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Self-Oriented Monetary Policy, Global Financial Markets and Excess Volatility of International Capital Flows ☆

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Abstract

This paper explores the nature of macroeconomic spillovers from advanced economies to emerging market economies (EMEs) and the consequences for independent use of monetary policy in EMEs. We first empirically document the effects of US monetary policy shocks on a sample group of EMEs. A contractionary monetary shock leads a retrenchment in EME capital flows, a fall in EME GDP, and an exchange rate depreciation. We construct a theoretical model which can help to account for these findings. In the model, macroeconomic spillovers are exacerbated by financial frictions. We assess the extent to which domestic monetary policy can mitigate the negative spillovers from foreign shocks. Absent financial frictions, international spillovers are minor, and an inflation targeting rule represents an effective policy for the EME. With frictions in financial intermediation, however, spillovers are substantially magnified, and an inflation targeting rule has little advantage over an exchange rate peg. However, an optimal monetary policy markedly improves on the performance of naive inflation targeting or an exchange rate peg. Furthermore, optimal policies don't need to be coordinated across countries. Under the specific set of assumptions maintained in our model, a non-cooperative, self-oriented optimal policy gives results very similar to those of a global cooperative optimal policy.

Keywords: International spillovers, Local Projections, Capital flows, Financial intermediaries, Monetary policy.

JEL: E3, E5, F3, F5, G1.

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1. Introduction

In recent years, the global economy has seen dramatic examples of volatility in capital flows to emerging market countries. Following the global financial crisis and the subsequent rapid monetary easing in the US and other advanced economies, there was a period of large capital inflows into many fast growing EMEs such as China, India and Brazil. In 2013, the threat of a US monetary 'taper' led to an abrupt reversal of inflows to many emerging economies. The defining characteristic of these two episodes is that capital flows were driven to a large degree by macroeconomic and financial conditions in the advanced economies, especially those in the US. Although the size of the US economy relative to world GDP has fallen in recent decades, the US still plays an outsized role in the global financial system (e.g. Fischer, 2014), one reason being the overwhelming predominance of the US dollar as a funding currency for global capital flows.

There is substantial empirical evidence linking international capital flows to US asset prices and US monetary policy. Rey (2013), Miranda-Agrippino and Rey (2014), and Bruno and Shin (2015) describe a 'global financial cycle' in which capital flows to many countries are highly positively correlated and closely tied to US monetary policy. Miranda-Agrippino and Rey (2014) find that a tightening of US monetary policy leads to a spike in global risk aversion, a fall in cross border lending, and a fall in asset prices at a global level. They identify a single global factor that can explain a large part of the movement in cross border credit flows, as well as domestic credit growth. Moreover, this factor can be related to changes in US policy rates.

A major policy question arising from these events is whether US monetary policy imparts a global 'externality' through spillover effects on world capital flows, credit growth and asset prices. Many policy makers in emerging markets (e.g. Rajan, 2014) have argued that the US Federal Reserve should adjust its monetary policy decisions to take account of the excess sensitivity of international capital flows to US policy. This criticism questions the view that a 'self-oriented' monetary policy based on inflation targeting principles represents an efficient mechanism for the world monetary system (e.g. Obstfeld and Rogoff, 2002), without the need for any cross-country coordination of policies.

A related question is whether EMEs that find themselves excessively affected by capital flow volatility need more policy tools besides interest rate and exchange rate adjustment. Rey (2013) argues that for small open countries in present day global financial markets, the classic policy 'trilemma' which states that independent policy may be followed provided the exchange rate is flexible, in fact collapses to a 'dilemma', since exchange rate adjustment cannot easily insulate against large reversals in capital flows. The 'dilemma' is one where emerging market countries can either maintain an open capital account but remain vulnerable to the global financial cycle, or choose to impose capital controls in order to achieve a greater degree of macro policy independence.

Our paper provides empirical as well as theoretical analysis of international spillovers, their consequence for the design of monetary policy, and the desirability of 'self-oriented' monetary policy. We add to the empirical literature on macroeconomic spillovers by examining the impact of US monetary policy shocks on EMEs using a panel of 16 emerging market countries. US monetary policy shocks are identified as in Coibion et al. (2012), who provide an update to the Romer and Romer (2004) shocks. We examine the response of EME policy rates, exchange rates, GDP, inflation, and gross capital flows to these shocks. The estimation is based on the local projection method proposed by Jordà (2005). We find that an unexpected US monetary policy tightening leads to a fall in EMEs' economic activity, a rise in policy rates, an exchange rate depreciation, and a retrenchment of capital flows; that is, a fall in both capital inflows to EMEs and outflows from EMEs.

In the theoretical analysis, we develop a simple core-periphery DSGE model driven by monetary policy and financial shocks in the core country whose currency dominates the flows of financial capital across borders. Our model is based on the relationship between financial institutions in a large financial centre (global banks or asset managers) and borrowing banks or financial institutions in an emerging market country. We find that when these financial institutions face agency constraints which restrict the growth of their balance sheets, then monetary policy shocks or financial shocks in the centre country can produce many of the features of international capital flows described above. A monetary contraction in the centre leads to a sharp decline in capital inflows to the peripheral country, a fall also in outflows from the periphery, a real exchange rate depreciation in the periphery, and a rise in interest rate spreads which precipitates a coordinated downturn in real economic activity.

We find that, for the baseline calibration of our model, the response of asset prices and interest rate spreads in emerging economies to a monetary contraction in the centre country can in fact be larger than the direct responses of these variables in the centre country itself. Thus, sudden reversals in the monetary policy stance of the centre country can generate what looks like excessive responses in the financial markets of emerging economies. This is the case even if the emerging economy allows its exchange rate to adjust freely.

The key mechanism in the model is the magnification effect of shocks to the balance sheets of global lenders compounded with those of local emerging market borrowers. A monetary tightening in the centre country raises interest rates and funding costs for global lenders. This erodes their net worth, requiring them to reduce lending to local emerging market borrowers. In addition, EMEs experience an immediate real exchange rate depreciation. The combination of increased borrowing costs and unanticipated depreciation, which raises the costs of servicing existing debt, leads a sharp decline in net worth for emerging market borrowing institutions. This leads to a rise in spreads in emerging markets. We find that the spreads rise significantly more in the emerging market country than in the centre country, since they are subject to a 'double agency' effect. In contrast to a basic core-periphery DSGE model without constrained financial institutions, a simple inflation targeting rule (like a Taylor rule) does not insulate the peripheral economy from international monetary spillovers.

We go on to explore the implications of alternative policy and financial structures on the nature of financial and real spillovers. We ask how the nature of spillovers would differ if the emerging market were able to borrow in its own currency. This would eliminate the direct deterioration of balance sheets coming from exchange rate depreciation. We find in this case that the contraction in lending and the rise in spreads is mitigated somewhat, so that the impact on the real economy is smaller. But despite this, the emerging economy is still highly vulnerable to the cutback in direct capital flows and the increase in funding costs coming from the centre country, so that the overall magnitude of spillovers is still very large.

With frictionless financial markets, a pegged exchange rate magnifies the response of real variables to the external shock, as it curtails the required adjustment in the real exchange rate. But when global and local financial firms are subject to agency constraints, the magnitude of spillovers differs little between an exchange rate peg and an inflation targeting monetary policy.

We find similar results when we allow drivers of capital flows other than core country monetary shocks. Direct shocks to the financial system in the core country triggers many of the same features as those of the monetary shock described above.

These results would seem to support the 'dilemma' view. But in fact, we show that this conclusion does not follow when we study optimal monetary policy responses. A global cooperative monetary response to a financial downturn can largely eliminate the negative impact of the capital flow spillovers. For this response to work however, it is essential that the periphery country exploit the flexibility of its exchange rate. Thus, when an optimal cooperative monetary rule is considered, the policy 'trilemma' becomes relevant again.

Practically speaking, monetary policy is set at the national level, and especially for the countries at the financial centre, national considerations alone will dictate policy responses. Although naive inflation targeting monetary rules have poor properties in dealing with international spillovers in the presence of agency distortions in international financial intermediation, this does not mean that *any* self-oriented monetary policy is ineffective. We show that in a model with non-cooperative (Nash) optimal monetary policy game where both core and peripheral countries independently choose an optimal monetary policy. We find that, under the specific assumptions of our model, the outcome of the non-cooperative game is very similar to the optimal cooperative solution.

Our paper is related to a large literature on capital flows and the macroeconomics of EMEs. Many recent papers have documented the empirical features of capital flows and spillovers from advanced economies to emerging market economies. In particular Ahmed and Zlate (2014), Chen et al. (2015), Bowman et al. (2015), and Chen et al. (2014) examine the impact of the recent US unconventional monetary policy on emerging markets. Except for Chen et al. (2015), who look at the response of emerging market inflation and real GDP, these papers restrict their focus to the impacts on interest rates, asset prices and capital flows. Gilchrist et al. (2014) examine the effect of US monetary policy shocks including the period before unconventional monetary policies, but focus on the response of sovereign bond yields. Fratzscher et al. (2014) examine the impact of ECB unconventional monetary policies on emerging market asset prices. In addition, as discussed above, Rey (2013), and Miranda-Agrippino and Rey (2014), examine spillovers in capital markets using factor analysis to identify global shocks. In a recent work Dedola et al. (2015) provide empirical evidence of strong international spillovers of US monetary policy shocks. Using a BVAR, they identify monetary policy shocks by means of sign restrictions. Bluwstein et al. (2015) study spillovers from the euro area to nine non-euro European economies using a mixed-frequency BVAR. Among their findings: counties with more integrated financial markets and larger shares of banks react more strongly to ECB unconventional policies. The credit-channel plays a minor role in the transmission.

Our paper differs from this previous literature in a number of respects. In particular, we focus on US monetary policy shocks before the advent of the zero lower bound, we focus on the general macroeconomic response in a group of emerging market countries, including the response of interest rates, real GDP, inflation and capital flows, and rather than employing a restrictive VAR specification, we follow Jordà (2005) in using a local projection method to construct impulse response functions to US monetary shocks. In addition, we explore the response of both gross capital inflows and outflows to EMEs. [1]

The conceptual framework employed in our paper is similar to that of Bruno and Shin (2014), although our structural model and analysis is very different from their paper. In some respects our modelling strategy is close to the works by Devereux and Yetman (2010), Dedola and Lombardo (2012), Dedola et al. (2013), Ueda (2012), Kollmann et al. (2011), Kolasa and Lombardo (2014), Choi and Cook (2004), Perri and Quadrini (2011) Korinek (2014), and Nuguer (2014). These authors study various positive and normative aspects of international spillovers due to financial frictions. Our paper builds on these ideas to address the specific questions highlighted above. A closely related investigation is carried out by Agénor et al. (2014), who model a small-open-economy DSGE model with two-layers of financial intermediation. Their main focus is on financial market regulation and macro-prudential policy.

The rest of the paper is organized as follows. Section 2 discusses the empirical evidence and provides novel estimates of the response of EMEs' variables to US policy shocks. Section 3 develops the theoretical model. Section 4 discusses the parametrization of the model. Section 5 discusses monetary policy shocks, while Section 6 provides results on financial shocks. Sections 7 and 8 introduce the optimal (Ramsey) cooperative policy and the optimal non-cooperative policy, respectively. Section 9 compares the results under the different policy arrangements. Finally Section 10 offers some concluding remarks.

2. Capital Flows to Emerging Markets: Some recent evidence

In 2013 and 2014, emerging market economies experienced significant volatility in gross and net capital flows. Observers have attributed much of this to actual or prospective changes in monetary policy in advanced economies. But in fact, highly volatile capital flows are a fact of life for emerging market countries. Figure 2.1 illustrates net flows into emerging market portfolio funds for a group of emerging markets since 2009. Following the highly accommodative monetary policies of advanced countries in 2009-2010, there was a significant uptick in net inflows to emerging markets. This continued with some volatility until 2013, when the proximate cause of the US 'taper' announcement led to large outflows from EME countries, both in bonds and equity assets.

Figure 2.2 shows the currency composition of emerging economies net issuance of debt securities over the past four years. A significant fraction of new issues remain denominated in foreign currencies, with the US dollar still representing the major share of these. The right hand panel of Figure 2.2 shows that the US dollar comprises about 90 percent of the outstanding stock of debt securities for this representative group of EMEs.

[1] Alberola et al. (2012) look at the response of gross foreign outflows as well as gross inflows to EMEs during episodes of financial crises. As in our empirical and theoretical analysis, they show that financial crises may be associated with a retrenchment of capital flows - there is a fall in both inflows to EMEs and outflows from EMEs. They show however that this response is critically related to the size of foreign exchange reserve holdings - EME economies with higher FX reserves tend to see a greater fall in capital outflows during financial crises. Our formal analysis abstracts from the importance of FX reserves. We further discuss the implication of explicitly allowing a role for FX reserves below.

Figure 2.1: Capital Flows to EMEs

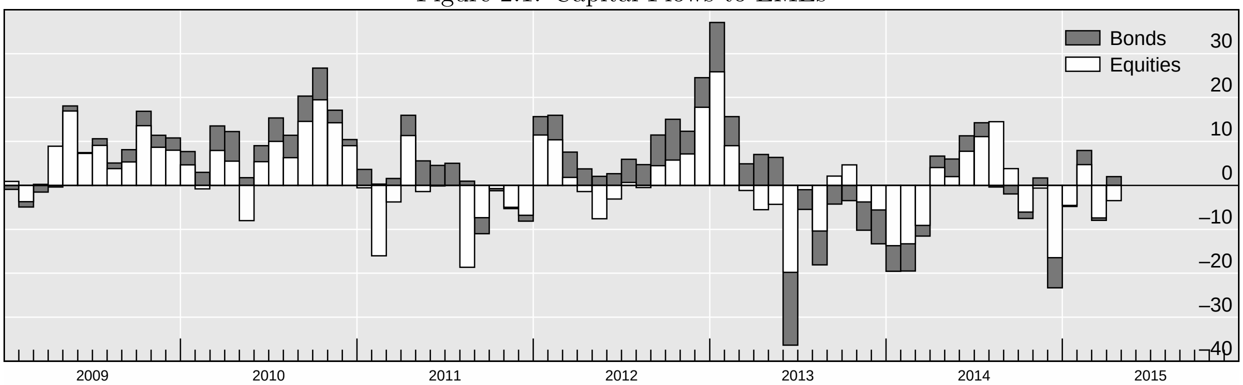
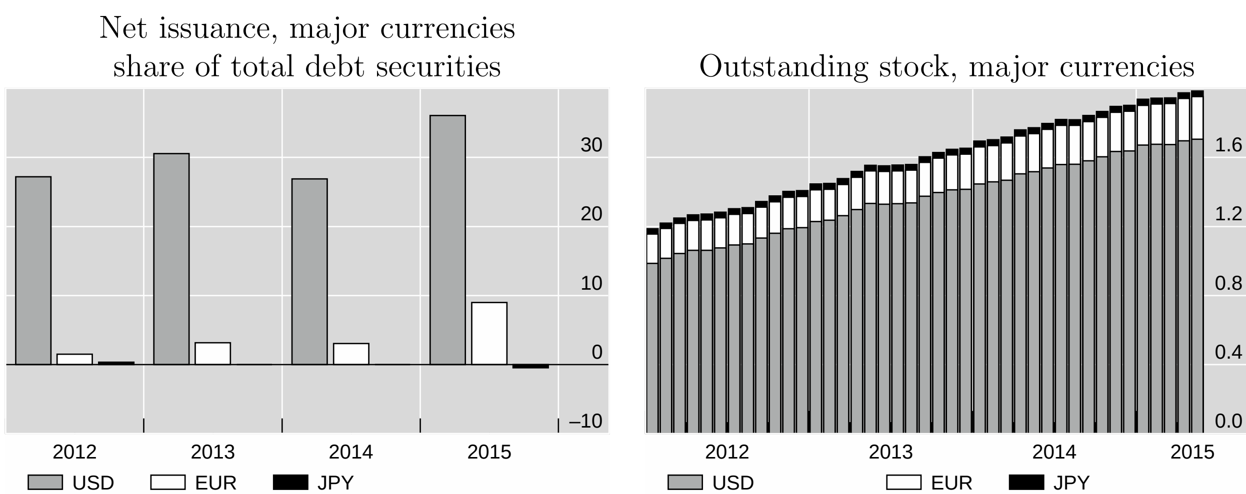


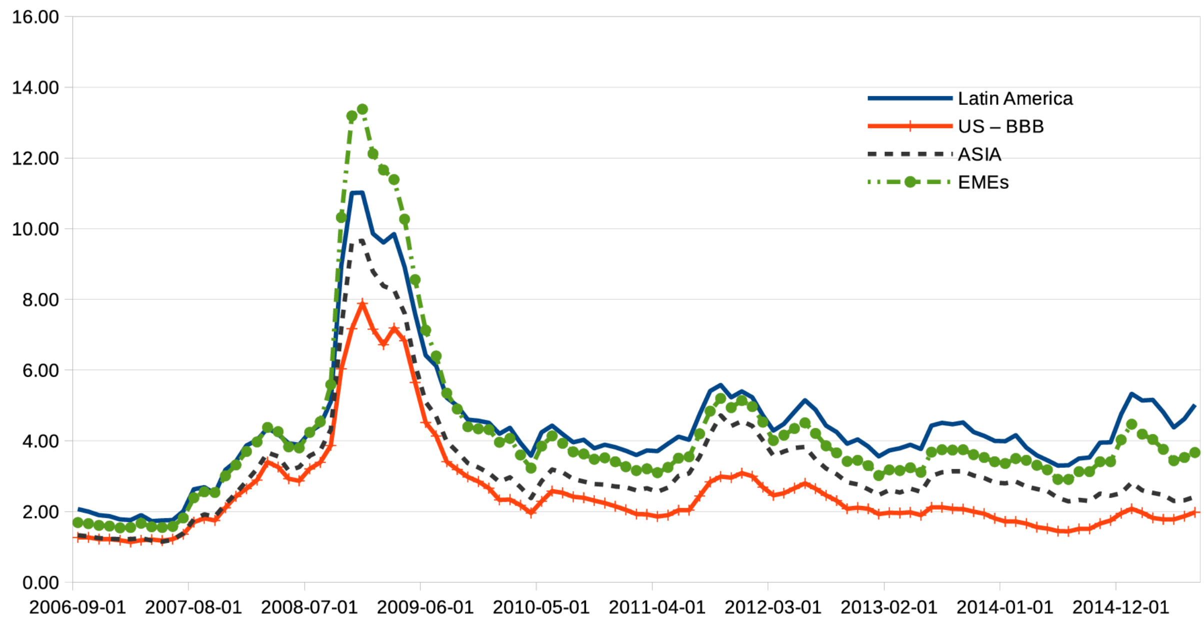
Figure 2.2: Currency Exposure for EMEs



All issuers, all maturities, by nationality of issuer. Countries: Argentina, Brazil, Chile, China, Colombia, the Czech Republic, Hong Kong SAR, Hungary, India, Indonesia, Israel, Malaysia, Mexico, Peru, the Philippines, Poland, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Thailand and Turkey. Data up to 13 April 2015.

Sources: Dealogic; Authors' calculations.

Figure 2.3: High Correlation of Spreads.



Source: BofA Merrill Lynch – option-adjusted spreads – retrieved from FRED, Federal Reserve Bank of St. Louis.

Our theoretical analysis of spillovers depends in a central way on the correlation of interest rate spreads across countries. Figure 2.3 illustrates the path of interest rate spreads in the US domestic economy, in Asia, Latin America and Emerging Markets generally. The US domestic issue on average has the lowest risk spreads, but clearly there is an extremely high correlation between all the spreads. We also see that the jump in spreads in EMEs during the 2008-9 financial crisis far exceeded the analogous increase in the US.

2.1. Empirical estimates of US monetary policy shocks spillovers to EMEs

As a backdrop to our theoretical analysis, we wish to document some general features of macroeconomic spillovers to emerging market economies. We do this by focusing on the response to one particular shock; a US monetary policy shock. In order to empirically examine how US monetary policy spills over to EMEs, we estimate the response of a number of EMEs' economic variables to an unexpected US monetary policy contraction. We identify monetary policy shocks following Coibion et al. (2012), who update the Romer and Romer (2004) estimates of US monetary policy shocks. Unlike the recent literature on the impacts of unconventional US monetary policy, our policy shocks are focused on the experience before the zero interest rate period.

Rather than explicitly specifying a VAR model, we following (Jordà, 2005) in using local projection techniques to estimate the impact of US monetary policy shocks across different economic states in a panel of emerging economies. We estimate the impact of the policy shock in period t labeled MS_t, on the variable of interest $y_{i,t+h}$ in country i at time $t+h$ from the following local projection

$$y_{i,t+h} - y_{i,t-1} = \alpha^h + \theta^h MS_t + \gamma^h w_{i,t-1} + \epsilon_{i,t+h} \text{ for} h = 0, 1, ..., H \quad (2.1.1)$$

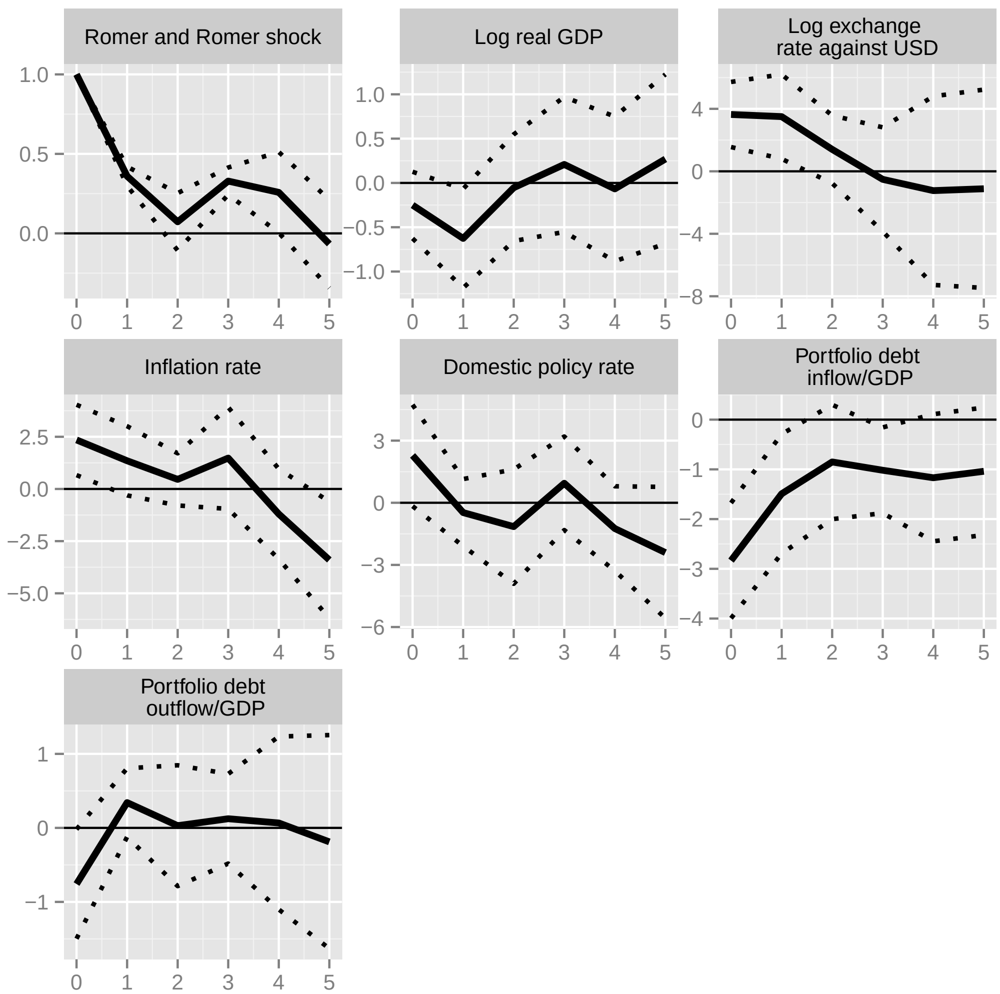
where $w_{i,t-1}$ is a vector of control variables known prior to the US monetary policy shocks. Assuming the conditional mean can be linearly approximated, θ^h estimates the average treatment effect of a period t US monetary policy shock in period $t+h$. Thus, impulse responses are computed as a sequence of the θ^h $(h = 0, 1, ..., H)$ estimated in a series of single regressions for each horizon. Standard errors are clustered by country to account for within country correlation.

Our estimates are based on quarterly data between Q1 1989 and Q2 2007. We construct a quarterly measure of US monetary policy shocks, MS_t, by aggregating the Coibion et al. (2012) US monetary policy shocks from each meeting in a given quarter. The emerging economies included in the unbalanced panel are Argentina, Brazil, Chile, China, Colombia, India, Indonesia, Korea, Malaysia, Mexico, Peru, the Philippines, Russia, South Africa, Thailand and Turkey. The dependent variables considered are the log bilateral exchange rate with the US dollar, log real GDP, inflation, the domestic policy rate, and both portfolio debt outflows and inflows as a share of GDP. The vector of control variables $w_{i,t-1}$ consist of two lags of output growth, export-weighted GDP growth of country i's major trading partners, inflation, the domestic policy rate, the log change in the US dollar bilateral exchange rate, the change in domestic long-term bond yields, the change in the ratio of foreign exchange reserves to short-term external borrowing, both portfolio debt inflows and outflows as a share of GDP, past US monetary policy surprises and US 10-year Treasury yields. The HP-filtered domestic output gap in period $t-1$ is also included as a control variable.

The top-left panel of Figure 2.4 shows that there is some persistence in US monetary policy surprises as measured by the Romer and Romer shocks, but they essentially die out after two quarters. Following a 100 basis point US monetary policy surprise (annualized), quarterly real GDP in emerging economies decline by around 0.5% after one quarter but this initial negative effect reverses. Bilateral exchange rates initially depreciate by around 4% (quarterly). The inflation rate initially increases by around 250 basis points (annualized), which could be due to strong exchange rate pass-through, but the subsequent decline is suggestive of a price puzzle, similar to that found in advanced economies. Domestic policy rates are initially tightened by nearly 200 basis points (annualized) in response to the 100 basis point US monetary policy tightening, but this initial tightening is quickly reversed after one quarter. In terms of the impact on gross capital flows, the impulse responses show a retrenchment of capital flows in response to US monetary policy tightening. There is a persistent fall in portfolio debt inflows to emerging economies which decline by nearly 3% of GDP (quarterly), and remain around 1% lower after four quarters. In addition, (quarterly) portfolio debt outflows also fall following US monetary policy tightening. This evidence of the retrenchment of gross capital flows is similar to that in Alberola et al. (2012) who find falls in both capital in- and out-flows from emerging economies following periods of financial stress.

We now go on to develop a DSGE model of macroeconomic spillovers which can be used to construct a theoretical counterpart to these empirical results.

Figure 2.4: EME impulse responses to US monetary policy shocks (90% confidence intervals)



3. The Global Model

Our results are structured around a two country core-periphery model. The centre/core country is assumed to be large relative to the peripheral country. We denote the emerging economy with the superscript 'e' and the centre country with the superscript 'c'.

The schemata for our model is described in Figure 3.1. In the centre country there are households, global financiers (banks or asset managers[2]), capital goods producers, production firms, and a monetary authority. There is a global capital market for one-period risk free bonds. In the emerging market country there are also households, local borrowers (banks or financial managers), capital goods producers, production firms, and a monetary authority. The centre country households make deposits with global financiers at the centre country risk free rate, and can hold centre country one-period nominal government debt, which may also be traded on international capital markets. The global banks receive deposits from households in the centre country, and invest in risky centre country technologies, as well as in emerging market banks. Along the lines of Gertler and Karadi (2011), banks in both countries finance purchases of capital from capital goods producers, and rent this capital to goods producers. The borrowing banks in the emerging market economy are funded through loans from global banks/financiers.[3] There are two levels of agency constraints; global banks must satisfy a net worth constraint in order to be funded by their domestic depositors, and local EME banks in turn must have enough capital in order to receive loans from global banks. In both countries, the production goods firms use capital and labour to produce differentiated goods, which are sold to retailers. Retailers are monopolistically competitive and sell to final consuming households, subject to a constraint on their ability to adjust prices. This set of assumptions constitutes the minimum arrangement whereby capital flows from advanced economies to EMEs have a distinct directional pattern, financial frictions act to magnify capital slow spillovers, and (due to sticky prices) the monetary policy and exchange rate regime may have real consequences for the nature of spillovers and economic fluctuations.

The emerging country is essentially a mirror image of the centre country, except that households in the emerging country do not finance local banks, but instead engage in intertemporal consumption smoothing through the purchase and sale of centre currency denominated nominal bonds.[4] Banks in the emerging market use their own capital and financing from global financiers to make loans to local entrepreneurs. The net worth constraints on banks in both the emerging market and centre countries are motivated along the lines of

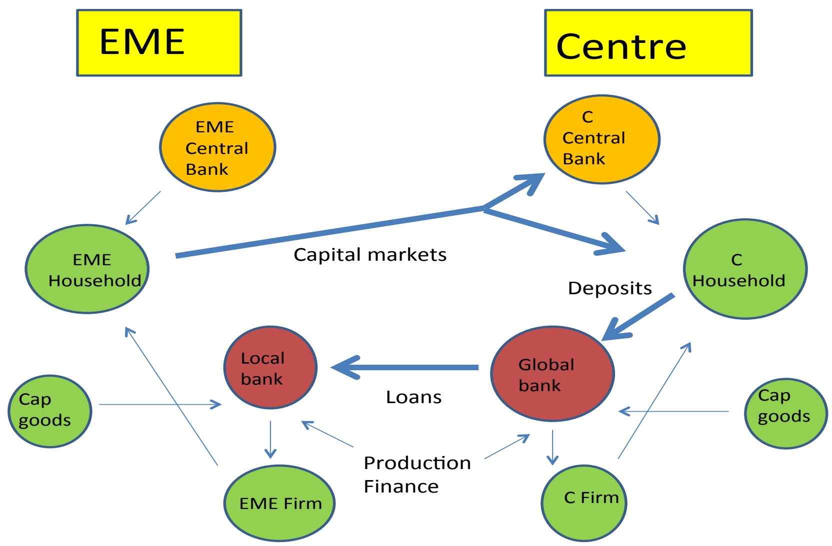
[2]In the remainder of the paper, to simplify the discussion, we will refer to capital goods financiers in both the centre and peripheral countries as banks. It should be noted however that the key thing that distinguishes them is that they make levered investments, and are subject to contract-enforcement constraints. In this sense, they need not be literally banks in the strict sense.

[3]This assumption is meant to capture the feature that within-country financial intermediation between savers and investors is more difficult in EMEs than in advanced economies. See e.g. Mendoza Quadrini and Rios-Rull 2009. We could relax the extreme assumption that EME households did not directly finance EME banks. Under the reasonable assumption that frictions in intermediation within EMEs exceeded those in the centre country, our qualitative results would remain unchanged.

[4]We assume that the market for centre country nominal bonds is frictionless. Adding additional frictions that limit the ability of emerging market households to invest in centre country nominal bonds would just exacerbate the impact of financial frictions that are explored below.

Figure 3.1: The world economy

Architecture of model



Gertler and Karadi (2011).

3.1. The Emerging Market Economy (EME)

A fraction n of the world's households live in the emerging economy. Households consume and work, and act separately as bankers. A banker member of a household has probability θ of continuing as a banker, upon which she will accumulate net worth, and a probability $1-\theta$ of exiting to the status of a consuming / working household member, upon which all net worth will be deposited to her household's account. In every period, non-bank household members are randomly assigned to be bankers so as to keep the population of bankers constant.

While EME households don't have access to the local financial market, they can trade in international bonds (B_t^e) with foreign agents.[5] These bonds can be thought of as T-bills of the core country (rebated directly to core-country households), deposits at core-country financial intermediaries, or simply bonds traded directly with core-country households. Under the assumptions of our model these three alternatives are equivalent.[6]

Households in the EME have preferences over (per capita) consumption C_t^e and labor H_t^e supply given by:

$$E_0 \sum_{t=0)}^{\infty} \beta^t \left(\frac{C_t^{e(1-\sigma)}}{1-\sigma} - \frac{H_t^{e(1+\psi)}}{1+\psi} \right)$$

where consumption is broken down further into consumption of home (C_{et}^e) and foreign (C_{ct}^e) baskets as

$$C_t^e = \left(v^{e\,\frac{1}{\eta}} C_{et}^{e1-\frac{1}{\eta}} + (1-v^e)^{\frac{1}{\eta}} C_{ct}^{e1-\frac{1}{\eta}} \right)^{\frac{1}{1-\eta}}$$

Here $\eta > 0$ is the elasticity of substitution between home and foreign goods, $v^e \geq n$ indicates the presence of home bias in preferences,[7] and we assume in addition that within each basket, goods are differentiated and within country elasticities of substitution are $\sigma_p > 1$.

Given this, the true price index for EME households is

$$P_t^e = \left(v^e P_{et}^{1-\eta} + (1-v^e) P_{ct}^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

Then the household budget constraint is described as follows

$$P_t^e C_t^e + S_t B_t^e = W_t^e H_t^e + \Pi_t^e + R_{t-1}^* S_t B_{t-1}^e$$

Households purchase dollar (centre country) denominated debt (B_t^e). S_t is the nominal

[5] This is clearly an extreme case. In reality EME households' saving does reach domestic firms via the local banks too. Since, in our model, EME households can lend to domestic firms indirectly, via the international financial market, our assumption emphasizes the strong influence that core-country financial conditions exert on EME financial markets.

[6] In particular we are not assuming a special role for government debt, nor asymmetries in the degree to which the contract between depositors and core-country banks can be enforced.

[7] Home bias is adjusted to take into account of country size. In particular, for a given degree of openness $x \leq 1$, $v^e = 1 - x(1-n)$, and a similar transformation for the centre country home bias parameter.

exchange rate (price of centre country currency). They consume home and foreign goods. W_t^e is the nominal wage, and Π_t^e represents profits earned from banks and firms, net of new capital infusion into banks. R_t^* is the centre country rate on bonds. Households have the standard Euler conditions and labor supply choices described by

$$E_t \Lambda_{t+1}^e \frac{R_t^*}{\pi_{t+1}^e} \frac{S_{t+1}}{S_t} = 1$$

$$\frac{W_t^e}{P_t^e} = C_t^{e\sigma} H_t^{e\psi}$$

where $\Lambda_{t+1}^e \equiv \beta \left(\frac{C_{t+1}^e}{C_t^e}\right)^{-\sigma}$, and $\pi_{t+1}^e \equiv \frac{P_{t+1}^e}{P_t^e}$.

Given two-stage budgeting, it is straightforward (and omitted here) to break down consumption expenditure of households into home and foreign consumption baskets.

3.2. Capital goods producers

Capital producing firms in the EME buy back the old capital from banks at price Q_t^e (in units of the consumption aggregator) and produce new capital from the final good in the EME economy subject to the following adjustment cost function:

$$P_t^e I_t^e \left(1 + \zeta \left(\frac{P_t^e I_t}{P_{t-1}^e I_{t-1}} - 1\right)^2\right)$$

where I_t^e represents investment in terms of the EME aggregator good.

EME banks then finish the capital goods and rent them to intermediate goods producers.[8]

$$K_t^e = I_t^e + (1 - \delta) K_{t-1}^e$$

where K_t^e is the capital stock in production.

3.3. EME banks

EME banks begin with some bequeathed net worth from their household, and continue to operate with probability θ, as described above. We also follow Gertler and Karadi in the nature of the incentive constraint. Ex ante, EME banks have an incentive to abscond with borrowed funds before the investment is made. Consequently, conditional on their net worth, their leverage must be limited by a constraint that ensures that they have no incentive to abscond.

At the end of time t a bank i that survives has net worth given by $N_{t,i}^e$ in terms the EME good. It can use this net worth, in addition to debt raised from the global bank, to invest in physical capital at price Q_t^e in the amount $K_{t+1,i}^e$. Debt raised from the global bank is denominated in centre country currency (although later we will experiment with

[8]Equivalently, we could assume that the bank provides risky loans to intermediate goods producers, who use the funds to purchase capital. The only risk of this loan concerns the (real) gross return on the underlying capital stock.

local-currency denomination). In real terms (in terms of the centre country CPI), we denote this debt as $V^e_{t,i}$. Thus, EME bank $i's$ balance sheet is given by

$$N^e_{t,i} + RER_t V^e_{t,i} = Q^e_t K_{t+1,i} \tag{3.3.1}$$

where $RER_t = \frac{S_t P^c_t}{P^e_t}$ is the real exchange rate.

Bank $i's$ net worth is the difference between the return on previous investment and its debt payments to the global bank.

$$N_{t,i} = R^e_{k,t} Q^e_{t-1} K^e_{t,i} - RER_t R_{ct-1} V^e_{t-1,i}$$

where R_{ct-1} is the ex-post real interest rate received by the global bank, equal to the predetermined nominal interest rate adjusted by ex-post inflation in the centre country, and $R^e_{k,t}$ is the gross return on capital.

Because it has the ability to abscond with the proceeds of the loan and its existing net worth, the loan from the global bank must be structured so that the EME bank's continuation value from making the investment exceeds the value of absconding. Following Gertler and Karadi (2011), we assume that the latter value is κ^e_t times the value of existing capital (κ^e_t is a random variable, and represents the stochastic degree of the agency problem). Hence denoting the bank's value function by $J^e_{t,i}$, it must be the case that

$$J^e_{t,i} \geq \kappa^e_t Q^e_t K^e_{t+1,i}. \tag{3.3.2}$$

This is the incentive compatibility constraint faced by the bank.

Once the bank has made the investment, at the beginning of period $t+1$ its return is realized.

The problem for an EME bank at time t is described as follows:

$$\text{Max} \quad J^e_{t,i}\ {}_{[K^e_{t+1,i}, V^e_{t,i}]} = E_t \Lambda^e_{t+1} \left[(1-\theta)(R^e_{k,t+1} Q^e_t K^e_{t+1,i} - RER_{t+1} R_{ct} V^e_{t,i}) + \theta J^e_{t+1,i} \right]$$

subject to (3.3.1) and (3.3.2).

The full set of first order conditions for this problem are set out in the Appendix.

The evolution of net worth averaged across all EME banks, taking account that banks exit with probability $1-\theta$, and that new banks receive infusions of cash from households at rate δ_T times the existing value of capital, can be written as:

$$N^e_{t+1} = \theta \left((R^e_{kt+1} - \frac{RER_{t+1}}{RER_t} R_{c,t}) Q^e_t K^e_t + \frac{RER_{t+1}}{RER_t} R_{c,t} N^e_t \right) + \delta_T Q^e_t K^e_{t-1}$$

The first term on the right hand side captures the increase in net worth due to surviving banks, given their average return on investment. The second term represents the 'start-up' financing given to newly created banks by households.

Firms in the EME hire labour and capital to produce retail goods. Since a central aim of our analysis is to explore the role of monetary policy and the exchange rate regime for capital flows and macroeconomic spillovers, we assume that firms in both countries have Calvo-style sticky prices with Calvo re-set parameter $1-\varsigma$. The representative EME firm has production function given by:

$$Y_t^e = A_t^e H_t^{e(1-\alpha)} K_{t-1}^{e(\alpha)}$$

Given this, then we can define the aggregate return on investment for EME banks (averaging across idiosyncratic returns) as

$$R_{kt+1}^e = \frac{R_{zt+1}^e + (1-\delta)Q_{t+1}^e}{Q_t^e}$$

where R_{zt+1} is the rental rate on capital and δ is the depreciation rate on capital.

The representative EME firm chooses labour and capital so as to minimize costs. We can then define the EME firm's real marginal cost implicitly by the conditions

$$MC_{et}(1-\alpha)A_t^e H_t^{e(-\alpha)} K_{t-1}^{e(\alpha)} = W_{rt}^e \tag{3.3.3}$$

$$MC_{et}\alpha H_t^{e(1-\alpha)} K_{t-1}^{e(\alpha-1)} = R_{zt}^e$$

The Calvo pricing formulation implies the following specification for the PPI rate of inflation π_{et}^{ppi} in the EME. Here Π_{et}^* denotes the inflation rate of newly adjusted goods prices, F_{et} and G_{et} are implicitly defined, and $\frac{\sigma_p}{\sigma_p - 1}$ represents the optimal static markup of price over marginal cost:

$$\Pi_{et}^* = \frac{\sigma_p}{\sigma_p - 1}\frac{F_{et}}{G_{et}}\pi_{et}^{ppi} \tag{3.3.4}$$

$$F_{et} = Y_{et}MC_{et} + \mathbb{E}_t\left[\beta\varsigma\Lambda_{t,t+1}^e {\pi_{et+1}^{ppi}}^{\eta} F_{et+1}\right] \tag{3.3.5}$$

$$G_{et} = Y_{et}P_{et} + \mathbb{E}_t\left[\beta\varsigma\Lambda_{t,t+1}^e {\pi_{et+1}^{ppi}}^{-(1-\eta)} G_{et+1}\right] \tag{3.3.6}$$

$${\pi_{et}^{ppi}}^{1-\eta} = \varsigma + (1-\varsigma)\left(\Pi_{et}^*\right)^{1-\eta} \tag{3.3.7}$$

3.4. Monetary policy

In the baseline specification, the central bank follows a flexible inflation targeting policy, here captured by a generalized Taylor rule, i.e.

$$\log R_t = \lambda_{r,e}\log R_{t-1} + (1-\lambda_{r,e})\left(\lambda_{\pi,e}\log\left(\frac{\pi_t^e}{\pi_{ss}^e}\right) + \lambda_{y,e}\log\left(\frac{Y_t^e}{Y_{ss}^e}\right)\right) + \varepsilon_{r,t}^e. \tag{3.4.1}$$

where $\varepsilon_{r,t}^e$ is a monetary policy shock.

In analysis below we will also consider the design of optimal monetary policies. We will focus on Ramsey optimal policy with commitment (or 'open loop' optimal policy), where the path of interest rates is adjusted in order to implement an optimal policy. We explore the nature of optimal policy under two strategic assumptions about policy making. In the first, we will assume that central banks cooperate in order to implement the Ramsey optimal allocation. In this case they choose the allocation that maximizes the size-weighted average of households' welfare across countries, subject to the competitive equilibrium conditions. Following this, we define and analyze a Ramsey optimal non-cooperative monetary policy, in which each central bank follows its own optimal monetary rule, taking that of the other monetary authority as given.

We will also consider the case of an exchange rate peg. In this case we implement the EME central bank's policy in terms of the simple targeting rule $\Delta S_t = 0$. The details are provided in Appendix A.[9]

3.5. The centre country

The centre country households have similar preferences to those of the EME, and its production firms sell to the emerging market country households. The centre country's financial institution (the global bank) receives deposits from the households and guarantees them the risk-free interest rate in return. The global bank then invests in the centre country technology as well as the EME bank debt.

Centre country representative household preferences are:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{c(1-\sigma)}}{1-\sigma} - \frac{H_t^{c(1+\psi)}}{1+\psi} \right)$$

and their budget constraint is given by:

$$P_t^c C_t^c + B_t^c = W_t^c H_t^c + \Pi_t^c + R_t^* B_t^c + T_t^c$$

Centre country households make deposits in the banking system, and receive returns R_t^*. They receive profits Π_t^c from (financial and non financial) firms, net of capital infusions into the new banks.

The definition of centre country CPI's, and bond and labour supply choices for the centre country households are exactly analogous to those of the EME country, so we omit them here. Likewise, the specification for capital producing firms and the dynamics of the aggregate capital stock for global banks is identical to that described for the EME economy. See Appendix A for details.

[9] We do not explicitly model the central bank balance sheet or the consequences of alternative exchange rate regimes for the accumulation of international reserves. This is justified on the same grounds as that of Woodford (2003) who models monetary policy in 'cashless' economies abstracting from monetary aggregates or the central bank balance sheet. In following this strategy, we are attempting to focus specifically on the role of the exchange rate and interest rates as monetary policy levers for EMEs. A more extended analysis could be done by explicitly modelling the effect of foreign exchange rate reserves. In particular, if as in Bacchetta et al. (2013), we assumed the EME residents had limited access to international financial markets, then central bank reserves, or foreign currency swaps with central banks, could play an effective role in providing risk sharing. Alternatively, following Gertler and Karadi (2011) and Dedola et al. (2013), we could allow for EME central banks to provide foreign currency loans to EME banks, thereby introducing a role for unconventional monetary policy in EMEs. We abstract away from the first option in this paper, since the consequences of limited capital mobility have been extensively examined elsewhere. The second option, direct foreign currency loans or foreign currency swaps, could be an interesting alternative policy tool. So, while in this paper we focus on standard policy interventions, we leave the second option for future research. Nuguer (2015) constructs a multi-country model with a global interbank market in a similar fashion to our model, and explores the effects of unconventional credit policies.

3.6. Centre country banks

A representative global bank j has a balance sheet constraint given by

$$V_{jt}^e + Q_t^c K_{jt}^c = N_{jt}^c + B_t^c$$

where V_{jt}^e is investment in the EME bank, and $Q_t^c K_{jt}^c$ is investment in the centre country capital stock. N_{jt}^e is the bank's net worth, and B_t^c are deposits received from households. All variables are denominated in real terms, (in terms of the centre country CPI).

The global bank's value function can then be written as:

$$J_{jt}^c = E_t \max_{K_{j,t+1}^c, V_{jt}^e, B_t^c} \Lambda_{t+1}^c \left[(1-\theta)(R_{kt+1}^c Q_t^c K_{jt}^c + R_{ct} V_{jt}^e - R_t^* B_t^c) + \theta J_{jt+1}^c\right]$$

Here, Λ_{t+1} is the stochastic discount factor for centre country households, R_{ct} is, as described above, the return on the global bank's loans to the EME bank, and R_t^* is the risk-free rate paid to domestic depositors.

The bank faces the no-absconding constraint:

$$J_{jt} \geq \kappa_t^c \left(V_{jt}^e + Q_{ct} K_{jt}^c\right)$$

where, as in the EME case, κ_t^c measures the degree of the agency problem, and as before we assume it is subject to exogenous shocks.

We describe the first order conditions for the global bank in detail in the appendix. As in the case of the EME banks, we can describe the dynamics of net worth for the global banking system by averaging across surviving banks, and including the 'start-up' funding provided by centre country households. We then get the following law of motion for net worth

$$N_{t+1}^c = \theta\left(\left(R_{kt+1}^c - R_t^*\right) Q_t^c K_t^c + \left(R_{c,t} - R_t^*\right) V_t^e + R_t^* N_t^c\right) + \delta_T Q_{t+1}^c K_{t-1}^c. \tag{3.6.1}$$

Again, the details of the production firms and price adjustment in the centre country are identical to those of the EME economy, so we leave the description to the appendix.

3.7. Monetary Policy

The central bank of the centre country, in our baseline specification, follows a Taylor rule of the type described above (see equation 3.4.1).

4. Calibration

Our aim is to use the model to provide a general qualitative assessment of the empirical evidence discussed above. We do not attempt to find the best fit of the theoretical model with the data. Therefore, we take parameters values that fall generally in line with the related literature, leaving a more quantitative assessment of the model to future research. Table 1 summarizes the values assigned to the parameters. In particular, we set the openness parameters ν^e and ν^c in line with the trade shares of the US with a group of emerging markets, and the trade shares of the same group of EMEs with the US using the IMF DOT statistics

Table 1: Parameter Values

Label	Value	Label	Value
n	0.15	ζ	1.728
σ_p	6	η	1.5
ς	0.8	ψ	0.276
$\lambda_{y,c}$	0.2	θ	0.96
$\lambda_{\pi,c}$	1.2	α	0.3
$\lambda_{r,c}$	0.85	$\nu^e = \nu^c$	0.96
β	0.99	σ	1.02
δ	0.025	$\kappa^c = \kappa^e$	0.38
δ_T	0.004		

(average shares since 2000). Given that the two shares are very similar in the data we set both to $\nu^c = \nu^e = 0.96$. The intertemporal elasticity of substitution is set at approximately unity, so that $\sigma = 1.02$. The Armington elasticity of substitution between home and foreign goods (η) is 1.5, while the micro elasticity of substitution σ_p is 6. The discount factor is set at $\beta = 0.99$, while the Frisch elasticity of labour supply $\frac{1}{1+\psi}$ is set at 0.8. The parameters of production are standard; the share of hours in production, $1-\alpha$ is .7, while the depreciation rate δ is set at 0.025 (at quarterly frequency), and the parameter in the adjustment cost technology is 1.73. From Gertler and Karadi (2011) we take the banking sector parameters so that $\theta = 0.96$ (the survival rate of banks), $\kappa^e = \kappa^c = 0.38$ (i.e. the steady-state value of the incentive compatibility parameter), and $\delta_T = 0.004$ (i.e. the transfer rate to new banks). [10] The probability of changing prices in a quarter $(1-\zeta)$ is 0.2.

We will focus on shocks to monetary policy and to 'financial shocks', represented by shocks to the parameter κ_t^c, the fraction of investment that can be obtained by an absconding global bank. We assume that monetary policy shocks are *i.i.d.* with a 1 percent standard deviation. Shocks to κ_t^c are AR(1) processes with persistent 0.9 and standard deviation of 1 percent also. The Taylor rule coefficients are chosen at standard levels (see Table 1).

5. The impact of monetary policy on capital flows and international transmission

We first explore the impact of centre country monetary shocks on global GDP, capital flows, asset prices, leverage, and interest rate spreads. The main set of questions we are interested in is how is the impact of monetary tightening in the centre country is affected by the presence of financial frictions. In addition, how does the relationship between global banks and local banks affect the spillover effects of monetary policy shocks, and how do these spillovers compare to the effect of a monetary policy shock in a standard multi country DSGE model without financial frictions?

[10] As in Gertler and Karadi (2011), these parameters target the steady state interest spread of 100 basis points, the horizon of bankers of about 10 years, and the steady state leverage ratio of 4. Although clearly leverage ratios differ across jurisdictions, we do not attempt to match EME ratios, as there is wide variability across different countries. A higher leverage ratio in the EME would magnify our results.

In addition, we wish to go beyond the question of transmission with financial frictions to address the question of how important is the monetary policy response in the EME country. Does the exchange rate policy followed by the EME significantly affect the international transmission mechanism in the presence of financial frictions? A closely related question is to what extent does the currency of denomination of nominal liabilities affect the transmission properties of the model in response to centre country monetary tightening. Does 'liability dollarization' significantly exacerbate the cross country transmission of monetary shocks?

Figure 5.1 illustrates the effect of a monetary policy tightening in the centre country in the case without financial frictions.[11] The monetary shock is scaled to represent a 1% innovation to the policy rule.[12] Without financial frictions, and under a flexible exchange rate (plain line) the shock is almost wholly absorbed within the centre country. The EME country's real economy is well insulated from the monetary policy shock. The EME policy rate rises only slightly, and there is a sharp real depreciation of the EME currency, but almost no effect on EME GDP, investment, or asset prices. In the centre country itself, there is a sharp fall in GDP, investment and asset prices. We note also that, in the absence of financial frictions, the monetary policy tightening leads to an *increase* in bank lending to the EME, and an increase in capital outflows from the EME. This pattern of gross capital flows goes against the empirical evidence described above.

The minimal degree of international transmission of monetary policy in the absence of financial frictions is in line with traditional models, and supports the theoretical presumption of an important role for flexible exchange rates in the response to external shocks. The Figure also illustrates the effect of the same shock, but assuming that the EME central bank chooses an exchange rate peg (but again without financial frictions, crossed line). In this case, the real exchange rate depreciation is dampened significantly, the EME short term policy rate rises sharply, and there is a significant fall in real GDP and investment in the EME. Interestingly however, in this case, bank lending to the EME still rises, relative to the initial steady state.

When we introduce financial frictions in the form described in our model however, the results are dramatically different. Figure 5.2 shows that in the baseline case, with financial frictions (solid-plain line), the monetary tightening in the centre country precipitates a large and persistent fall in capital inflows to the EME. The fall in bank loans causes a sharp fall in asset prices, an increase in bank leverage[13] , and a rise in interest rate spreads in the EME. There is a general fall in investment and GDP of similar orders of magnitude in both the centre country and the EME. We also see a fall in capital outflows from the

[11]In the IRFs, NFA_E denotes the aggregate net foreign assets of the EME in terms of steady-state GDP in units of the consumption aggregator. Households NFA, denotes the net foreign assets of the households sector, in terms of their steady-state value. Note that EME-bank debt is also in terms of its steady-state value. The latter is equal to households' net foreign assets in the steady state (implying a zero net foreign asset position in the steady state). ΔFX is the change in nominal foreign exchange, while "spread" measures the ex-ante difference between the gross return on capital and the policy rate: a measure of financial inefficiency.

[12]Due to the endogeneity of the policy rate, the latter moves by less.

[13]The question of whether leverage is procylical or countercyclical has been debated in the literature. Bruno and Shin 2014b, argue bank leverage is pro cyclical, but Gertler (2012), points out that book value and market value leverage may move in different directions over the cycle. In particular, in a model similar to ours, he shows that book value leverage may be procyclical while market value leverage is countercyclical, as in our impulse responses.

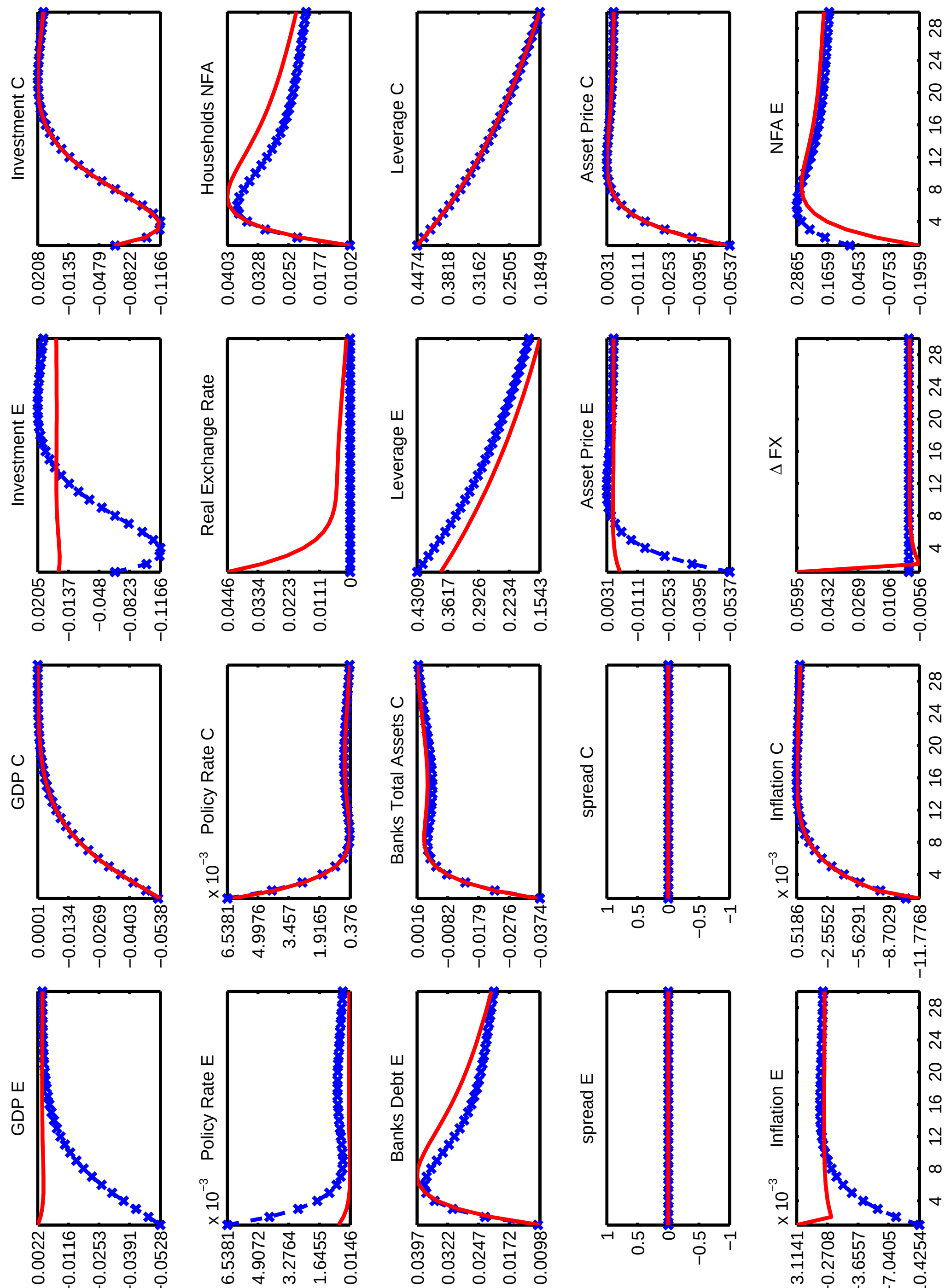


Figure 5.1: Monetary Policy Shock in centre country: no financial frictions. Plain line=Flexible exchange rate; Crossed line=Peg.

EME, so that there is a general retrenchment in gross capital flows. The contrast with the case without financial frictions is highlighted even more when we look at the comparison of the quantitative effects on leverage, asset prices and spreads across the two countries. Even though the monetary tightening is precipitated by the shock in the centre country, the response of spreads, leverage and asset prices is greater in the EME. This is associated with a much greater fall in investment spending in the EME than in the centre country itself.

These results are consistent with the observation that emerging markets are highly sensitive to sudden reversals of capital flows, especially those associated with monetary tightening in advanced economy markets. The international transmission in this model is critically tied to the financial amplification mechanism coming from the linkage between bank's net worth and their asset valuation. A monetary tightening reduces aggregate demand and investment, which leads to a fall in the price of capital. This leads to a fall in bankers net worth in the centre country, amplifying the fall in investment. At the same time, the fall in centre country bank net worth leads to fall in capital flows to the EME, reducing investment and asset prices in the EME, generating a further fall in EME net worth. As a result interest rate spreads rise in both countries. In contrast to the case without financial frictions, we see that monetary tightening in the centre country leads to a substantial and persistence fall in global bank lending to the EME.

We can again ask how the exchange rate regime affects the international transmission in the case of financial frictions. Here the results are very different from the conventional DSGE model. With financial frictions and bank-balance sheet linkages, there is relatively little difference between the baseline case and the EME monetary policy with pegged exchange rates (dashed line). The exchange rate peg does limit the EME real depreciation. This magnifies the fall in real GDP, since there is less compensating expenditure switching towards EME goods. But the fall in capital inflows and outflows, the rise in leverage and spreads, the fall in asset prices, and the fall in EME investment is almost identical to that in the baseline case with flexible exchange rates. Thus, these results tend to support the argument that in the presence of financial frictions in capital flows, there is only a limited role for nominal exchange rate adjustment in insulating the economy from external shocks. We will see this even more clearly in the case of a financial shock in the analysis below.

How do the results depend on the denomination of bank lending? The baseline case assumes that all borrowing is done in centre country currency (e.g. US dollars). Hence, the centre country monetary shocks precipitates an unanticipated depreciation in the EME currency that has a direct negative impact on the EME bank's net worth. This negative effect of 'liability dollarization' on balance sheets has been much discussed in the literature on emerging market crises and exchange rate adjustment (Bruno and Shin, 2014). Figure 5.2 illustrates the case where debt is denominated in domestic currency (dotted line). In that alternative specification, an unanticipated centre country monetary shock still generates a real exchange rate depreciation for the EME country, but there is no direct negative valuation effect on the EME banks balance sheet. The impulse responses show that under local currency denomination of liabilities the transmission effect of the centre country monetary contraction is lessened. There is a smaller spike in the EME spread relative to the baseline case. EME leverage rises by less, and the asset price falls by less. Consequently the fall in investment and GDP is reduced by about 30% at their trough. But even without the direct valuation effect of the exchange rate change, the effect of the fall in centre country capital

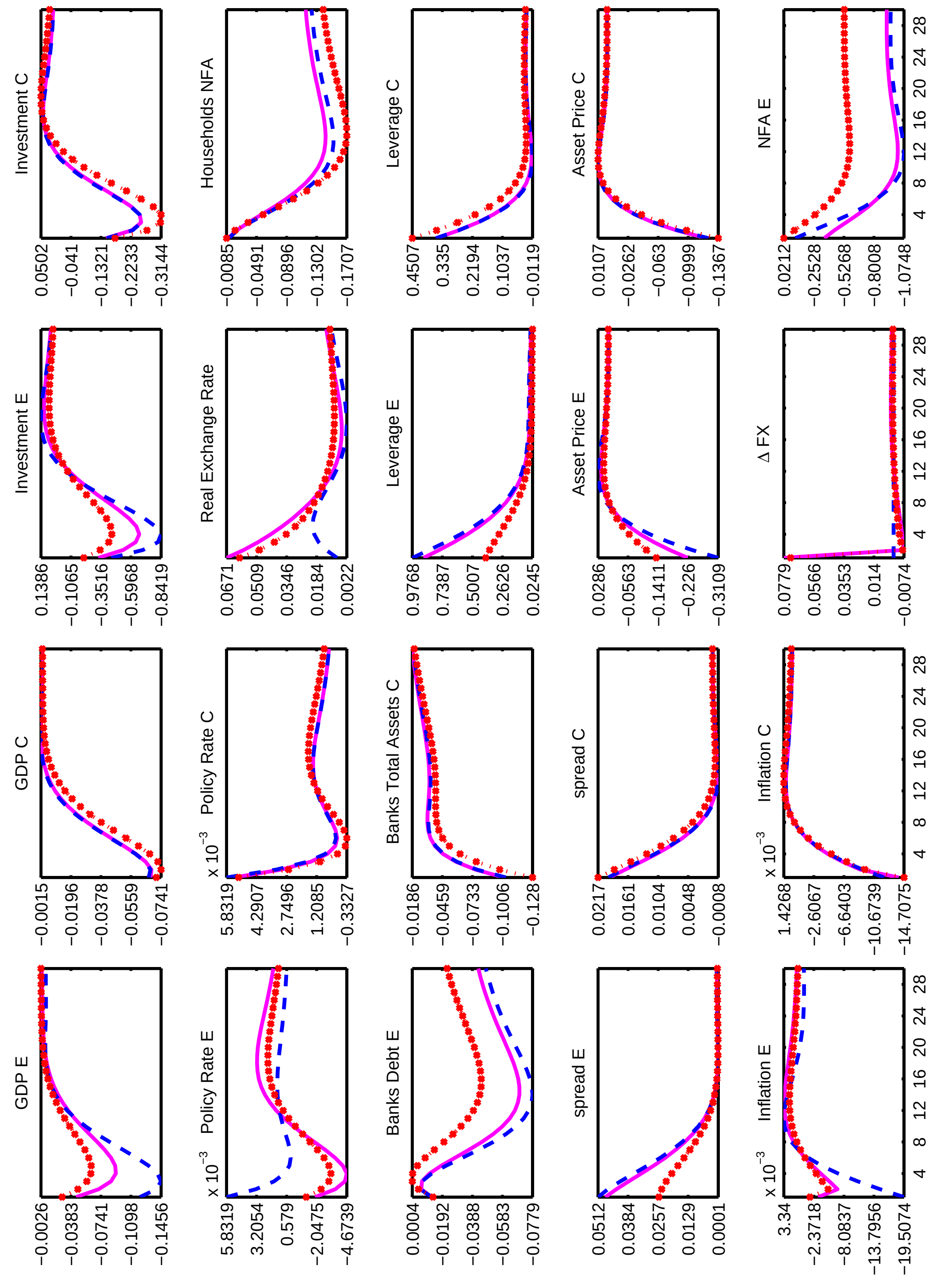


Figure 5.2: Monetary Policy Shock in centre country. Solid=baseline; dashed=peg; dots=local currency debt.

flows still leads to a large balance sheet deterioration and a fall in real activity. Relative to the case without financial frictions, there is still a large negative impact on EME investment and real GDP.

These results would seem to underscore the message of Rey (2013) and others, suggesting that despite having flexible exchange rates, emerging market countries are extremely vulnerable to volatile capital flows related to US monetary policy shocks. Under a conventional monetary policy rule, exchange rate adjustment can then only play a limited role in mitigating the impact of shocks, and it suggests the need for other direct forms of capital restrictions or macro-prudential policies that directly target the balance sheets of banks.

We should note of course that the monetary rule described above is an ad-hoc specification. An optimal monetary policy response can be designed that will do much better in response to the centre country monetary shock. In the case of an optimal cooperative monetary rule, this statement becomes trivial, because then it is always optimal to directly offset the monetary shock itself, and the impact of the monetary shock is entirely eliminated. But a more interesting question arises when the EME must respond unilaterally. We explore this response in the section on non-cooperative monetary policy and financial shocks below.

Finally, we note that the impact of shocks in our model is extremely asymmetric. Figure 5.3 reports the effect on both the EME and the centre country of a monetary policy contraction of similar magnitude to that of Figure 5.2 but now coming from the EME. The impact on the centre country real activity is negligible. This is to be expected, since the EME is small relative to the world economy. There is a fall in GDP in the EME, since the monetary contraction leads to an immediate real exchange rate appreciation. But remarkably, we find that the contraction in real activity in the EME is now smaller than in the response to the centre country shock. The critical feature is that the monetary shock in the EME does not directly impact on the EME bank's balance sheet. In fact, there is a small boost to the bank's net worth, coming from the unanticipated real appreciation. But the effects on spreads, leverage and asset prices is small, and as a consequence, investment falls by substantially less than in response to an external monetary tightening.

6. Financial Shocks

In this section we discuss the spillover effects of financial shocks originating in the centre country.[14] Figure 6.1 shows impulse responses for a 1% increase in the incentive compatibility constraint parameter κ_t^c. The first noticeable effect of this shock is the relatively strong comovement across countries. As discussed by Devereux and Yetman (2010) and Dedola and Lombardo (2012), financial shocks in one single economy, in a world characterized by financial integration and financial frictions, can generate highly synchronized

[14]The 2008-2009 financial crisis has motivated considerable research on the role of credit shocks. Jermann and Quadrini (2012) show, in a model with financial constraints, that financial shocks can explain the 2008-2009 US recession as well as other previous episodes. Helbling et al. (2011) provide empirical evidence on the role of financial shocks in driving global recessions. Boivin et al. (2013) shed light on the macroeconomic consequences of financial shocks for the US economy using a large set of macro and financial variables. Christiano et al. (2014) estimate a DSGE model with financial frictions à la Bernanke et al. (1999) and show that financial shocks (the idiosyncratic shock to financially constrained borrowers) are the most important shock driving the business cycle.

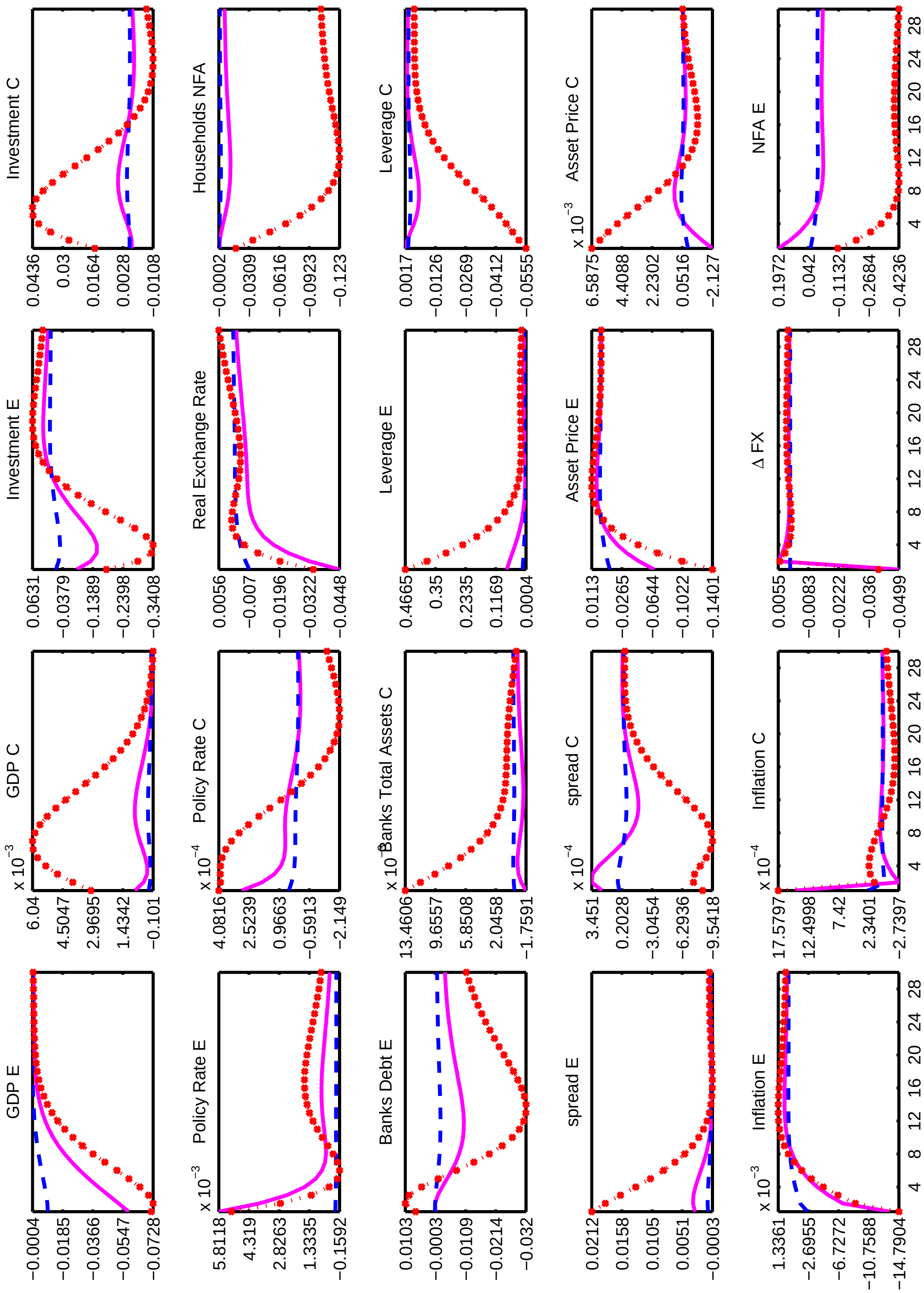


Figure 5.3: Monetary Policy Shock in EME. Solid=baseline; dashed=peg; dots=local currency debt.

responses across countries. As in the case of the response to centre country monetary policy shocks, we see that impulse responses are essentially invariant to the exchange rate regime or the currency denomination of liabilities. The synchronization of credit spreads (measured as wedges between the return on capital and the domestic policy rate) is the dominant factor in generating business cycle movements. Again, the contraction in the emerging economy is markedly larger than that in the centre country (the epicentre of the shock), mainly due to the asymmetric size of the two economic regions.[15] In terms of capital flows the consequence of the centre-country financial shock is a "retrenchment" of international capital. As before, gross inflows into EME banks fall as do EME outflows from households. This adjustment is reminiscent of the capital flows observed during the 2008-2009 financial crisis (e.g. Broner et al., 2013).

7. Optimal cooperative monetary policy

So far we have documented that financial market integration can generate disproportional effects on EME of shocks originating in the centre country, quite independently of the exchange rate regime. These results, therefore, seem to provide theoretical support to the idea of the changed nature of the monetary policy problem in a world characterized by financial market integration: even under flexible exchange rates, free capital mobility is incompatible with an independent domestic monetary policy (Rey, 2013).[16] Nevertheless, in this section we show that a more appropriate description of the effects of financial integration on the policy problem is that capital flows exacerbate the policy trade-offs and, thus, require different policy strategies. It is well known that openness, in general, affects the optimal monetary policy response to shocks (e.g. Corsetti et al., 2010, Faia and Monacelli, 2008, Devereux and Sutherland, 2007, Devereux and Engel, 2003, Lombardo and Ravenna, 2014 and Kolasa and Lombardo, 2014). In particular a monetary policy strategy that seems appropriate under a particular mix of shocks ceases to be attractive under a different mix of shocks. Financial integration not only changes the trade-offs faced by central banks, it also changes the type of shocks that the economy is likely to experience. To illustrate this point, we study the response of the two economies to financial shocks under the Ramsey cooperative optimal policy.[17].

The optimal cooperative policy solves the following problem

$$\max_{\mathcal{Y}_t} E_0 \sum_{i=0}^{\infty} \beta_{CB}^i \left(n\, U\left(C_{t+i}^e, H_{t+i}^e\right) + (1-n)\, U\left(C_{t+i}^c, H_{t+i}^c\right)\right) \tag{7.0.1}$$

subject to all the equations characterizing the decentralized equilibrium (i.e. FOC of the private agents and resource constraints, see Appendix A for details), where β_{CB} is the discount factor of the central bank (which we take to be identical to the discount factor of

[15]Note that the "financial wedges" move almost identically. The double layer of financial frictions de facto faced by the EME bank does not generate larger spreads than in the centre country.

[16]Georgiadis and Mehl (2015) provide some GVAR-based evidence that financial integration might actually have increased monetary policy effectiveness, due to valuation effects.

[17]Fujiwara et al. (2015) provides theoretical support to the idea that cooperation in the presence of financial frictions is welfare improving.

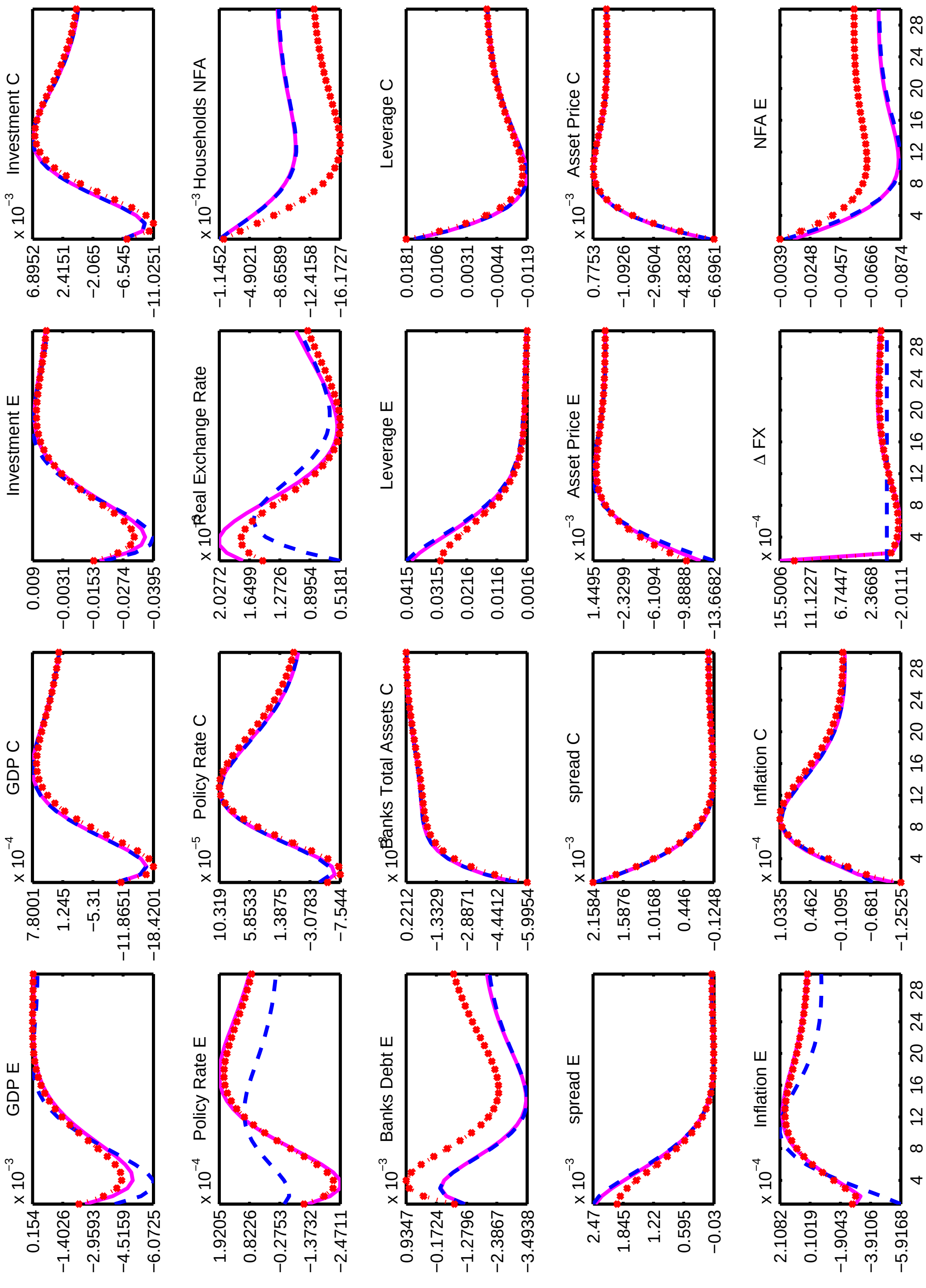


Figure 6.1: Financial shock in centre country. Solid=baseline; dashed=peg; dots=local currency debt.

the households) and $\mathcal{Y}_t$ is the vector containing all the endogenous variables of the model. In solving for the optimal policy we follow the "timeless" perspective advocated by Woodford (2003).

Figure 7.1 compares the baseline case with the optimal cooperative policy. The optimal policy reduces considerably the effect of financial shocks on both economies. In particular the EME spread increases only modestly and less than the spread in the centre country. This is reflected in a considerably smaller asset-price decline and, thus, in a smaller fall in investment. Leverage and spreads co-move much less across countries than under the Taylor rule. In order to achieve this allocation, the Ramsey policy-maker needs to depart from the interest rate adjustment observed under the Taylor rule. In particular nominal interest rates fall markedly in both countries and inflation is allowed to increase, albeit only temporarily. The real exchange rate in the EME appreciates on impact, providing extra relief to the balance sheet of EME banks. The optimal policy strongly mitigates capital "retrenchment", thus preventing the strong credit contraction that the Taylor rule brings about.

The implication of these results is that domestic monetary policy matters, in a non-trivial way, even under financial integration and financial frictions in international capital flows. Nevertheless, it also shows that financial integration, and the spillovers of foreign financial shocks that come with openness, do exacerbate the trade-offs faced by central banks. The objective of inflation stabilization cannot be achieved to the same extent as in a frictionless international capital market. Stabilization of financial market variables becomes an important objective of policy, suggesting room for macro-prudential interventions (e.g. Farhi and Werning, 2013).

8. Non-cooperative monetary policy

The previous sections showed that while a naive Taylor rule has little advantage over an exchange rate peg, an optimal cooperative discretionary monetary policy could play an effective role in dealing with spillovers in international financial markets. But an obvious objection to this is that cooperative monetary policy is an unrealistic ideal. Practically speaking, monetary policy is set at the national level based on domestic objectives. How would our results differ if we allow for optimal monetary policy, but recognizing that policy is set by each country separately? In this section we analyse the effects of non-cooperative, self-oriented monetary policies. In particular we solve our model for the open-loop, Nash equilibrium and compare it with the baseline Taylor-type rule and the globally optimal Ramsey policy.

As is well known, there is no single non-cooperative optimal policy, as the solution depends on the strategy space underlying the game. Also, defining the strategy space in terms of policy rates does not yield a saddle-path equilibrium. Alternatively one could choose to solve for the non-cooperative equilibrium in terms of explicit instrument rules (closed-loop Nash equilibrium). Nevertheless, in this case too there is some degree of arbitrariness both in the choice of the instrument and in the choice of the feedback variables and lags. Mindful of these issues, we proceed by providing results for a baseline case where the strategy space is defined in terms of PPI inflation (as for example in Benigno and Benigno, 2006).

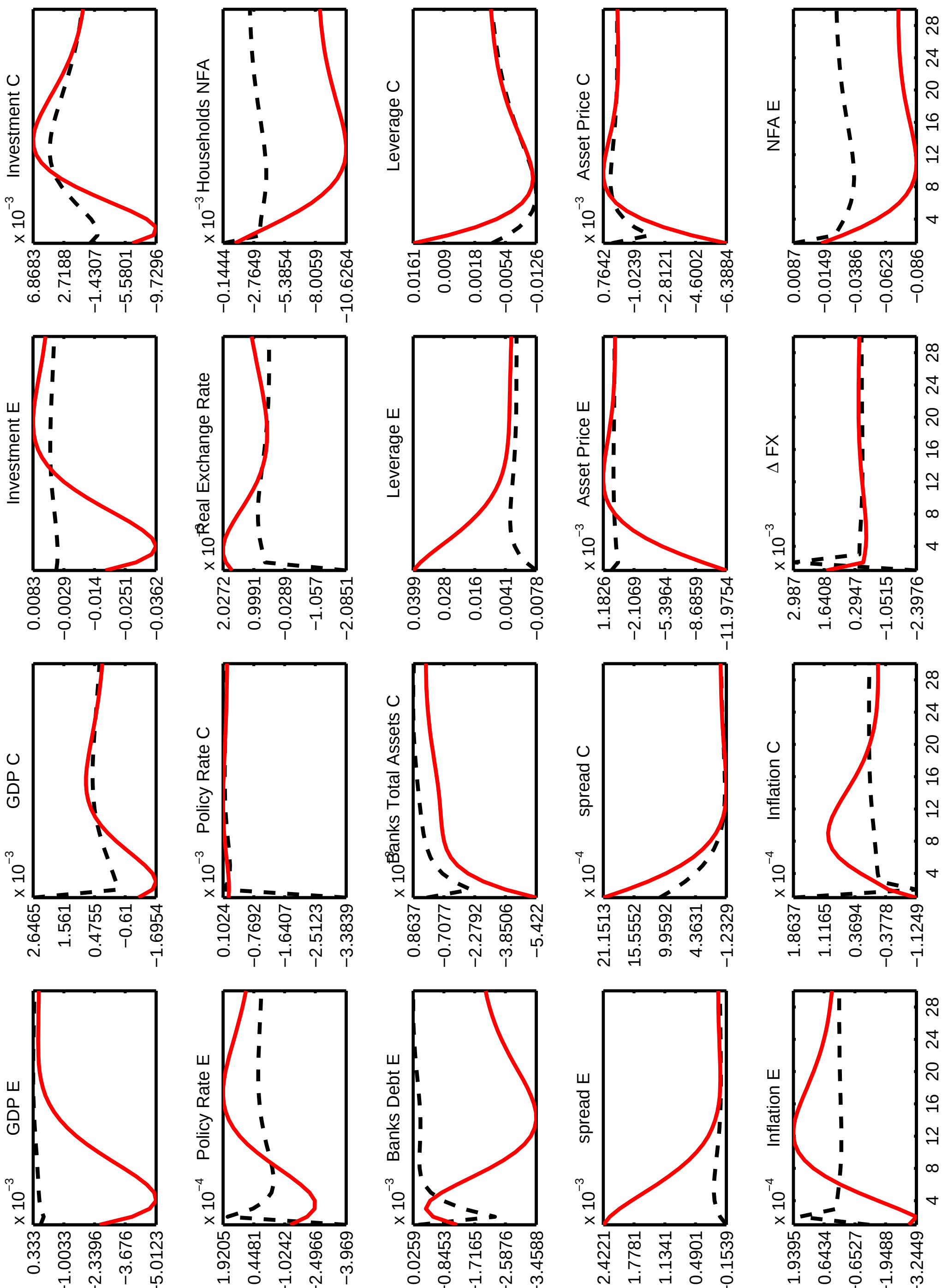


Figure 7.1: Financial shock in centre country. Solid=baseline; dashed=Ramsey

8.1. The non-cooperative policy problem

Each central bank chooses the allocation that maximizes the intertemporal welfare of the households living in its jurisdiction, i.e.

$$\max_{\mathcal{Y}_t^e} E_0 \sum_{i=0}^{\infty} \beta_{CB}^i U\left(C_{t+i}^e, H_{t+i}^e\right) \tag{8.1.1}$$

subject to all the equations characterizing the decentralized equilibrium (i.e. FOC of the private agents and resource constraints, see Appendix for details), where $\mathcal{Y}_t^e$ is the vector containing all the endogenous variables of the model *except* the foreign variable that co-defines the strategy space.[18] A similar problem is solved by the center-country central bank.

The set of first order conditions of the two monetary authorities jointly defines the set of best-responses and, thus, the implicit policy rules followed by the central banks. As in the optimal cooperative monetary policy case, we follow the "timeless" perspective advocated by Woodford (2003).

9. Comparison

Figure 9.1 compares the (cooperative) Ramsey policy with the Taylor-type rule used in our baseline specification as well as with the non-cooperative policy described above, under the assumption that the strategy space is defined in terms of domestic PPI inflation rates.

Under this strategy the non-cooperative policy generates dynamics in the main macro variables that are essentially identical to the fully cooperative one.

The lessons that we can draw from this results are the following. First, monetary policy is crucial in determining the response of the economy to shocks (compare the arbitrary Taylor-type rule with the two optimal rules). Second, an appropriately chosen monetary policy can considerably mitigate the spillovers from foreign shocks. Third, a self-oriented monetary policy response can achieve the same outcome of the fully cooperative policy.

So, while financial frictions and financial globalization could generate scope for cooperation in other policy dimensions (e.g. regulation), our analysis suggests that, to first order, the response of the economies under the two regimes (cooperation and non-cooperation) are virtually identical. The intuition behind this similarity is the following. Self-oriented stabilization requires smoothing of credit-spread volatility. This policy is beneficial for all countries. The spillover from foreign stabilization, while positive, is not strong enough to generate free-riding incentives (e.g. see Dedola et al., 2013), since, in particular, financial structures are not symmetric. The classic negative spillovers due to price rigidities are also sufficiently small (e.g. Obstfeld and Rogoff, 2002). The net result entails negligible gains from cooperation.

As a caveat, it should be noted that we are not considering exceptionally large shocks leading to a liquidity-trap equilibrium. Looking at the coordination gains of unconventional

[18] Thus, if the PPI inflation rates $\pi_t^{ppi,e}$ and $\pi_t^{ppi,c}$ define the strategy space, $\mathcal{Y}_t^e$ excludes $\pi_t^{ppi,c}$ and $\mathcal{Y}_t^c$ excludes $\pi_t^{ppi,e}$. The policymakers recognize that the counterpart can freely choose one variable: it has one degree of freedom.

policies when policy rates hit the zero lower bound is beyond the scope of the present analysis.[19]

10. Conclusions

The post crisis years have exposed substantial strains in the workings of the international financial system. Excessive volatility in international capital flows have raised questions about the efficacy of self-oriented monetary policies and the benefits of flexible exchange rates under inflation targeting.

We offer some further empirical evidence on the international transmission of US monetary policy shocks to emerging market economies. We do so by applying local projection methods to a large panel of countries and conditioning on monetary policy shocks identified using standard techniques. We find that US monetary policy shocks tends to generate a contraction in emerging markets, as well as a fall in both in- and out-flows of capital: a global retrenchment.

We then develop a simple template which allows both for an understanding of the sources of excess volatility of capital flows to emerging markets, as well as an evaluation of policy responses to capital flows. We show that, like in the data, under financial frictions a core-country monetary policy shock generates a contraction in the emerging economy, alongside a global capital retrenchment. We show that financial frictions play a crucial role both in our positive as well as in our normative analysis. Absent financial frictions, and with flexible exchange rates, the spillovers to the emerging economy are minimal.

Our results indicate that the simple prescriptions about the benefits of flexible exchange rates and inflation targeting are very unlikely to hold in a global financial environment dominated by the currency and policy of a large financial centre, such as the current situation with the US dollar and US monetary policy. Our preliminary analysis does suggest however that an optimal monetary policy can substantially improve the workings of the international system, even in the absence of direct intervention in capital markets through macro-prudential policies or capital controls. Moreover, under the specific assumptions maintained in this paper, this outcome can still be consistent with national independence in policy, or in other words, a system of 'self-oriented' monetary policy making.

[19] See Caballero et al. (2015) for a recent analysis of monetary policy spillovers at the ZLB.

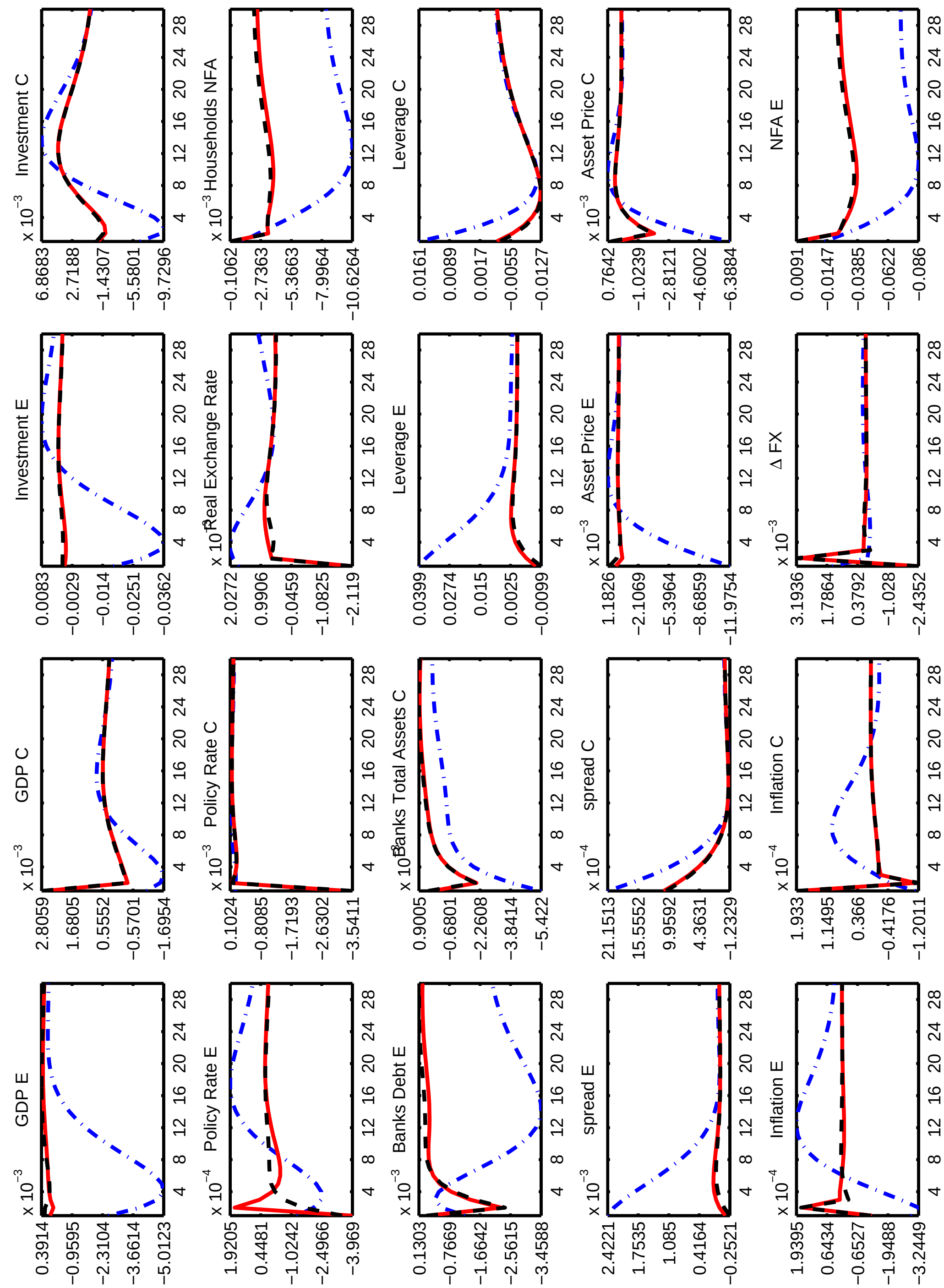


Figure 9.1: Policy responses to a financial shock in centre country; dot-dashed=Taylor, dashed=Nash, solid=Ramsey.

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Appendix A. Full list of equations used in the simulation

In this appendix we list all the equations of the model used in the derivation of the numerical results.

All variables preceded by exp are in expressed in logs (i.e. we take a log-approximation). A $_{ss}$ subscript indicates the value of that variable in the non-stochastic steady state. For simplicity we omit the expectation operator, with the understanding that variables dated $t+1$ are unknown at time t, so that the related expression implicitly involves the expectation operator

Objective of the policymaker(s):

$$U_t^{cb} = uu\_h\, n \left(\frac{exp\left(C_t^e\right)^{1-\sigma}}{1-\sigma} - \frac{\chi\, exp\left(H_t^e\right)^{1+\psi}}{1+\psi} \right) + uu\_f\ (1-n) \left(\frac{exp\left(C_t^c\right)^{1-\sigma}}{1-\sigma} - \frac{\chi\, exp\left(H_t^c\right)^{1+\psi}}{1+\psi} \right) \quad (A.1)$$

where uu_h and uu_f are $\{0,1\}$ weights defining the policy problem (both equal 1 for cooperation and either equal to zero for Nash).

Price dispersion measures:

$$exp\left(D_t^e\right) = \varsigma\, exp\left(D_{t-1}^e\right)\ exp\left(\pi_t^{ppi,e} - \chi_\pi\, \pi_{ppi,e,ss}\right)^{\sigma_p} + (1-\varsigma)\ exp\left(\pi_t^{*,e}\right)^{(-\sigma_p)} \quad (A.2)$$

$$exp\left(D_t^c\right) = \varsigma\, exp\left(D_{t-1}^c\right)\ exp\left(\pi_t^{ppi,c} - \chi_\pi\, \pi_{ppi,c,ss}\right)^{\sigma_p} + (1-\varsigma)\ exp\left(\pi_t^{*,c}\right)^{(-\sigma_p)} \quad (A.3)$$

Optimal price set by price-changing firms:

$$exp\left(\Pi_t^{*,e}\right) = \frac{exp\left(F_t^e\right)}{exp\left(G_t^e\right)} \quad (A.4)$$

$$exp\left(\Pi_t^{*,c}\right) = \frac{exp\left(F_t^c\right)}{exp\left(G_t^c\right)} \quad (A.5)$$

where

$$exp\left(F_t^e\right) = exp\left(Y_t^e\right)\ exp\left(MC_t^e\right) + \varsigma\, exp\left(\Lambda_{t+1}^e\right)\ exp\left(\pi_{t+1}^{ppi,e} - \chi_\pi\, \pi_{ppi,e,ss}\right)^{\sigma_p}\ exp\left(F_{t+1}^e\right) \quad (A.6)$$

$$exp\left(F_t^c\right) = exp\left(Y_t^c\right)\ exp\left(MC_t^c\right) + \varsigma\, exp\left(\Lambda_{t+1}^c\right)\ exp\left(\pi_{t+1}^{ppi,c} - \chi_\pi\, \pi_{ppi,c,ss}\right)^{\sigma_p}\ exp\left(F_{t+1}^c\right) \quad (A.7)$$

$$exp\left(G_t^e\right) = \frac{exp\left(Y_t^e\right)\ exp\left(P_t^e\right)}{\frac{\sigma_p}{\sigma_p-1}} + \varsigma\, exp\left(\Lambda_{t+1}^e\right)\ exp\left(\pi_{t+1}^{ppi,e} - \chi_\pi\, \pi_{ppi,e,ss}\right)^{\sigma_p-1}\ exp\left(G_{t+1}^e\right) \quad (A.8)$$

$$exp\left(G_t^c\right) = \frac{exp\left(Y_t^c\right)\ exp\left(P_t^c\right)}{\frac{\sigma_p}{\sigma_p-1}} + \varsigma\, exp\left(\Lambda_{t+1}^c\right)\ exp\left(\pi_{t+1}^{ppi,c} - \chi_\pi\, \pi_{ppi,c,ss}\right)^{\sigma_p-1}\ exp\left(G_{t+1}^c\right) \quad (A.9)$$

where MC is the marginal cost.

Relative PPI price dynamics:

$$1 = \varsigma\, exp\left(\pi_t^{ppi,e} - \chi_\pi\, \pi_{ppi,e,ss}\right)^{\sigma_p-1} + (1-\varsigma)\ exp\left(\Pi_t^{*,e}\right)^{1-\sigma_p} \quad (A.10)$$

$$1 = \varsigma\, exp\left(\pi_t^{ppi,c} - \chi_\pi\, \pi_{ppi,c,ss}\right)^{\sigma_p-1} + (1-\varsigma)\ exp\left(\Pi_t^{*,c}\right)^{1-\sigma_p} \quad (A.11)$$

Euler equation for foreign bonds:

$$\frac{\frac{exp\left(\Lambda_{t+1}^e\right) exp\left(R_t^*\right)}{exp\left(\pi_{t+1}^c\right)}\ exp\left(RER_{t+1}\right)}{exp\left(RER_t\right)} - 1 = 0 \quad (A.12)$$

Centre country consumption Euler equation:

$$\frac{exp\left(\Lambda^c_{t+1}\right)\ exp\left(R^*_t\right)}{exp\left(\pi^c_{t+1}\right)} - 1 = 0 \tag{A.13}$$

Gross return on capital:

$$exp\left(R^{k,e}_t\right)\ exp\left(Q^e_{t-1}\right) = \left(exp\left(MC^e_t\right)\ exp\left(A^e_t\right)\ \alpha\, exp\left(H^e_t\right)^{1-\alpha}\ exp\left(K^e_{t-1}\right)^{\alpha-1} + (1-\delta)\ exp\left(Q^e_t\right)\right) \tag{A.14}$$

$$exp\left(R^{k,c}_t\right)\ exp\left(Q^c_{t-1}\right) = \left(\alpha\, exp\left(MC^c_t\right)\ exp\left(A^c_t\right)\ exp\left(H^c_t\right)^{1-\alpha}\ exp\left(K^c_{t-1}\right)^{\alpha-1} + (1-\delta)\ exp\left(Q^c_t\right)\right) \tag{A.15}$$

Aggregate price indexes (in units of consumption aggregator):

$$1 = \nu^e\, exp\left(P^e_t\right)^{1-\eta_p} + (1-\nu^e)\ \left(exp\left(P^c_t\right)\ exp\left(RER_t\right)\right)^{1-\eta_p} \tag{A.16}$$

$$1 = \nu^c\, exp\left(P^c_t\right)^{1-\eta_p} + (1-\nu^c)\ \left(\frac{exp\left(P^e_t\right)}{exp\left(RER_t\right)}\right)^{1-\eta_p} \tag{A.17}$$

CPI inflation measures:

$$exp\left(P^e_t\right)\ exp\left(\pi^e_t\right) = exp\left(P^e_{t-1}\right)\ exp\left(\pi^{ppi,e}_t\right) \tag{A.18}$$

$$exp\left(P^c_t\right)\ exp\left(\pi^c_t\right) = exp\left(P^c_{t-1}\right)\ exp\left(\pi^{ppi,c}_t\right) \tag{A.19}$$

Labor market clearing condition:

$$exp\left(A^e_t\right)\ exp\left(MC^e_t\right)\ (1-\alpha)\ exp\left(H^e_t\right)^{(-\alpha)}\ exp\left(K^e_{t-1}\right)^{\alpha}\ exp\left(C^e_t\right)^{(-\sigma)} = \chi\, exp\left(H^e_t\right)^{\psi} \tag{A.20}$$

$$exp\left(A^c_t\right)\ exp\left(MC^c_t\right)\ (1-\alpha)\ exp\left(H^c_t\right)^{(-\alpha)}\ exp\left(K^c_{t-1}\right)^{\alpha}\ exp\left(C^c_t\right)^{(-\sigma)} = \chi\, exp\left(H^c_t\right)^{\psi} \tag{A.21}$$

Accumulation law for capital:

$$exp\left(K^e_t\right) = \left(exp\left(I^e_t\right) + exp\left(K^e_{t-1}\right)\ (1-\delta)\right) \tag{A.22}$$

$$exp\left(K^c_t\right) = \left(exp\left(I^c_t\right) + (1-\delta)\ exp\left(K^c_{t-1}\right)\right) \tag{A.23}$$

Investment Euler equations:

$$\begin{aligned} exp\left(Q^e_t\right) = 1 + \frac{\eta}{2}\ \left(\frac{exp\left(I^e_t\right)}{exp\left(I^e_{t-1}\right)} - 1\right)^2 + \left(\frac{exp\left(I^e_t\right)}{exp\left(I^e_{t-1}\right)} - 1\right)\ \frac{exp\left(I^e_t\right)\ \eta}{exp\left(I^e_{t-1}\right)} \\ - exp\left(\Lambda^e_{t+1}\right)\ \eta\ \left(\frac{exp\left(I^e_{t+1}\right)}{exp\left(I^e_t\right)}\right)^2\ \left(\frac{exp\left(I^e_{t+1}\right)}{exp\left(I^e_t\right)} - 1\right) \end{aligned} \tag{A.24}$$

$$\begin{aligned} exp\left(Q^c_t\right) = 1 + \frac{\eta}{2}\ \left(\frac{exp\left(I^c_t\right)}{exp\left(I^c_{t-1}\right)} - 1\right)^2 + \left(\frac{exp\left(I^c_t\right)}{exp\left(I^c_{t-1}\right)} - 1\right)\ \frac{exp\left(I^c_t\right)\ \eta}{exp\left(I^c_{t-1}\right)} \\ - exp\left(\Lambda^c_{t+1}\right)\ \eta\ \left(\frac{exp\left(I^c_{t+1}\right)}{exp\left(I^c_t\right)}\right)^2\ \left(\frac{exp\left(I^c_{t+1}\right)}{exp\left(I^c_t\right)} - 1\right) \end{aligned} \tag{A.25}$$

Aggregate budget constraint for EME households:

$$\begin{aligned} exp\left(C_t^e\right)+B_t^e\, exp\left(RER_t\right) = & \; exp\left(Y_t^e\right)\, exp\left(P_t^e\right) - exp\left(K_{t-1}^e\right)^{\alpha}\, exp\left(H_t^e\right)^{1-\alpha}\, exp\left(MC_t^e\right)\, exp\left(A_t^e\right)\, \alpha \\ & + exp\left(Q_t^e\right)\, exp\left(I_t^e\right) - exp\left(I_t^e\right)\left(1+\frac{\eta}{2}\left(\frac{exp\left(I_t^e\right)}{exp\left(I_{t-1}^e\right)}-1\right)^2\right) \\ & + exp\left(K_{t-1}^e\right)\, exp\left(Q_{t-1}^e\right)\, exp\left(R_t^{k,e}\right)\,(1-\theta)\,(1-\Gamma_t) \\ & - exp\left(K_{t-1}^e\right)\, exp\left(Q_t^e\right)\,\delta_T + exp\left(RER_t\right)\frac{exp\left(R_{t-1}^*\right)}{exp\left(\pi_t^c\right)}\, B_{t-1}^e \end{aligned} \tag{A.26}$$

Goods market clearing conditions:

$$exp\left(K_{t-1}^e\right)^{\alpha}\, exp\left(A_t^e\right)\, exp\left(H_t^e\right)^{1-\alpha} = exp\left(D_t^e\right)\, exp\left(Y_t^e\right) \tag{A.27}$$

$$exp\left(K_{t-1}^c\right)^{\alpha}\, exp\left(A_t^c\right)\, exp\left(H_t^c\right)^{1-\alpha} = exp\left(D_t^c\right)\, exp\left(Y_t^c\right) \tag{A.28}$$

Aggregate demand for domestic and foreign goods:

$$\begin{aligned} exp\left(Y_t^e\right) = & \; \nu^e\, exp\left(P_t^e\right)^{(-\eta_p)}\left(exp\left(C_t^e\right)+exp\left(I_t^e\right)\left(1+\frac{\eta}{2}\left(\frac{exp\left(I_t^e\right)}{exp\left(I_{t-1}^e\right)}-1\right)^2\right)\right) + (1 \\ & -\nu^c)\,\frac{1-n}{n}\left(\frac{exp\left(P_t^e\right)}{exp\left(RER_t\right)}\right)^{(-\eta_p)}\left(exp\left(C_t^c\right)+exp\left(I_t^c\right)\left(1+\frac{\eta}{2}\left(\frac{exp\left(I_t^c\right)}{exp\left(I_{t-1}^c\right)}-1\right)^2\right)\right) \end{aligned} \tag{A.29}$$

$$\begin{aligned} exp\left(Y_t^c\right) = & \left(exp\left(C_t^e\right)+exp\left(I_t^e\right)\left(1+\frac{\eta}{2}\left(\frac{exp\left(I_t^e\right)}{exp\left(I_{t-1}^e\right)}-1\right)^2\right)+\right)(1 \\ & -\nu^e)\,\frac{n}{1-n}\left(exp\left(P_t^c\right)\, exp\left(RER_t\right)\right)^{(-\eta_p)} \\ & +\left(exp\left(C_t^c\right)+exp\left(I_t^c\right)\left(1+\frac{\eta}{2}\left(\frac{exp\left(I_t^c\right)}{exp\left(I_{t-1}^c\right)}-1\right)^2\right)\right)\nu^c\, exp\left(P_t^c\right)^{(-\eta_p)} \end{aligned} \tag{A.30}$$

Optimal lending contract between center country banks and EME banks:

$$\begin{aligned} & exp\left(\Lambda_{t+1}^e\right)\,(1-\Gamma_{t+1})\, exp\left(R_{t+1}^{k,e}\right)\left(1-\theta+\theta\, exp\left(\alpha_{t+1}^{v,e}\right)\right) \\ & + exp\left(\varphi_t\right)\left(exp\left(R_{t+1}^{k,e}\right)\left(\Gamma_{t+1}\right)\left(\frac{exp\left(RER_t\right)}{exp\left(RER_{t+1}\right)}\right)^{ld} - \frac{exp\left(R_t^b\right)}{exp\left(\pi_{t+1}^c\right)^{ld}\, exp\left(\pi_{t+1}^e\right)^{1-ld}}\right) \\ & -\gamma_t^e\,\kappa_e\, exp\left(\kappa_t^e\right) = 0 \end{aligned} \tag{A.31}$$

where $ld = 1$ under "liability dollarization" and 0, otherwise; where $exp\left(\alpha^{v,e}\right) \equiv \frac{\partial exp\left(J_t^e\right)}{\partial exp\left(N_t^e\right)}$; where

$$\Gamma_t = \frac{exp\left(RER_t\right)^{ld}\, exp\left(R_{t-1}^b\right)}{exp\left(\pi_t^c\right)^{ld}\, exp\left(\pi_t^e\right)^{1-ld}\, exp\left(R_t^{k,e}\right)}\,\frac{exp\left(V_{t-1}^e\right)}{exp\left(Q_{t-1}^e\right)\, exp\left(K_{t-1}^e\right)} \tag{A.32}$$

and where

$$exp\left(\varphi_t\right) = \frac{exp\left(\alpha_t^{v,e}\right)\,\left(1-\gamma_t^e\right)}{\frac{exp\left(R_t^b\right)}{exp\left(\pi_{t+1}^c\right)^{ld}\, exp\left(\pi_{t+1}^e\right)^{1-ld}}} \tag{A.33}$$

Envelope condition:

$$exp\left(K_t^e\right)\ exp\left(Q_t^e\right)\ exp\left(R_{t+1}^{k,e}\right)\left(exp\left(\Lambda_{t+1}^e\right)\ \left(1-\theta+\theta\, exp\left(\alpha_{t+1}^{v,e}\right)\right)\ -\left(\frac{exp\left(RER_t\right)}{exp\left(RER_{t+1}\right)}\right)^{ld}\ exp\left(\varphi_t\right)\right)=0 \tag{A.34}$$

Incentive compatibility constraint for EME banks (using the fact that $exp\left(\alpha_t^{v,e}\right)\ exp\left(N_t^e\right)=exp\left(J_t^e\right)$):

$$exp\left(\alpha_t^{v,e}\right)\ exp\left(N_t^e\right)-exp\left(K_t^e\right)\ exp\left(Q_t^e\right)\ \kappa_e\, exp\left(\kappa_t^e\right)=0 \tag{A.35}$$

Net worth:

$$\begin{aligned} exp\left(N_t^e\right)=exp\left(K_{t-1}^e\right)\ exp\left(Q_t^e\right)\ \delta_T+\theta&\left(exp\left(R_t^{k,e}\right)\ exp\left(Q_{t-1}^e\right)\ exp\left(K_{t-1}^e\right)\right.\\ &\left.-\left(exp\left(RER_t\right)^{ld}\ \frac{exp\left(R_{t-1}^b\right)}{exp\left(\pi_t^c\right)^{ld}\ exp\left(\pi_t^e\right)^{1-ld}}\ exp\left(V_{t-1}^e\right)\right)\right)\end{aligned} \tag{A.36}$$

Optimal choice of total assets by centre country banks:

$$\begin{aligned} &exp\left(\Lambda_{t+1}^c\right)\ \left(1-\theta+\theta\, exp\left(\alpha_{t+1}^{v,c}\right)\right)\left(exp\left(R_{t+1}^{k,c}\right)-\frac{exp\left(R_t^*\right)}{exp\left(\pi_{t+1}^c\right)}\right.\\ &\left.-\frac{\frac{\frac{n}{1-n}\, exp(V_t^e)}{exp(RER_t)^{1-ld}}}{exp\left(\mathcal{W}_t\right)}\left(exp\left(R_{t+1}^{k,c}\right)-\frac{exp\left(R_t^b\right)\ \left(\frac{exp(RER_t)}{exp(RER_{t+1})}\right)^{1-ld}}{exp\left(\pi_{t+1}^c\right)^{ld}\ exp\left(\pi_{t+1}^e\right)^{1-ld}}\right)\right)=\kappa_c\, exp\left(\kappa_t^c\right)\ \gamma_t^c\end{aligned} \tag{A.37}$$

where $\mathcal{W}_t$ denotes total assets of centre country banks.

Centre country banks efficient investment in EME (asset pricing equation):

$$exp\left(\Lambda_{t+1}^c\right)\ \left(1-\theta+\theta\, exp\left(\alpha_{t+1}^{v,c}\right)\right)\ \left(exp\left(R_{t+1}^{k,c}\right)-\frac{exp\left(R_t^b\right)\ \left(\frac{exp(RER_t)}{exp(RER_{t+1})}\right)^{1-ld}}{exp\left(\pi_{t+1}^c\right)^{ld}\ exp\left(\pi_{t+1}^e\right)^{1-ld}}\right)=0 \tag{A.38}$$

Envelope condition for centre country optimal plan:

$$\left(-exp\left(\alpha_t^{v,c}\right)\right)\ \left(1-\gamma_t^c\right)+\frac{exp\left(R_t^*\right)\ exp\left(\Lambda_{t+1}^c\right)\ \left(1-\theta+\theta\, exp\left(\alpha_{t+1}^{v,c}\right)\right)}{exp\left(\pi_{t+1}^c\right)}=0 \tag{A.39}$$

Incentive compatibility constraint:

$$exp\left(\alpha_t^{v,c}\right)\ exp\left(N_t^c\right)-exp\left(\mathcal{W}_t\right)\ \kappa_c\, exp\left(\kappa_t^c\right)=0 \tag{A.40}$$

Net worth of centre country banks:

$$\begin{aligned} exp\left(N_t^c\right)=\theta&\left(\left(exp\left(R_t^{k,c}\right)-\frac{exp\left(R_{t-1}^*\right)}{exp\left(\pi_t^c\right)}\right)\ exp\left(\mathcal{W}_{t-1}\right)\right.\\ &\left.-\frac{\frac{n}{1-n}\, exp\left(V_{t-1}^e\right)}{exp\left(RER_t\right)^{1-ld}}\left(exp\left(R_t^{k,c}\right)-\frac{exp\left(R_{t-1}^b\right)\ \left(\frac{exp(RER_{t-1})}{exp(RER_t)}\right)^{1-ld}}{exp\left(\pi_t^c\right)^{ld}\ exp\left(\pi_t^e\right)^{1-ld}}\right)+\frac{exp\left(R_{t-1}^*\right)}{exp\left(\pi_t^c\right)}\ exp\left(N_{t-1}^c\right)\right)\\ &+exp\left(K_{t-1}^c\right)\ \delta_T\end{aligned} \tag{A.41}$$

Resource constraint for centre country banks:

$$exp\left(Q_t^e\right)\, exp\left(K_t^e\right) = exp\left(N_t^e\right) + exp\left(RER_t\right)^{ld}\, exp\left(V_t^e\right) \tag{A.42}$$

Definition of total assets of centre country banks:

$$exp\left(\mathcal{W}_t\right) = \frac{\frac{n}{1-n}\, exp\left(V_t^e\right)}{exp\left(RER_t\right)^{1-ld}} + exp\left(Q_t^c\right)\, exp\left(K_t^c\right) \tag{A.43}$$

Consumption Euler equation for centre country

$$exp\left(R_t^e\right)\frac{exp\left(\Lambda_{t+1}^e\right)}{exp\left(\pi_{t+1}^e\right)} = 1 \tag{A.44}$$

Leverage:

$$exp\left(\phi_t^e\right) = \frac{exp\left(Q_t^e\right)\, exp\left(K_t^e\right)}{exp\left(N_t^e\right)} \tag{A.45}$$

$$exp\left(\phi_t^c\right) = \frac{exp\left(\mathcal{W}_t\right)}{exp\left(N_t^c\right)} \tag{A.46}$$

Spreads (financial efficiency wedges):

$$exp\left(\chi_t^e\right) = \frac{exp\left(R_{t+1}^{k,e}\right)}{\frac{exp\left(R_t^e\right)}{exp\left(\pi_{t+1}^e\right)}} \tag{A.47}$$

$$exp\left(\chi_t^c\right) = \frac{exp\left(R_{t+1}^{k,c}\right)}{\frac{exp\left(R_t^*\right)}{exp\left(\pi_{t+1}^c\right)}} \tag{A.48}$$

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