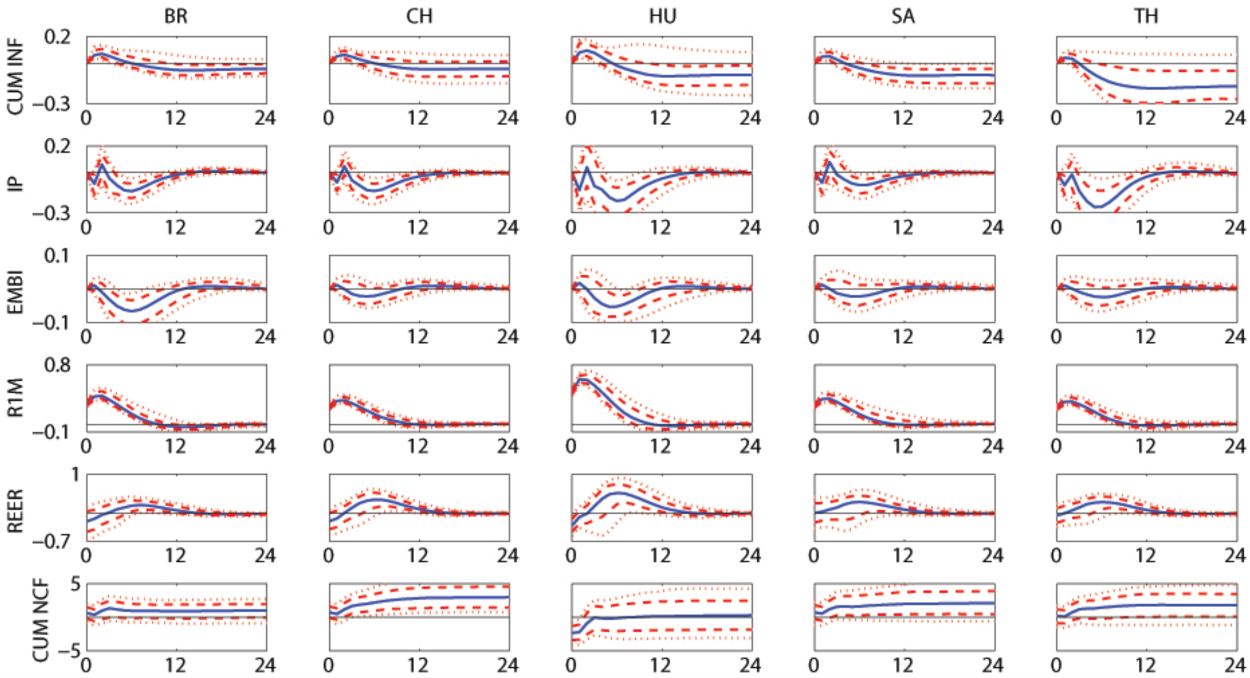
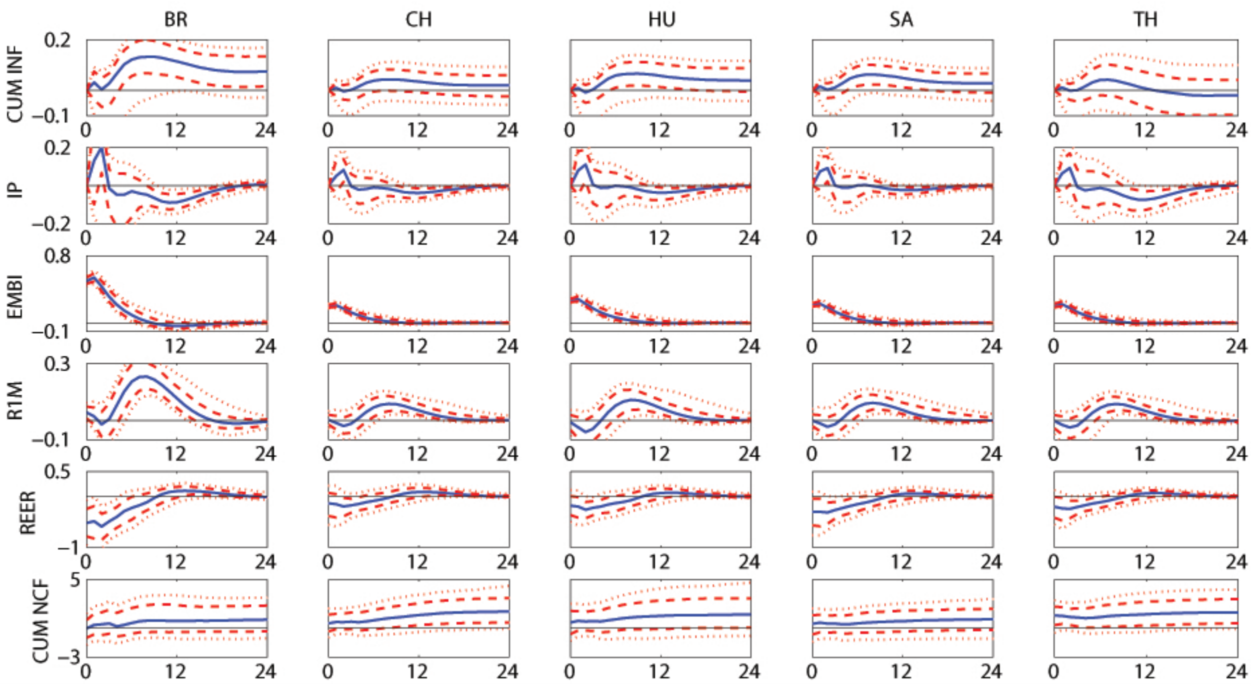


Figure 8
Domestic risk shock

(%, 5 country sample, 5, 16, 50, 84, 95 percentiles)



6 Conclusion

Often appearing in the press is the reasoning that monetary policy is less effective or even counterproductive in small, open, emerging market economies because speculative capital flows, chasing interest rate differentials weaken, or totally turn around the traditional monetary transmission mechanism. This has also become a very popular topic among central bankers. This paper is the first empirical test of this "carry trade channel of monetary policy" hypothesis. It investigates how monetary policy shocks affect net capital flows and other main macroeconomic variables in six emerging economies (Chile, Brazil, Hungary, Israel, South Africa and Thailand). It also analyses how monetary policy reacts to exogenous demand shocks for domestic financial assets, whether monetary policy is only ineffective in this case.

A robust finding is that unexpected monetary tightening is followed by a decline in production and inflation. There is no evidence that monetary tightening causes capital inflows. Essentially, this contradicts the carry trade channel hypothesis. These effects were not imposed on the model as identifying restrictions. There is no sign of a perverse effect of monetary policy in the data.

It is also tested how monetary policy reacts to an exogenous rise in the demand for home country's assets. These are the episodes of capital inflows. Interestingly, monetary policy loosens significantly and persistently in all countries. The reason for this can be twofold. First, because of balance sheet vulnerabilities, central banks lean against the wind when facing exchange rate volatility. Secondly, the resulting currency appreciation results in a strong decline in inflation in the short-term, which is the central banks' target variable, and they may try to dampen this shock. The lower risk premia (the original capital inflow shock) and the lower real interest rates (monetary policy's reaction) increase industrial production and inflation between 6-12 months after the shock. From this point of view, emerging market central banks really seem to amplify the effect of capital flows. However, this is the result of a pro-cyclical policy, not a counter-cyclical one.

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Appendix A Conditional posteriors

The full posterior:

$$f(\Delta|\mathbf{Y}_1,\ldots,\mathbf{Y}_K) \propto \prod_{i=1}^{K}[f(\mathbf{Y}_i|\Delta_i)f(\mathbf{b}_i|\bar{\mathbf{b}},\Lambda_i)f(\Sigma_i)]. \tag{6}$$

where $\Delta_i \doteq \{\mathbf{f}_i,\mathbf{b}_i,\Lambda_i,\Sigma_i\}$, $\Delta \doteq \{\bar{\mathbf{b}},\mathbf{R},\Delta_1,\ldots,\Delta_K\}$.

THE LIKELIHOOD FUNCTION

The likelihood can be written either as:

$$L \propto |\Sigma_k|^{-T_k/2}e^{-\frac{1}{2}\mathrm{tr}\left[(\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)\Sigma_k^{-1}(\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)'\right]}, \tag{7}$$

where $\mathbf{Y}_k^* = \mathbf{Y}_k - \mathbf{W}\mathbf{F}_k$, or as:

$$L \propto |\Sigma_k \otimes \mathbf{I}_{T_k}|^{-TN/2}e^{-\frac{1}{2}\mathrm{tr}\left[(\mathbf{y}_k-(\mathbf{I}_N\otimes\mathbf{X}_k)\mathbf{b}_k)'(\Sigma_k^{-1}\otimes\mathbf{I}_{T_k})(\mathbf{y}_k-(\mathbf{I}_N\otimes\mathbf{X}_k)\mathbf{b}_k)\right]}, \tag{8}$$

where $\mathbf{y}_k = \mathrm{vec}(\mathbf{Y}_k^*)$.

CONDITIONAL POSTERIOR FOR Σ_K

$$\begin{aligned} f(\Sigma_k|\Delta_{-\Sigma_k}) &\propto f(\mathbf{Y}_k|\Delta_k)f(\Sigma_k) \\ &\propto |\Sigma_k|^{-T/2}e^{-\frac{1}{2}\mathrm{tr}\left[(\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)\Sigma_k^{-1}(\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)'\right]} \\ &\quad\times |\Sigma_k|^{-\frac{N+\rho+1}{2}}e^{-\frac{1}{2}\mathrm{tr}(\mathrm{R}\Sigma_k^{-1})} \\ &= |\Sigma_k|^{-\frac{N+(\rho+T)+1}{2}}e^{-\frac{1}{2}\mathrm{tr}\left[\left((\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)'(\mathbf{Y}_k^*-\mathbf{X}_k\mathbf{B}_k)+\mathrm{R}\right)\Sigma_k^{-1}\right]}. \end{aligned} \tag{9}$$

Which is the kernel of a Wishart distribution:

$$\begin{aligned} f(\Sigma_k|\Delta_{-\Sigma_k}) &= \mathcal{W}^{-1}(\rho_k,\mathbf{R}_k) \\ \rho_k &= \rho + T \\ \mathbf{R}_k &= \mathbf{R} + (\mathbf{Y}_k^* - \mathbf{X}_k\mathbf{B}_k)'(\mathbf{Y}_k^* - \mathbf{X}_k\mathbf{B}_k). \end{aligned} \tag{10}$$

CONDITIONAL POSTERIOR FOR $\mathbf{b}_K$

$$\begin{aligned} f(\mathbf{b}_k|\Delta_{-\mathbf{b}_k}) &\propto f(\mathbf{Y}_k|\Delta_k)f(\mathbf{b}_k|\bar{\mathbf{b}},\Lambda_k) \\ &\propto e^{-\frac{1}{2}\mathrm{tr}\left[(\mathbf{y}_k-(\mathbf{I}_N\otimes\mathbf{X}_k)\mathbf{b}_k)'(\Sigma_k^{-1}\otimes\mathbf{I}_T)(\mathbf{y}_k-(\mathbf{I}_N\otimes\mathbf{X}_k)\mathbf{b}_k)\right]} \\ &\quad\times e^{-\frac{1}{2}\mathrm{tr}\left[(\mathbf{b}_k-\bar{\mathbf{b}})'\Lambda_k^{-1}(\mathbf{b}_k-\bar{\mathbf{b}})\right]} \end{aligned} \tag{11}$$

After collecting terms involving $\mathbf{b}_k$ in the exponent we get:

$$f(\mathbf{b}_k|\Delta_{-\mathbf{b}_k}) \propto e^{-\frac{1}{2}\left[\mathrm{tr}\left(\mathbf{b}_k'\mathbf{b}_k(\Lambda_k^{-1}+\Sigma_k^{-1}\otimes(\mathbf{X}_k'\mathbf{X}_k))\right)-2\,\mathrm{tr}\left(\mathbf{b}'[\Lambda_k^{-1}\bar{\mathbf{b}}+(\Sigma_k^{-1}\otimes\mathbf{X}_k)'\mathbf{y}_k]\right)\right]}. \tag{12}$$

Which is the kernel of a normal distribution:

$$\begin{aligned} f(\mathbf{b}_k|\Delta_{-\mathbf{b}_k}) &= \mathcal{N}(\bar{\mathbf{b}}_k,\bar{\Lambda}_k) \\ \bar{\Lambda}_k &= \left(\Lambda_k^{-1} + \Sigma_k^{-1}\otimes(\mathbf{X}_k'\mathbf{X}_k)\right)^{-1} \\ \bar{\mathbf{b}}_k &= \bar{\Lambda}_k[\Lambda_k^{-1}\bar{\mathbf{b}} + (\Sigma_k^{-1}\otimes\mathbf{X}_k)'\mathbf{y}_k]. \end{aligned} \tag{13}$$

CONDITIONAL POSTERIOR FOR $\bar{\mathbf{b}}$

$$\begin{aligned} f(\bar{\mathbf{b}} \mid \Delta_{-\bar{\mathbf{b}}}) &\propto \prod_{i=1}^{K} [f(\mathbf{b}_i \mid \bar{\mathbf{b}}, \Lambda_i)] \\ &\propto \prod_{i=1}^{K} e^{-\frac{1}{2}\operatorname{tr}\left[(\mathbf{b}_i - \bar{\mathbf{b}})'\Lambda_i^{-1}(\mathbf{b}_i - \bar{\mathbf{b}})\right]} \\ &\propto e^{-\frac{1}{2}\left[\operatorname{tr}(\bar{\mathbf{b}}'\bar{\mathbf{b}}\sum_{i=1}^{K}\Lambda_i^{-1}) - 2\operatorname{tr}(\bar{\mathbf{b}}'\sum_{i=1}^{K}\Lambda_i^{-1}\mathbf{b}_i)\right]}. \end{aligned} \tag{14}$$

Which is the kernel of a normal distribution:

$$\begin{aligned} f(\bar{\mathbf{b}} \mid \Delta_{-\bar{\mathbf{b}}}) &= \mathcal{N}(\bar{\bar{\mathbf{b}}}, \bar{\Lambda}) \\ \bar{\Lambda} &= \left(\sum_{i=1}^{K} \Lambda_i^{-1}\right)^{-1} \\ \bar{\bar{\mathbf{b}}} &= \bar{\Lambda}\left(\sum_{i=1}^{K} \mathbf{b}_i \Lambda_i^{-1}\right). \end{aligned} \tag{15}$$

CONDITIONAL POSTERIOR FOR $\mathbf{R}$

$$\begin{aligned} f(\mathbf{R} \mid \Delta_{-\mathbf{R}}) &\propto \prod_{i=1}^{K} [f(\Sigma_i)] \\ &\propto \prod_{i=1}^{K} |\mathbf{R}|^{\frac{\rho}{2}} e^{-\frac{1}{2}\operatorname{tr}(\mathbf{R}\Sigma_i^{-1})}. \end{aligned} \tag{16}$$

Which is the kernel of a Wishart distribution:

$$\begin{aligned} f(\mathbf{R} \mid \Delta_{-\mathbf{R}}) &= \mathcal{W}(\bar{\rho}, \bar{\mathbf{R}}) \\ \bar{\rho} &= K\rho + N + 1 \\ \bar{\mathbf{R}} &= \left(\sum_{i=1}^{K} \Sigma_i^{-1}\right)^{-1}. \end{aligned} \tag{17}$$

Appendix B Data sources

Data	Source
Brazil	
Nominal GDP	IMF IFS
Change in NFA	IMF IFS
Industrial production	IBGE
REER	BIS
CPI	IMF IFS
Selic target rate	Banco Central do Brasil
Chile	
Nominal GDP	IFS
Change in NFA	IMF IFS
Industrial production	Instituto Nacional de Estadisticas
REER	BIS
CPI	Instituto Nacional de Estadisticas
Policy interest rate	Banco Central de Chile
Hungary	
Nominal GDP	OECD
Change in NFA	IMF IFS
Industrial production	Hungarian Central Statistical Office
REER	National Bank of Hungary
CPI	OECD
1 month interbank deposit rate	National Bank of Hungary
Israel	
Nominal GDP	Central Bureau of Statistics
Change in NFA	IMF IFS
Industrial production	Central Bureau of Statistics
REER	BIS
CPI	Central Bureau of Statistics
1 month interbank deposit rate	Thomson Reuters
South Africa	
Nominal GDP	IMF IFS
Change in NFA	IMF IFS
Industrial production	Thomson Reuters
REER	BIS
CPI	IMF IFS
1 month interbank deposit rate	SAFEX
Thailand	
Nominal GDP	Office of Nat. Econ. & Soc. Dev.
Change in NFA	IMF IFS
Industrial production	Office of Industrial Economics
REER	BIS
CPI	Bureau of Trade and Economic Indices
1 month interbank deposit rate	Bank of Thailand
Exogenous variables	
Agricultural commodity index	S&P
Precious metal index	S&P
Copper index	S&P
Petroleum index	S&P

Data	Source
1 month interbank deposit rate (USD)	BBA
1 month interbank deposit rate (EUR)	Deutsche Bundesbank
1 month interbank deposit rate (JPY)	BBA
VIX index	CBOE
IPO USA	Federal Reserve
IPO Germany	Deutsche Bundesbank
IPO China	National Bureau of Statistics
IPO Japan	Ministry of Economy, Trade & Industry

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