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External Shocks, Banks and Optimal Monetary Policy in an Open Economy[1]

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Abstract

We document empirically that the 2007-09 Global Financial Crisis exposed emerging market economies (EMEs) to an adverse feedback loop of capital outflows, depreciating exchange rates, deteriorating balance sheets, rising credit spreads and falling real economic activity. In order to account for these empirical findings, we build a New-Keynesian DSGE model of a small open economy with a banking sector that has access to both domestic and foreign funding. Using the calibrated model, we investigate optimal, simple and operational monetary policy rules that respond to domestic/external financial variables alongside inflation and output. The Ramsey-optimal policy rule is used as a benchmark. The results suggest that such an optimal policy rule features direct and non-negligible responses to lending spreads over the cost of foreign debt, the real exchange rate and the US policy rate, together with a mild anti-inflationary policy stance in response to domestic and external shocks. Optimal policy faces trade-offs in smoothing inefficient fluctuations in the intratemporal and intertemporal wedges driven by inflation, credit spreads and the real exchange rate. In response to productivity and external shocks, a countercyclical reserve requirement (RR) rule used in coordination with a conventional interest rate rule attains welfare levels comparable to those implied by spread- and real exchange rate-augmented rules.

Keywords: Optimal monetary policy, banks, credit frictions, external shocks, foreign debt.
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1 Introduction

The 2007–09 Global Financial Crisis exposed EMEs to an adverse feedback loop of capital outflows, depreciating exchange rates, deteriorating balance sheets, rising credit spreads and falling real economic activity. Furthermore, the unconventional response of advanced economy policymakers to the crisis caused EMEs to sail in unchartered waters from a monetary policymaking perspective. These adverse developments revitalised the previous debate about whether central banks should pay attention to domestic or external financial variables over and above their effects on inflation and real economic activity. Consequently, the lean-against-the-wind policies (hereafter LATW)- defined as augmented Taylor-type monetary policy rules that respond to financial variables beyond their impact on price stability- are now central to discussions in both academic and policy circles.[1] This debate is even more pronounced in EMEs since exchange rate developments affect both inflation and balance sheet dynamics, and therefore threaten both price and financial stability objectives. Therefore, the question of whether domestic/external financial factors should play a role in monetary policymaking, or in short-term policy rate determination, should be accompanied by a consideration of additional relevant policy tools such as RRs.

This paper studies optimal monetary policy in an open economy with financial market imperfections in the presence of both domestic and external shocks. Using a canonical New-Keynesian DSGE model of a small open economy augmented by a banking sector that has access to both domestic and foreign funds, we investigate the quantitative performances of optimal, simple and implementable LATW-type interest rate rules relative to a Ramsey-optimal monetary policy rule. We follow the definition of Schmitt-Grohé and Uribe (2007) in constructing optimal, simple and implementable monetary policy rules. Such rules respond to easily observable macroeconomic variables while preserving the determinacy of equilibrium. We consider a small number of targets among a wide range of variables that are arguably important for policymaking. In particular, we look at the level of credit, asset prices, credit spreads, the US policy rate and the real exchange rate as additional inputs to policy. We then compare these optimal LATW-type Taylor rules with standard optimised Taylor rules (with and without interest-rate smoothing). We use the Ramsey-optimal monetary policy rule as our benchmark and compute the welfare losses implied by each optimised Taylor rule vis-à-vis the Ramsey rule.

Our model builds on Galí and Monacelli (2005). The main departure from their canonical New-Keynesian small open economy model is that we introduce an active banking sector as in Gertler and Kiyotaki (2011). In this class of models, financial frictions require banks to collect funds from external sources while limiting their ability to borrow because of an endogenous leverage constraint resulting from a costly enforcement problem. This departure generates a financial accelerator mechanism by which the balance sheet fluctuations of banks affect real economic activity. Our model differs from that of Gertler and Kiyotaki (2011) in that it replaces interbank borrowing by foreign debt in an open economy setup. Consequently, the endogenous leverage constraint of bankers that we posit is additionally affected by fluctuations in the exchange rate.

We assume that frictions between banks, on one side, and their domestic and foreign creditors, on the other side, are asymmetric. Specifically, domestic depositors are assumed to be more efficient than international depositors in recovering assets from banks in case of bankruptcy. This makes foreign debt more risky and depresses the magnitude of intermediated foreign funds relative to domestic funds. Consequently, loan/deposit spreads over foreign debt become higher than those

[1] See the discussions in Angelini et al. (2011) and Gambacorta and Signoretti (2014).

of domestic debt as empirically observed in EMEs.[2] This key ingredient gives us the ability to empirically match the liability structure of domestic banks (which is defined as the share of non-core liabilities) and analyse changes in this measure in response to external shocks. Lastly, our model incorporates various real rigidities that generally form part of medium-scale DSGE models such as those studied by Christiano et al. (2005), and Smets and Wouters (2007). In particular, the model's empirical fit is improved by features such as habit formation in consumption, variable capacity utilisation and investment adjustment costs.

First, we derive analytically the intratemporal and intertemporal wedges in our model economy and compare them to a first-best flexible-price closed economy model to better understand the policy trade-offs that the Ramsey planner (and his optimal, simple and operational monetary policy rule) faces in response to shocks. We show that the distortions in the intratemporal wedge are mainly driven by variations in the inflation rate and the real exchange rate induced by monopolistic competition, price stickiness, home bias and incomplete exchange rate pass-through. At the same time, the distortions in the intertemporal wedge are mainly driven by variations in the domestic and foreign lending spreads together with those in the real exchange rate induced by financial market imperfections and open economy features. We confirm these findings by numerical simulations of the model.

We then conduct our quantitative analysis under five different types of shock that might be crucial for optimal policy prescription in EMEs. The first two of these are total factor productivity and government spending, which we label as domestic shocks. The remaining three are the country borrowing premium, the US interest rate and export demand, which we label as external shocks.[3] Finally, we also analyse optimal policy in an economy driven jointly by all of these shocks given that it might be difficult for the monetary authority to perfectly disentangle the different sources of business cycle movements while designing its policy.

Our main results suggest that a Ramsey-optimal policy rule limits inefficient fluctuations in the intratemporal and intertemporal wedges, which are mainly caused by inefficient movements in the inflation rate, the domestic and foreign lending spreads and the real exchange rate. In particular, in an economy driven by both domestic and external shocks, the planner substantially reduces the relative volatilities of the consumer price inflation (CPI) index, the aggregate markup and the real exchange rate, together with the relative volatilities of the domestic and foreign lending spreads, compared with a decentralised economy. We also observe a considerable reduction in the relative volatilities of bank leverage and net worth, mainly due to lower variations of the lending spreads and the real exchange rate. However, the policy rate under the Ramsey-optimal policy rule is more volatile than the rate prevailing under optimal, simple and operational monetary policy rules. Furthermore, the Ramsey-optimal policy rule achieves the lowest volatility in inflation compared with all the other optimal, simple and operational policy rules. At the same time, the volatilities of the lending spreads and the real exchange rate are smaller under the optimal spread-augmented Taylor rule compared with the Ramsey-optimal policy rule. On the other hand, the volatility of inflation is much higher under the spread-augmented rule relative to the Ramsey-optimal policy rule. This shows that, under both domestic and external shocks, the Ramsey planner puts more

[2] We illustrate in the bottom-left panel of Figure 1 that, with the exception of the period Q2 2010-Q3 2011, credit spreads on foreign debt are larger than credit spreads on domestic deposits. This implies that domestic deposit rates are higher than foreign deposit rates. This regularity dates back to Q4 2002 for the average EME in our sample.

[3] A shock to a country's borrowing premium can be justified arguably by the reduction in the global risk appetite driven by the collapse of Lehman Brothers in September 2008 or the taper tantrum of May 2013. A shock to the US policy rate can be justified by the accommodative monetary stance of the Federal Reserve in the aftermath of the crisis and the policy normalisation expected in late 2015.

weight at the margin on mitigating the distortions resulting from price dispersion compared with stabilising the inefficiencies resulting from credit frictions.

An optimal, simple and operational policy rule that prescribes a negative and non-negligible response to credit spreads over the cost of foreign debt (beyond their effects on inflation and the output gap) achieves the highest welfare possible under all shocks. The welfare cost of implementing this policy relative to the Ramsey-optimal policy rule is 0.987% in compensating consumption variation terms, whereas that of implementing a standard optimised Taylor rule with smoothing stands at 3.1%. This implies that significant welfare gains can be captured by using an optimal spread-augmented Taylor rule. In addition, the model-implied degrees of response to foreign lending spreads are found to be higher for external shocks than domestic shocks. The response to inflation in the optimal spread-augmented Taylor policy rule under each type of shock is milder than what it would be in a closed-economy model without financial market imperfections. The intuition hinges on the fact that the optimal policy smooths inefficient fluctuations in credit spreads at the expense of creating higher inflation volatility. By resolving the trade-off between stabilising the intratemporal and intertemporal wedges, the spread-augmented policy rule attains the lowest measured volatility for the real exchange rate relative to output, in comparison with the other optimal, simple and operational policy rules.

An optimal, simple and operational policy rule that features a positive response to the real exchange rate achieves a level of welfare that is very close to that of an optimal spread-augmented Taylor rule in a model economy driven by all shocks. In particular, the welfare cost of implementing this policy rule relative to the Ramsey-optimal policy rule is 0.993% in consumption-equivalent welfare terms. This policy rule significantly reduces the volatility of inflation compared with the optimal spread-augmented Taylor rule while featuring higher volatilities of credit spreads and the real exchange rate. In this case, the policy trade-off is resolved in favour of stabilising movements in the intratemporal wedge at the expense of higher volatility in the intertemporal wedge.

We also analyse a particular augmented policy rule that systematically responds to movements in the US policy rate in addition to inflation and output variations. This rule might be of particular interest for policymakers in EMEs as domestic policy rates in such countries might be driven by changes in the US policy rate over and above what domestic factors would imply, which is empirically shown by Takáts and Vela (2014), and Hofmann and Takáts (2015). The model results confirm the empirical findings, suggesting that it is optimal for an EME policymaker to positively respond to the US policy rate. In response to a 100 basis points increase in the US policy rate, the EME central bank should raise its policy rate by 21 basis points. The welfare cost of implementing this policy is 1.11% relative to the Ramsey-optimal policy rule. Lastly, our main findings indicate that it is not optimal to respond to credit growth under any shock whereas it is optimal to respond to asset prices only under domestic shocks.

Augmenting the short-term policy rate by a LATW objective might be counterproductive from the perspective of a central bank if hitting multiple targets necessitates different trajectories for the single policy tool. To that end, Shin (2013) and Chung et al. (2014) have recently emphasised the usefulness of liability-based macroprudential policy tools alongside conventional monetary policy. Motivated by these studies and the experience of EMEs, we consider a RR rule that responds countercyclically to deviations of the credit spread over the cost of non-core debt from its long-run value. We also examine whether the optimal policy mix of this countercyclical rule with a conventional Taylor rule can compete with an optimal LATW-type monetary policy rule in maximising welfare. We also consider a case in which the RR rule is optimised in isolation from the Taylor rule to reflect cases for which there is a lack of coordination among authorities.

The results regarding the uses of a conventional Taylor rule and a countercyclical RR policy suggest that employing the two rules in response to multiple wedges is better than using only the short-term policy rate. That is, under domestic, external and all other shocks, the optimal RR ratio rule always prescribes a negative response to credit spreads over the cost of foreign borrowing. Moreover, in response to each separate shock, the welfare costs implied by a joint optimisation of these policy instruments are always strictly lower than for the cases for which the interest-rate rule and the RR rule are optimised separately. Indeed, the welfare costs implied by the jointly optimised rules are very close to those implied by the best optimal, simple and applicable LATW-type interest rate rule in the case of productivity, country risk premium and US interest rate shocks. Hence, our findings suggest that if under certain shocks the central bank finds it hard to employ a LATW-type interest rate rule, it might rely on RRs as an additional tool without foregoing substantial stabilisation gains.

Related literature

This paper is related to a vast body of literature on the optimality of responses to financial variables. In closed-economy frameworks, Faia and Monacelli (2007) use a New-Keynesian model with agency costs to argue that responding to asset prices with a Taylor-type interest rate rule is welfare improving when the response to inflation is not strong. Cúrdia and Woodford (2010) find that it is optimal to respond to credit spreads under financial disturbances in a model with costly financial intermediation. Gilchrist and Zakrajšek (2011) show that a spread-augmented Taylor rule smooths fluctuations in real and financial variables in the Bernanke et al. (1999) model. Hirakata et al. (2013), and Gambacorta and Signoretti (2014) consider frameworks with an explicit and simultaneous modeling of the balance sheets of non-financial firms and banks. The former shows that a spread-augmented Taylor rule stabilises the adverse effects of shocks that widen credit spreads while the latter shows that LATW-type interest rate rules that respond to asset prices improve upon the standard Taylor-type rules even in response to supply side shocks. Fendoğlu (2014), using the Bernanke et al. (1999) model, argues that it is optimal to respond to credit spreads under uncertainty shocks but not under first-moments shocks such as productivity changes and government spending. Kannan et al. (2012), Lambertini et al. (2013), and Notarpietro and Siviero (2015) investigate whether it is welfare-improving to respond to house price movements using the Iacoviello and Neri (2010) model with housing assets and collateral constraints. Angeloni and Faia (2013) suggest that smoothing movements in asset prices in conjunction with capital requirements is welfare improving relative to simple policy rules in a New-Keynesian model with risky banks. Moreover, Angelini et al. (2011) show that macroprudential policy instruments, such as capital requirements and loan-to-value ratios, are effective in response to financial shocks. Mimir et al. (2013) illustrate that countercyclical RRs that respond to credit growth have desirable stabilisation properties (as opposed to time-invariant required reserve ratios).

Glocker and Towbin (2012) use a New-Keynesian small open economy model of the financial accelerator that works through firms balance sheets to investigate the interaction of alternative monetary policy rules and RRs in a setup where firms borrow either from domestic depositors or from foreign investors. Medina and Roldós (2014) focus on the effects of alternative parameterised monetary and macroprudential policy rules in an open economy setting with a modeling of the financial sector that is different from ours. They find that the LATW capabilities of conventional monetary policy might be limited. However, none of these papers consider the Ramsey-optimal policy rule and nor they investigate optimal, simple and implementable interest rate rules. Moreover, closely related to our work, Kolasa and Lombardo (2014) study optimal monetary policy in a two-country DSGE model of the euro area with financial frictions considered by Bernanke et al. (1999), and under which firms can collect both domestic and foreign currency-denominated debt.

They find that the monetary authority should correct credit market distortions at the expense of deviations from price stability. Finally, Banerjee et al. (forthcoming) use a core-periphery DSGE model, with global and local banks being exposed to financial frictions, to investigate the role of optimal monetary policy coordination in mitigating the macroeconomic spillovers from advanced economies to EMEs under US monetary policy shocks. Their results suggest that there is no need for optimal monetary policy coordination among countries.

This paper contributes to the literature surveyed above in four main respects. First, we investigate the optimality of responding to financial variables in an open economy framework since such a framework gives us the ability to consider external shocks leading to capital outflows, which is highly relevant for EMEs. In addition, it enables us to study the transmission of changes in real exchange rates to inflation and the impact of such changes on balance sheet dynamics, and to determine whether monetary policy should respond to changes in real exchange rates over and above their effects on inflation and output variations. Second, in this open economy setting, we study the role of a banking sector that can borrow simultaneously domestic and foreign funds in the transmission of LATW-type interest rate rules and RRs to the macroeconomy. Third, we derive analytically the intratemporal and intertemporal wedges in the model economy, and characterise the optimal monetary policy rule by solving the Ramsey planner's problem. Finally, we construct optimal, simple and operational monetary policy rules that respond to a wide array of financial variables together with the optimal policy mix of a conventional Taylor rule and RRs. We then compute the welfare costs of these policies relative to the Ramsey-optimal policy.

The rest of the paper is structured as follows. Section 2 provides a systematic documentation of the adverse feedback loop faced by EMEs during the Global Financial Crisis. In Section 3, we describe our theoretical framework. Section 4 focuses on our quantitative analysis and investigates optimal, simple and implementable monetary policy rules for EMEs. Finally, Section 5 concludes.

2 The 2007-09 crisis and macroeconomic dynamics in the EMEs

Although the crisis originated in advanced economies, EMEs experienced the severe contractionary effects induced by the crisis as Figure 1 clearly illustrates for 20 EMEs around the 2007-09 episode. In the Figure, variables regarding the real economic activity and the external side are depicted by cross-country simple means of deviations from HP trends.[4] The top-left panel of the Figure illustrates that capital inflows to EMEs sharply reversed accompanied by roughly 400 basis points increase in the country borrowing premium (the top-middle panel), as measured by the EMBI Global spread, leading to sharp hikes in lending spreads over the costs of domestic and foreign funds by around 400 basis points (the bottom-left panel). Finally, the cyclical components of the real effective exchange rate and current account-to-GDP ratios (illustrated in the bottom-middle panel) displayed reversals of about 10% and 2%, respectively. In addition to these facts, Mihaljek (2011) documents that the tightening in domestic financial conditions in EMEs coincides with substantial declines in external bank finance (including both domestic deposits and foreign debt) which resulted in dramatic falls in their loans to corporations. As a result of these adverse developments in domestic and external financial conditions, GDP and consumption declined by around 4% and investment fell by 8% compared to their HP trend levels in EMEs.

[4]Data sources used in this section are the Bank for International Settlements, Bloomberg, EPFR, International Monetary Fund and individual country central banks. Countries included in the analysis are Brazil, Chile, China, Colombia, Czech Republic, Hungary, India, Indonesia, Israel, Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, Singapore, South Africa, Thailand, and Turkey. Using medians of deviations for the plotted variables produce similar patterns.

We also illustrate cross-sectional developments in the EME group by providing Table 1, which displays the peak-to-trough changes in macroeconomic and financial variables in the 2007:Q1-2011:Q3 episode for each individual EME in our sample. The average changes in variables might be different than those plotted in Figure 1 since the exact timing of peak-to-trough is different for each EME. The table indicates that there is a substantial heterogeneity among EMEs in terms of realised severity of the financial crisis. In order to mitigate the adverse effects of the financial crisis, EME central banks raised policy rates when capital outflows emerged in the run up to the crisis, then gradually eased their policy stances (of about 4 percentage points in 6 quarters) in response to the accommodative policies of advanced economies during the crisis. Reserve requirements, on the other hand, complemented conventional monetary policy at the onset of the crisis and appear to substitute short-term policy rates when there was a sharp upward reversal in capital flows in the aftermath of the crisis.[5]

All in all, it is plausible to argue that the 2007-09 global financial crisis exposed emerging market economies (EMEs) to an adverse feedback loop of capital outflows, depreciating exchange rates, deteriorating balance sheets, rising credit spreads and falling real economic activity. The policy response of authorities in these countries on the other hand, is strongly affected by the repercussions of the unconventional policy measures introduced by advanced economies and displayed diversity in the set of policy tools used. The next section provides a theory that replicates these features of the data and explores what kind of monetary policy design could be deemed as optimal from a welfare point of view.

3 Model economy

The analytical framework is a medium-scale New Keynesian small open economy model inhabited by households, banks, non-financial firms, capital producers, and a government. Financial frictions define bankers as a key agent in the economy. The modeling of the banking sector follows Gertler and Kiyotaki (2011), with the modification that bankers make external financing from both domestic depositors and international investors, potentially bearing currency risk. The consolidated government makes an exogeneous stream of spending and determines monetary as well as macroprudential policy. The benchmark monetary policy regime is a Taylor rule that aims to stabilise inflation and output. In order to understand the effectiveness of alternative monetary policy rules, we augment the baseline policy framework with a number of various domestic and external financial stability objectives. In addition, we analyze the countercyclical use of reserve requirements in reducing the volatility of credit spreads over the cost of non-core bank borrowing. Unless otherwise stated, variables denoted by upper (lower) case characters represent nominal (real) values in domestic currency. Variables that are denominated in foreign currency or related to the rest of the world are indicated by an asterisk. For brevity, we include key model equations in the main text. Interested readers might refer to Appendix A for detailed derivations of the optimization problems of agents and a definition of the competitive equilibrium.

3.1 Households

There is a large number of infinitely-lived identical households, who derive utility from consumption c_t, leisure $(1 - h_t)$, and real money balances $\frac{M_t}{P_t}$. The consumption good is a constant-elasticity-

[5] The abrupt decline of about 4 percentage points in reserve requirements from 2009:Q4 to 2010:Q1 is mostly due to Colombia and Peru as they reduced their reserve requirement ratios by 16 and 9 percentage points, respectively.

of-substitution (CES) aggregate of domestically produced and imported tradable goods as in Galí and Monacelli (2005) and Gertler et al. (2007),

$$c_t = \left[\omega^{\frac{1}{\gamma}}(c_t^H)^{\frac{\gamma-1}{\gamma}} + (1-\omega)^{\frac{1}{\gamma}}(c_t^F)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{1}$$

where $\gamma > 0$ is the elasticity of substitution between home and foreign goods, and $0 < \omega < 1$ is the relative weight of home goods in the consumption basket, capturing the degree of home bias in household preferences. Let P_t^H and P_t^F represent domestic currency denominated prices of home and foreign goods, which are aggregates of a continuum of differentiated home and foreign good varieties respectively. Then, then the expenditure minimization problem of households subject to the consumption aggregator (1) produces the domestic consumer price index (CPI),

$$P_t = \left[\omega(P_t^H)^{1-\gamma} + (1-\omega)(P_t^F)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{2}$$

and the condition that determines the optimal demand frontier for home and foreign goods,

$$\frac{c_t^H}{c_t^F} = \frac{\omega}{1-\omega}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma}. \tag{3}$$

We assume that each household is composed of a worker and a banker who perfectly insure each other. Workers consume the consumption bundle and supply labor h_t. They also save in local currency assets which are *deposited* within financial intermediaries owned by the banker members of *other* households.[6] The balance of these deposits is denoted by B_{t+1}, which promises to pay a net nominal risk-free rate r_{nt} in the next period. There are no interbank frictions, hence r_{nt} coincides with the policy rate of the central bank. Furthermore, the borrowing contract is *real* in the sense that the risk-free rate is determined based on the expected inflation. By assumption, households cannot directly save in productive capital, and only banker members of households are able to borrow in foreign currency.

Preferences of households over consumption, leisure, and real balances are represented by the lifetime utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t, h_t, \frac{M_t}{P_t}\right), \tag{4}$$

where U is a CRRA type period utility function given by

$$U\left(c_t, h_t, \frac{M_t}{P_t}\right) = \left[\frac{(c_t - h_c c_{t-1})^{1-\sigma} - 1}{1-\sigma} - \frac{\chi}{1+\xi}h_t^{1+\xi} + \upsilon\ \log\left(\frac{M_t}{P_t}\right)\right]. \tag{5}$$

E_t is the mathematical expectation operator conditional on the information set available at t, $\beta \in (0,1)$ is the subjective discount rate, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $h_c \in [0,1)$ governs the degree of habit formation, χ is the utility weight of labor, and $\xi > 0$ determines the Frisch elasticity of labor supply. We also assume that the natural logarithm of real money balances provides utility in an additively separable fashion with the utility weight υ.[7]

Households face the flow budget constraint,

[6] This assumption is useful in making the agency problem that we introduce in Section 3.2 more realistic.

[7] The logarithmic utility used for real money balances does not matter for real allocations as it enters into the utility function in an additively separable fashion and money does not appear in any optimality conditions except the consumption-money optimality condition.

$$c_t + \frac{B_{t+1}}{P_t} + \frac{M_t}{P_t} \ = \ \frac{W_t}{P_t} h_t + \frac{(1 + r_{nt-1}) B_t}{P_t} + \frac{M_{t-1}}{P_t} + \Pi_t - \frac{T_t}{P_t}. \tag{6}$$

On the right hand side are the real wage income $\frac{W_t}{P_t} h_t$, real balances of the domestic currency interest bearing assets at the beginning of period t $\frac{B_t}{P_t}$, and real money balances at the beginning of period t $\frac{M_{t-1}}{P_t}$. Π_t denotes real profits remitted from firms owned by the households (banks, intermediate home goods producers, and capital goods producers). T_t represents nominal lump-sum taxes collected by the government. On the left hand side are the outlays for consumption expenditures and asset demands.

Households choose c_t, h_t, B_{t+1}, and M_t to maximise preferences in (5) subject to (6) and standard transversality conditions imposed on asset demands, B_{t+1}, and M_t. The first order conditions of the utility maximization problem of the households are given by

$$\varphi_t = (c_t - h_c c_{t-1})^{-\sigma} - \beta h_c E_t \left(c_{t+1} - h_c c_t\right)^{-\sigma}, \tag{7}$$

$$\frac{W_t}{P_t} = \frac{\chi h_t^{\xi}}{\varphi_t}, \tag{8}$$

$$\varphi_t = \beta E_t \left[\varphi_{t+1} (1 + r_{nt}) \frac{P_t}{P_{t+1}} \right], \tag{9}$$

$$\frac{\upsilon}{M_t / P_t} = \beta E_t \left[\varphi_{t+1} r_{nt} \frac{P_t}{P_{t+1}} \right]. \tag{10}$$

Equation (7) defines the Lagrange multiplier, φ_t as the marginal utility of consuming an additional unit of income. Equation (8) equates marginal disutility of labor to the shadow value of real wages. Finally, equations (9) and (10) represent the Euler equations for bonds, the consumption-savings margin, and money demand, respectively.

The nominal exchange rate of the foreign currency in domestic currency units is denoted by S_t. Therefore, the real exchange rate of the foreign currency in terms of real home goods becomes $s_t = \frac{S_t P_t^*}{P_t}$, where foreign currency denominated CPI P_t^*, is taken exogenously.

We assume that foreign goods are produced in a symmetric setup as in home goods. That is, there is a continuum of foreign intermediate goods that are bundled into a composite foreign good, whose consumption by the home country is denoted by c_t^F. We assume that the law of one price holds for the import prices of intermediate goods, that is, $MC_t^F = S_t P_t^{F*}$, where MC_t^F is the marginal cost for intermediate good importers and P_t^{F*} is the foreign currency denominated price of such goods. Foreign intermediate goods producers put a markup over the marginal cost MC_t^F while setting the domestic currency denominated price of foreign goods. The small open economy also takes P_t^{F*} as given. In Section 3.4, we elaborate further on the determination of the domestic currency denominated prices of home and foreign goods, P_t^H and P_t^F.

3.2 Banks

The modeling of banks closely follows Gertler and Kiyotaki (2011) except that banks in our model borrow in local currency from domestic households and in foreign currency from international lenders. They combine these funds with their net worth, and finance capital expenditures of home based tradable goods producers. For tractability, we assume that banks only lend to home based production units.

The main financial friction in this economy originates in the form of a moral hazard problem between bankers and their funders and leads to an endogenous borrowing constraint on the former. The agency problem is such that depositors (both domestic and foreign) believe that bankers might divert a certain fraction of their assets for their own benefit. Additionally, we formulate the diversion assumption in a particular way to ensure that in equilibrium, an endogeneous positive spread between the costs of domestic and foreign borrowing emerges, as in the data. Ultimately, in equilibrium, the diversion friction restrains funds raised by bankers and limits the credit extended to non-financial firms, leading up to nonnegative credit spreads.

Banks are also subject to symmetric reserve requirements on domestic and foreign deposits i.e., they are obliged to hold a certain fraction of domestic and foreign deposits rr_t, within the central bank. We retain this assumption to facilitate the investigation of reserve requirements as a policy tool used by the monetary authority.

3.2.1 Balance sheet

The period-t balance sheet of a banker j denominated in domestic currency units is,

$$Q_t l_{jt} = B_{jt+1}(1 - rr_t) + S_t B^*_{jt+1}(1 - rr_t) + N_{jt}, \tag{11}$$

where B_{jt+1} and B^*_{jt+1} denote domestic deposits and foreign debt (in nominal foreign currency units) respectively. N_{jt} denotes bankers' net worth, Q_{jt} is the nominal price of securities issued by non-financial firms against their physical capital demand and l_{jt} is the quantity of such claims. rr_t is the required reserves ratio on domestic and foreign deposits. It is useful to divide equation (11) by the aggregate price index P_t and re-arrange terms to obtain banker j's balance sheet in real terms. Those manipulations imply

$$q_t l_{jt} = b_{jt+1}(1 - rr_t) + b^*_{jt+1}(1 - rr_t) + n_{jt}, \tag{12}$$

where q_t is the relative price of the security claims purchased by bankers and $b^*_{jt+1} = \frac{S_t B^*_{jt+1}}{P_t}$ is the foreign borrowing in real domestic units. Notice that if the exogenous foreign price index P^*_t is assumed to be equal to 1 at all times, then b^*_{jt+1} incorporates the impact of the real exchange rate, $s_t = \frac{S_t}{P_t}$ on the balance sheet.

Next period's real net worth n_{jt+1}, is determined by the difference between the return earned on assets (i.e., loans and reserves) and the cost of borrowing. Therefore we have,

$$n_{jt+1} = R_{kt+1} q_t l_{jt} + rr_t(b_{jt+1} + b^*_{jt+1}) - R_{t+1} b_{jt+1} - R^*_{t+1} b^*_{jt+1}, \tag{13}$$

where R_{kt+1} denotes the state-contingent real return earned on the purchased claims issued by the production firms. R_{t+1} is the real risk-free deposit rate offered to domestic workers, and R^*_{t+1} is the country borrowing rate of foreign debt, denominated in real domestic currency units. R_t and R^*_t both satisfy Fisher equations,

$$R_t = E_t\left\{(1 + r_{nt})\frac{P_t}{P_{t+1}}\right\}$$

$$R^*_t = E_t\left\{\Psi_t(1 + r^*_{nt})\frac{S_{t+1}}{S_t}\frac{P_t}{P_{t+1}}\right\} \quad \forall t, \tag{14}$$

where r_n denotes the net nominal deposit rate as in equation (6) and r^*_n denotes the net nominal international borrowing rate. Bankers face a premium over this rate while borrowing from abroad.

Specifically, the premium is an increasing function of foreign debt that is, $\Psi_t = \exp\left(\psi_1 \hat{b^*_{t+1}}\right)\psi_t$, where $\hat{b^*_{t+1}}$ represents the log deviation of the aggregate foreign debt of bankers from its steady-state level, $\psi_1 > 0$ is the foreign debt elasticity of country risk premium, and ψ_t is a random disturbance to this premium.[8] Particularly, we assume ψ_t follows,

$$\log(\psi_{t+1}) = \rho^{\psi}\log(\psi_t) + \epsilon^{\psi}_{t+1}$$

with zero mean and constant variance innovations ϵ^{Ψ}_{t+1}. Introducing ψ_t enables us to study the domestic business cycle responses to exogenous cycles in global capital flows. In order to capture the impact of monetary policy normalization on emerging economies, we assume that exogenous world interest rates follow an autoregressive process denoted by,

$$r^*_{nt+1} = \rho^{r^*_n} r^*_{nt} + \epsilon^{r^*_n}_{t+1}.$$

The innovations $\epsilon^{r^*_n}_{t+1}$ are normally distributed with zero mean and constant variance $\sigma^{r^*_n}$. Solving for b_{jt+1} in equation (12) and substituting it in equation (13), and re-arranging terms imply that bank's net worth evolves as,

$$n_{jt+1} = \left[R_{kt+1} - \hat{R}_{t+1}\right] q_t l_{jt} + \left[R_{t+1} - R^*_{t+1}\right] b^*_{jt+1} + \hat{R}_{t+1} n_{jt}. \tag{15}$$

with $\hat{R}_{t+1} = \frac{R_{t+1} - rr_t}{1 - rr_t}$ representing the reserves adjusted domestic deposit rate. This equation illustrates that individual bankers' net worth depends positively on the premium of the return earned on assets over the reserves adjusted cost of borrowing, $R_{kt+1} - \hat{R}_{t+1}$. The second term on the right-hand side shows the benefit of raising foreign debt as opposed to domestic debt. Finally, the last term highlights the contribution of internal funds, that are multiplied by $\hat{R}_{t+1}$, the opportunity cost of raising one unit of external funds via domestic borrowing.

Banks would find it profitable to purchase securities issued by non-financial firms only if

$$E_t\left\{\Lambda_{t,t+i+1}\left[R_{kt+i+1} - \hat{R}_{t+i+1}\right]\right\} \geq 0 \;\; \forall t,$$

where $\Lambda_{t,t+i+1} = \beta E_t\left[\frac{U_c(t+i+1)}{U_c(t)}\right]$ denotes the $i+1$ periods-ahead stochastic discount factor of households, whose banker members operate as financial intermediaries. Notice that in the absence of financial frictions, an abundance in intermediated funds would cause R_k to decline until this premium is completely eliminated. In the following, we also establish that

$$E_t\left\{\Lambda_{t,t+i+1}\left[R_{t+i+1} - R^*_{t+i+1}\right]\right\} > 0 \;\; \forall t,$$

so that the cost of domestic debt entails a positive premium over the cost of foreign debt at all times.

In order to rule out any possibility of complete self-financing, we assume that bankers have a finite life and survive to the next period only with probability $0 < \theta < 1$. At the end of each period, $1-\theta$ measure of new bankers are born and are remitted $\frac{\epsilon^b}{1-\theta}$ fraction of the assets owned by exiting bankers in the form of start-up funds.

[8] By assuming that the cost of borrowing from international capital markets increases in the net foreign indebtedness of the aggregate economy, we ensure the stationarity of the foreign asset dynamics as in Schmitt-Grohé and Uribe (2003).

3.2.2 Net worth maximization

Bankers maximise expected discounted value of the terminal net worth of their financial firm V_{jt}, by choosing the amount of security claims purchased l_{jt} and the amount of foreign debt b^*_{jt+1}. For a given level of net worth, the optimal amount of domestic deposits can be solved for by using the balance sheet. Bankers solve the following value maximization problem,

$$V_{jt} = \max_{l_{jt+i}, b^*_{jt+1+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\ n_{jt+1+i},$$

which can be written in recursive form as,

$$V_{jt} = \max_{l_{jt}, b^*_{jt+1}} E_t \Big\{ \Lambda_{t,t+1} [(1-\theta) n_{jt+1} + \theta V_{jt+1}] \Big\}. \tag{16}$$

For a nonnegative premium on credit, the solution to the value maximization problem of banks would lead to an unbounded magnitude of assets. In order to rule out such a scenario, we follow Gertler and Kiyotaki (2011) and introduce an agency problem between depositors and bankers. Specifically, lenders believe that banks might divert λ fraction of their total divertable assets, where divertable assets constitute total assets minus a fraction ω_l, of domestic deposits. When lenders become aware of the potential confiscation of assets, they would initiate a bank run and lead to the liquidation of the bank altogether. In order to rule out bank runs in equilibrium, in any state of nature, bankers' optimal choice of l_{jt} should be incentive compatible. Therefore, the following constraint is imposed on bankers,

$$V_{jt} \geq \lambda \Big(q_t l_{jt} - \omega_l b_{jt+1} \Big), \tag{17}$$

where λ and ω_l are constants between zero and one. This inequality suggests that the liquidation cost of bankers from diverting funds V_{jt}, should be greater than or equal to the diverted portion of assets. When this constraint binds, bankers would never choose to divert funds and lenders adjust their position and restrain their lending to bankers accordingly.

We introduce asymmetry in financial frictions by excluding ω_l fraction of domestic deposits from diverted assets. This is due to the idea that domestic depositors would arguably have a comparative advantage over foreign depositors in recovering assets in case of a bankruptcy. Furthermore, they would also be better equipped than international lenders in monitoring domestic bankers.[9]

Our methodological approach is to linearly approximate the stochastic equilibrium around the deterministic steady state. Therefore, we are interested in cases in which the incentive constraint of banks is always binding, which implies that (17) holds with equality. This is the case in which the loss of bankers in the event of liquidation is just equal to the amount of loans that they can divert.

We conjecture the optimal value of financial intermediaries to be a linear function of bank loans, foreign debt, and bank capital, that is,

$$V_{jt} = \nu^l_t q_t l_{jt} + \nu^*_t b^*_{jt+1} + \nu_t n_{jt}. \tag{18}$$

Among these recursive objects ν^l_t represents the marginal value of assets, ν^*_t stands for the excess value of borrowing from abroad, and ν_t denotes the marginal value of bank capital at the end of period t. The solution to the net worth maximization problem implies,

$$q_t l_{jt} - \omega_l b_{jt+1} = \frac{\nu_t - \frac{\nu^*_t}{1-rr_t}}{\lambda - \zeta_t} n_{jt} = \kappa_{jt} n_{jt}, \tag{19}$$

[9] See Section 4.3 for a detailed discussion of the asymmetry in financial frictions.

where $\zeta_t = \nu_t^l + \frac{\nu_t^*}{1-rr_t}$. This endogenous constraint, which emerges from the costly enforcement problem described above, ensures that banks' leverage of risky assets is always equal to κ_{jt} and is decreasing with the fraction of divertable funds λ.

Replacing the left-hand side of (18) to verify our linear conjecture on bankers' value and using equation (15), we find that ν_t^l, ν_t, and ν_t^* should consecutively satisfy,

$$\nu_t^l = E_t\Big\{\Xi_{t,t+1}\Big[R_{kt+1} - \hat{R}_{t+1}\Big]\Big\}, \tag{20}$$

$$\nu_t = E_t\Big\{\Xi_{t,t+1}\hat{R}_{t+1}\Big\}, \tag{21}$$

$$\nu_t^* = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1} - R_{t+1}^*\right]\Big\}, \tag{22}$$

with $\Xi_{t,t+1} = \Lambda_{t,t+1}\Big[1-\theta+\theta\Big(\zeta_{t+1}\kappa_{t+1} + \nu_{t+1} - \frac{\nu_{t+1}^*}{1-rr_{t+1}}\Big)\Big]$ representing the augmented stochastic discount factor of bankers, which is a weighted average defined over the likelihood of survival.

Equation (20) suggests that bankers' marginal valuation of total assets is the premium between the expected discounted total return to loans and the benchmark cost of domestic funds. Equation (21) shows that marginal value of net worth should be equal to the expected discounted opportunity cost of domestic funds, and lastly, equation (22) demonstrates that the excess value of raising foreign debt is equal to the expected discounted value of the premium in the cost of raising domestic debt over the cost of raising foreign debt. One can show that this spread is indeed positive, that is, $\nu_t^* > 0$ by studying first order condition (A.3) and observing that $\lambda, \mu, \omega_l > 0$, and $rr_t < 1$ with μ denoting the Lagrange multiplier of bankers' problem.

The definition of the augmented pricing kernel of bankers is useful in understanding why banks shall be a veil absent financial frictions. Specifically, the augmented discount factor of bankers can be re-written as $\Xi_{t,t+1} = \Lambda_{t,t+1}\Big[1-\theta+\theta\lambda\kappa_{t+1}\Big]$ by using the leverage constraint. Financial frictions would vanish when non of the assets are diverted, i.e. $\lambda = 0$ and bankers never have to exit, i.e. $\theta = 0$. Consequently, $\Xi_{t,t+1}$ simply collapses to the pricing kernel of households $\Lambda_{t,t+1}$. This case would also imply efficient intermediation of funds driving the arbitrage between the lending and deposit rates down to zero. The uncovered interest parity on the other hand, is directly affected by the asymmetry in financial frictions. That is, as implied by equation (22), the uncovered interest parity obtains only when $\nu_t^* = 0$.

3.2.3 Aggregation

We confine our interest to equilibria in which all households behave symmetrically, so that we can aggregate equation (19) over j and obtain the following aggregate relationship:

$$q_t l_t - \omega_l b_{t+1} = \kappa_t n_t, \tag{23}$$

where $q_t l_t$, b_{t+1}, and n_t represent aggregate levels of bank assets, domestic deposits, and net worth, respectively. Equation (23) shows that aggregate credit net of nondivertable domestic deposits can only be up to an endogenous multiple of aggregate bank capital. Furthermore, fluctuations in asset prices q_t, would feed back into fluctuations in bank capital via this relationship. This would be the source of the financial accelerator mechanism in our model.

The evolution of the aggregate net worth depends on that of the surviving bankers n_{et+1}, which might be obtained by substituting the aggregate bank capital constraint (23) into the net worth evolution equation (15), and adding up the start-up funds of the new entrants n_{nt+1}. The latter is equal to $\frac{\epsilon^b}{1-\theta}$ fraction of exiting banks' assets $(1-\theta)q_t l_t$. Therefore,

$$n_{nt+1} = \epsilon^b q_t l_t.$$

As result, the transition for the aggregate bank capital becomes,

$$n_{t+1} = n_{et+1} + n_{nt+1}.$$

3.3 Capital producers

Capital producers play a profound role in the model since variations in the price of capital drives the financial accelerator. We assume that capital producers operate in a perfectly competitive market, purchase investment goods and transform them into new capital. They also repair the depreciated capital that they buy from the intermediate goods producing firms. At the end of period t, they sell both newly produced and repaired capital to the intermediate goods firms at the unit price of q_t. Intermediate goods firms use this new capital for production at time $t+1$. Capital producers are owned by households and return any earned profits to their owners. We also assume that they incur investment adjustment costs while producing new capital, given by the following quadratic function of the investment growth

$$\Phi\left(\frac{i_t}{i_{t-1}}\right) = \frac{\Psi}{2}\left[\frac{i_t}{i_{t-1}} - 1\right]^2.$$

Capital producers use an investment good that is composed of home and foreign final goods in order to repair the depreciated capital and to produce new capital goods

$$i_t = \left[\omega_i^{\frac{1}{\gamma_i}}\left(i_t^H\right)^{\frac{\gamma_i-1}{\gamma_i}} + (1-\omega_i)^{\frac{1}{\gamma_i}}\left(i_t^F\right)^{\frac{\gamma_i-1}{\gamma_i}}\right]^{\frac{\gamma_i}{\gamma_i-1}},$$

where ω_i governs the relative weight of home input in the investment composite good and γ_i measures the elasticity of substitution between home and foreign inputs. Capital producers choose the optimal mix of home and foreign inputs according to the intratemporal first order condition

$$\frac{i_t^H}{i_t^F} = \frac{\omega_i}{1-\omega_i}\left(\frac{P_t^H}{P_t^F}\right)^{-\gamma_i}.$$

The resulting aggregate investment price index P_t^I, is given by

$$P_t^I = \left[\omega_i (P_t^H)^{1-\gamma_i} + (1-\omega_i)(P_t^F)^{1-\gamma_i}\right]^{\frac{1}{1-\gamma_i}}.$$

Capital producers require i_t units of investment good at a unit price of $\frac{P_t^I}{P_t}$ and incur investment adjustment costs $\Phi\left(\frac{i_t}{i_{t-1}}\right)$ per unit of investment to produce new capital goods i_t and repair the depreciated capital, which will be sold at the price q_t. Therefore, a capital producer makes an investment decision to maximise its discounted profits represented by

$$\max_{i_t} \sum_{t=0}^{\infty} E_0\left[\Lambda_{t,t+1}\left(q_t i_t - \Phi\left(\frac{i_t}{i_{t-1}}\right) q_t i_t - \frac{P_t^I}{P_t} i_t\right)\right]. \tag{24}$$

The optimality condition with respect to i_t produces the following Q-investment relation for capital goods

$$\frac{P_t^I}{P_t} = q_t \left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right) - \Phi'\left(\frac{i_t}{i_{t-1}}\right)\frac{i_t}{i_{t-1}}\right] + E_t\left[\Lambda_{t,t+1} q_{t+1} \Phi'\left(\frac{i_{t+1}}{i_t}\right)\frac{i_{t+1}}{i_t}\right].$$

Finally, the aggregate physical capital stock of the economy evolves according to

$$k_{t+1} = (1-\delta_t)k_t + \left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t, \tag{25}$$

with δ_t being the endogenous depreciation rate of capital determined by the utilization choice of intermediate goods producers.

3.4 Firms

Final and intermediate goods are produced by a representative final good producer and a continuum of intermediate goods producers that are indexed by $i \in [0, 1]$ respectively. Among these, the former repackages the differentiated varieties produced by the latter and sell in the domestic market. The latter on the other hand, acquire capital and labor and operate in a monopolistically competitive market. In order to assume rigidity in price setting, we assume that intermediate goods firms face menu costs.

3.4.1 Final goods producers

Finished goods producers combine different varieties $y_t(i)$, that sell at the monopolistically determined price $P_t^H(i)$, into a final good that sell at the competitive price P_t^H, according to the constant returns-to-scale technology,

$$y_t^H = \left[\int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon}} di\right]^{\frac{1}{1-\frac{1}{\epsilon}}}.$$

The profit maximization problem, combined with the zero profit condition implies that the optimal variety demand is,

$$y_t^H(i) = \left(\frac{P_t^H(i)}{P_t^H}\right)^{-\epsilon} y_t^H,$$

with, $P_t^H(i)$ and P_t^H satisfying,

$$P_t^H = \left[\int_0^1 P_t^H(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}.$$

We assume that imported intermediate good varieties are repackaged via a similar technology with the same elasticity of substitution between varieties as in domestic final good production. Therefore, $y_t^F(i) = \left(\frac{P_t^F(i)}{P_t^F}\right)^{-\epsilon} y_t^F$ and $P_t^F = \left[\int_0^1 P_t^F(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}$ hold for imported intermediate goods.

3.4.2 Intermediate goods producers

There is a large number of intermediate goods producers indexed by i, who produce variety $y_t(i)$ using the constant returns-to-scale production technology,

$$y_t(i) = A_t\Big(u_t(i)k_t(i)\Big)^{\alpha} h_t(i)^{1-\alpha}.$$

As shown in the production function, firms choose the level of capital and labor used in production, as well as the utilization rate of the capital stock. A_t represents the aggregate productivity level and follows an autoregressive process given by

$$\ln(A_{t+1}) = \rho^A \ln(A_t) + \epsilon^A_{t+1},$$

with zero mean and constant variance innovations ϵ^A_{t+1}.

Part of $y_t(i)$ is sold in the domestic market as $y^H_t(i)$, in which the producer i operates as a monopolistically competitor. Accordingly, the nominal sales price $P^H_t(i)$ is chosen by the firm to meet the aggregate domestic demand for its variety,

$$y^H_t(i) = \left(\frac{P^H_t(i)}{P^H_t}\right)^{-\epsilon} y^H_t,$$

which depends on the the aggregate home output y^H_t. Apart from incurring nominal marginal costs of production MC_t, these firms additionally face Rotemberg (1982)-type quadratic menu costs of price adjustment, in the form of

$$P_t\frac{\varphi^H}{2}\left[\frac{P^H_t(i)}{P^H_{t-1}(i)} - 1\right]^2.$$

These costs are denoted in nominal terms with φ^H capturing the intensity of the price rigidity.

Domestic intermediate goods producers choose their nominal price level to maximise the present discounted real profits. We confine our interest to symmetric equilibrium, in which all intermediate producers choose the same price level that is, $P^H_t(i) = P^H_t \quad \forall i$. Imposing this condition to the first order condition of the profit maximization problem and using the definitions $rmc_t = \frac{MC_t}{P_t}$, $\pi^H_t = \frac{P^H_t}{P^H_{t-1}}$, and $p^H_t = \frac{P^H_t}{P_t}$ yield

$$p^H_t = \frac{\epsilon}{\epsilon-1}rmc_t - \frac{\varphi^H}{\epsilon-1}\frac{\pi^H_t(\pi^H_t - 1)}{y^H_t} + \frac{\varphi^H}{\epsilon-1}E_t\left\{\Lambda_{t,t+1}\frac{\pi^H_{t+1}(\pi^H_{t+1}-1)}{y^H_t}\right\}. \tag{26}$$

Notice that even if prices are flexible, that is $\varphi^H = 0$, the monopolistic nature of the intermediate goods market implies that the optimal sales price reflects a markup over the marginal cost that is, $P^H_t = \frac{\epsilon}{\epsilon-1}MC_t$.

The remaining part of the intermediate goods is exported as $c^{H*}_t(i)$ in the foreign market, where the producer is a price taker. To capture the foreign demand, we follow Gertler et al. (2007) and impose an autoregressive exogenous export demand function in the form of

$$c^{H*}_t = \left[\left(\frac{P^{H*}_t}{P^*_t}\right)^{-\Gamma} y^*_t\right]^{\nu^H} (c^{H*}_{t-1})^{1-\nu^H},$$

which positively depends on foreign output that follows an autoregressive exogeneous process,

$$\ln(y^*_{t+1}) = \rho^{y^*}\ln(y^*_t) + \epsilon^{y^*}_{t+1}.$$

with zero mean and constant variance innovations. The innovations to the foreign output process are perceived as export demand shocks by the domestic economy. For tractability, we further assume that the small open economy takes $P_t^{H*} = P_t^* = 1$ as given.

Imported intermediate goods are purchased by a continuum of producers that are analogous to the domestic producers except that these firms face exogenous import prices as their marginal cost. In other words, the law of one price holds for the import prices, so that $MC_t^F = S_t P_t^{F*}$. Since these firms also face quadratic price adjustment costs, the domestic price of imported intermediate goods is determined as,

$$p_t^F = \frac{\epsilon}{\epsilon - 1} s_t - \frac{\varphi^F}{\epsilon - 1} \frac{\pi_t^F(\pi_t^F - 1)}{y_t^F} + \frac{\varphi^F}{\epsilon - 1} E_t \left\{ \Lambda_{t,t+1} \frac{\pi_{t+1}^F(\pi_{t+1}^F - 1)}{y_t^F} \right\}, \tag{27}$$

with $p_t^F = \frac{P_t^F}{P_t}$, $s_t = \frac{S_t P_t^{F*}}{P_t}$, and $P_t^{F*} = 1\ \forall t$ is taken exogenously by the small open economy.

For a given sales price, optimal factor demands and utilization of capital are determined by the solution to a symmetric cost minimization problem, where the cost function shall reflect the capital gains from market valuation of firm capital and resources that are devoted to the repair of the worn out part of it. Consequently, firms minimise

$$\min_{u_t, k_t, h_t} q_{t-1} r_{kt} k_t - (q_t - q_{t-1}) k_t + p_t^I \delta(u_t) k_t + w_t h_t + rmc_t \Big[y_t - A_t \Big(u_t k_t \Big)^{\alpha} h_t^{1-\alpha} \Big] \tag{28}$$

subject to the endogeneous depreciation rate function,

$$\delta(u_t) = \delta + \frac{d}{1+\varrho} u_t^{1+\varrho}, \tag{29}$$

with $\delta, d, \varrho > 0$. The first order conditions to this problem govern factor demands and the optimal utilization choice as,

$$p_t^I \delta'(u_t) k_t = \alpha \Big(\frac{y_t}{u_t} \Big) rmc_t, \tag{30}$$

$$R_{kt} = \frac{\alpha \Big(\frac{y_t}{k_t} \Big) rmc_t - p_t^I \delta(u_t) + q_t}{q_{t-1}}, \tag{31}$$

and

$$w_t = (1-\alpha) \Big(\frac{y_t}{h_t} \Big) rmc_t. \tag{32}$$

3.5 Monetary authority and the government

The monetary authority sets the short-term nominal interest rate via a simple (and implementable) monetary policy rule that includes only a few observable macroeconomic variables and ensures a unique rational expectations equilibrium.[10] We consider a general formulation for the Taylor type interest rate rule that allows response to a LATW variable f_t alongside inflation and output gap,

[10] For further discussion on simple and implementable rules, see Schmitt-Grohé and Uribe (2007).

$$\log\left(\frac{1+r_{nt}}{1+\overline{r_n}}\right) = \rho_{r_n}\log\left(\frac{1+r_{nt-1}}{1+\overline{r_n}}\right) + (1-\rho_{r_n})\left[\varphi_\pi \log\left(\frac{1+\pi_t}{1+\overline{\pi}}\right) + \varphi_y \log\left(\frac{y_t}{\overline{y}}\right) + \varphi_f \log\left(\frac{f_t}{\overline{f}}\right)\right], \tag{33}$$

where r_{nt} is the short-term policy rate, π_t is the net CPI inflation rate, y_t is the output, variables with bars denote respective steady-state values that are targeted by the central bank, and f_t corresponds to the level of credit, asset prices, real exchange rate, and credit spreads in alternative specifications. In each specification, φ_f measures the responsiveness of the interest rate rule to the LATW variable of interest. To be general, we allow for persistence in the monetary policy rule so that $0 \leq |\rho_{r_n}| < 1$.

In the benchmark specification, we assume that the required reserves ratio is fixed at $rr_t = \overline{rr}\ \forall t$, with $\overline{rr}$ denoting a steady state level. In section 4.8 we investigate whether reserve requirements can be used to reduce the pro-cyclicality of the financial system. In particular, we assume that required reserve ratios for both domestic and foreign deposits respond negatively to the deviations of the foreign lending spread from its steady-state value. That is,

$$\log\left(\frac{1+rr_t}{1+\overline{rr}}\right) = \rho_{rr}\log\left(\frac{1+rr_{t-1}}{1+\overline{rr}}\right) + (1-\rho_{rr})\left[\varphi_{rr}\log\left(\frac{R_{kt+1}-R^*_{t+1}}{\overline{R_k - R^*}}\right)\right], \tag{34}$$

with $0 < |\rho_{rr}| < 1$ and $\varphi_{rr} < 0$. Notice that credit spreads are countercyclical, since the magnitude of intermediated funds decline in response to adverse shocks. Therefore, the proposed reserve requirement rule would support the balance sheet of bankers by reducing the tax on domestic and foreign liabilities.[11]

Money supply in this economy is demand determined and compensates for the cash demand of workers and the required reserves demand of bankers. Consequently, the money market clearing condition is given by

$$M_{0t} = M_t + rr_t B_{t+1},$$

where M_{0t} denotes the supply of monetary base at period t.

Government consumes a time-varying fraction of home goods g_t^H that follows the exogenous process

$$\ln(g_{t+1}^H) = (1-\rho^{g^H})\ln \bar{g}^H + \rho^{g^H}\ln(g_t^H) + \epsilon_{t+1}^{g^H},$$

where $\epsilon_{t+1}^{g^H}$ is a Gaussian process with zero mean and constant variance. We introduce this shock to capture disturbances in domestic aggregate demand that create a trade off for the monetary policy in responding to inflation or output.

The fiscal and monetary policy arrangements lead to the consolidated government budget constraint,

$$p_t^H g_t^H y_t^H = \frac{M_t - M_{t-1}}{P_t} + \frac{rr_t B_{t+1} - rr_{t-1}B_t}{P_t} + \frac{T_t}{P_t}.$$

Lump sum taxes $\tau_t = \frac{T_t}{P_t}$ are determined endogenously to satisfy the consolidated government budget constraint at any date t.

The resource constraints and the definition of competitive equilibrium are included in Appendix A.

[11] See Glocker and Towbin (2012) and Mimir et al. (2013) for similar reserve requirement specifications.

4 Quantitative analysis

This section analyzes the quantitative predictions of the model by studying the results of numerical simulations of an economy calibrated to an emerging market such as Turkey, for which financial frictions in the banking sector and monetary policy tools analyzed here are particularly relevant. To investigate the dynamics of the model and carry out welfare calculations, we compute a second-order approximation to the equilibrium conditions. All computations are conducted using the open source package, Dynare.

4.1 Model parametrization and calibration

Table 2 lists the parameter values used for the quantitative analysis of the model economy. The reference period for the long-run ratios implied by the Turkish data is 2002-2014. The data sources for empirical targets are the Central Bank of the Republic of Turkey and the Banking Regulation and Supervision Agency. The preference and production parameters are standard in the business cycle literature. Starting with the former, we set the quarterly discount factor $\beta = 0.9821$ to match the average annualised real deposit rate of 7.48% observed in Turkey. The relative risk aversion $\sigma = 2$ is taken from the literature. We calibrate the relative utility weight of labor $\chi = 199.348$ in order to fix hours worked in the steady state at 0.3333. The Frisch elasticity of labor supply parameter $\xi = 3$ and the habit persistence parameter $h_c = 0.7$ are set to values commonly used in the literature. The relative utility weight of money $\upsilon = 0.0634$ is chosen to match 2.25 as the quarterly output velocity of M2. Following the discussion in Faia and Monacelli (2007), we set the intratemporal elasticity of substitution for the consumption composite $\gamma = 0.5$ to retain constrained efficiency. The intratemporal elasticity of substitution for the investment composite good $\gamma_i = 0.25$ is chosen as in Gertler et al. (2007). The share of domestic goods in the consumption composite $\omega = 0.62$ is set to match the long-run consumption-to-output ratio of 0.57.

We calibrate the financial sector parameters to match some long-run means of financial variables for the 2002-2014 period. Specifically, the fraction of the revenues that can be diverted $\lambda = 0.65$, the proportional transfer to newly entering bankers $\epsilon^b = 0.00195$, the fraction of domestic deposits that cannot be diverted $\omega_l = 0.81$, and the survival probability of bankers $\theta = 0.925$ are jointly calibrated to match the following four targets: an average domestic credit spread of 34 basis points, which is the difference between the quarterly commercial loan rate and the domestic deposit rate, an average foreign credit spread of 152 basis points, which is the difference between the quarterly commercial loan rate and the real foreign borrowing rate in domestic currency units, an average bank leverage of 7.94, and the share of foreign funds in total bank liabilities, which is around 40% for Turkish commercial banks.

Regarding the technology parameters, the share of capital in the production function $\alpha = 0.4$ is set to match the labor share of income in Turkey. We pick the share of domestic goods in the investment composite $\omega_i = 0.87$ to match the long-run mean of investment-to-output ratio of 15%. The steady-state utilization rate is normalised at one and the quarterly depreciation rate of capital $\delta = 3.5\%$ is chosen to match the average annual investment-to-capital ratio. The elasticity of marginal depreciation with respect to the utilization rate $\varrho = 1$ is set as in Gertler et al. (2007). The investment adjustment cost parameter $\psi = 5$ is calibrated to a value in line with the literature. We set the elasticity of substitution between varieties in final output $\epsilon = 11$ to have a steady-state mark-up value of 1.1. Rotemberg price adjustment cost parameters in domestic and foreign intermediate goods production $\varphi_H = \varphi_F = 113.88$ are chosen to imply a probability of 0.75 of not changing prices in both sectors. We pick the elasticity of export demand with respect to foreign prices $\Gamma = 1$ and the foreign output share parameter $\nu^F = 0.25$ as in Gertler et al. (2007).

Given these parameters, the mean of foreign output $\bar{y^*} = 0.16$ is chosen to match the long-run mean of exports-to-output ratio of 18%.

We use the estimated interest rate rule persistence $\rho_{r_n} = 0.89$ and inflation response $\varphi_\pi = 2.17$ parameters (for the 2003:Q1-2014:Q4 period) in the approximation of the decentralised equilibrium around a zero inflation non-stochastic steady-state.[12] The long-run value of required reserves ratio $\bar{rr} = 0.09$ is set to its empirical counterpart for the period 1996-2015. The steady state government expenditures-to-output ratio $\bar{g^H} = 10\%$ reflects the value implied by the Turkish data for the 2002-2014 period.

Finally, we estimate three independent AR(1) processes for the share of public demand for home goods g_t^H, country risk premium Ψ_{t+1} and the US interest rate R^*_{nt+1}, where $\epsilon^{g^H}_{t+1}$, ϵ^{Ψ}_{t+1}, and $\epsilon^{R^*_n}_{t+1}$ are i.i.d. Gaussian shocks. The resulting estimated persistence parameters are $\rho^{g^H} = 0.457$, $\rho^{\Psi} = 0.963$, and $\rho^{R^*_n} = 0.977$. The estimated standard deviations are $\sigma^{g^H} = 0.04$, $\sigma^{\Psi} = 0.0032$, and $\sigma^{R^*_n} = 0.001$. The long-run mean of quarterly foreign real interest rate is set to 64 basis points and the long-run foreign inflation rate is set to zero. The foreign debt elasticity of risk premium is set to $\psi_1 = 0.015$. Parameters underlying the TFP shock are taken from Bahadir and Gumus (2014), who estimate an AR(1) process for the Solow residuals coming from tradable output in Turkey for the 1999:Q1-2010:Q1 period. Their estimates for the persistence and volatility of the tradable TFP emerge as $\rho^A = 0.662$ and $\sigma^A = 0.0283$. Finally, we calibrate the export demand shock process under all shocks to match both the persistence and the volatility of euro area GDP, which are 0.31 and 0.48% respectively. The implied persistence and volatility parameters are $\rho^{y^*} = 0.977$ and $\sigma^{y^*} = 0.0048$.

4.2 Model versus data

The quantitative performance of the decentralised model economy is illustrated in Table 3, in which the relative volatilities, correlations with output and autocorrelations of the simulated time series are compared with corresponding moments implied by the data. The first column of the table shows that for the reference time period, consumption is less volatile than output, whereas investment is more volatile in the data. When financial variables are considered, we observe that credit spreads are less volatile than output, whereas bankers' foreign debt share and loans are more volatile. The data also suggest that real exchange rate is more volatile than output, while the current account- and trade balance-to-output ratios are less volatile. Finally, inflation and policy rate are less volatile than output in the data. The second column of Table 3 reports that despite the benchmark model is not estimated and includes a few number of structural shocks, it is able to get the direction of relative volatilities right for all of the variables of interest except for current account-to-output ratio.

When correlations with output and autocorrelations are considered, the benchmark model performs well on quantitative grounds as well. Columns 3 and 4 imply that the model is able to generate same signs for correlations of all model variables in interest with output. Most importantly, credit spreads, real exchange rate, current account balance-to-GDP ratio and inflation are countercyclical, whereas bank credit, investment and consumption are pro-cyclical. Furthermore, apart from the short term interest rate, the level of model implied correlation coefficients are fairly similar to those implied by the data. These patterns are also observed for the model generated autocorrelations in comparison to the data, as shown in the last two columns of the table.

[12]These values naturally change when we analyze the dynamics of the optimal simple and implementable monetary policy rule economies.

Table 4 reports the variance decomposition of main model variables for alternative horizons under TFP, government spending and external shocks operating simultaneously. The unconditional variance decomposition results illustrate that country risk premium and world interest rate shocks explain most of the variation in financial and external variables as well as a considerable part of the variation in the inflation and the short term interest rates. Remarkably, U.S. interest rate shocks in isolation explain about 12% of the variation in model variables on average, whereas the explanatory power of country premium shocks are much stronger, which is fairly different than what the findings of Uribe and Yue (2006) suggest. TFP shocks on the other hand, roughly account for one-third of volatilities in output, credit and the inflation rate and a quarter of the variation in policy rates. Export demand and government spending shocks derive a negligible part of fluctuation in model variables with the only exception of the spending shocks' dampening effect on output as the horizon gets longer. These patterns are also confirmed for one-quarter and one-year ahead conditional variance decompositions (top two panels of the table).

We further assess the quantitative performance of the calibrated model by analysing impulse responses of model simulations to an exogenous increase in the country risk premium of 127 basis points, which is at the ballpark of what emerging economies have experienced during the *taper tantrum* in May 2013. The straight plots in Figure 2 are the impulse responses of model variables in the benchmark economy with the estimated inflation targeting rule. The initial impact of country borrowing premium shock is reflected on the floating exchange rate in the direction of a sharp real depreciation of 5%, which amplifies the increase in the cost of foreign borrowing. The resulting correction in the cyclical component of current account balance-to-output ratio is about 0.75%. In line with capital outflows, bankers' share of foreign debt declines more than 3% in 18 quarters. The exchange rate pass-through from increased nominal depreciation leads to a rise in inflation by about 1 percentage point per annum. Banks cannot substitute foreign funds with domestic deposits easily as domestic debt is more expensive than foreign debt on average. Therefore, bankers' demand for capital claims issued by non-financial firms collapses, which ignites a 1.5% decline in asset prices.

The fall in asset prices feeds back into the endogenous leverage constraint, (23) and hampers bank capital severely, 11% fall on impact. The tightening financial conditions and declining asset prices in total, reduces bank credit by 1.5% on impact, and amplifies the decline in investment up to more than 3% and output up to 0.7% in five quarters. Observed surges in credit spreads over both domestic and foreign borrowing costs (by about 120 and 12 basis points per annum for foreign and domestic credit spreads, respectively) reflect the tightened financial conditions in the model. The decline in output and increase in inflation eventually calls for about 55 annualised basis points increase in the short term policy rate in the baseline economy. In conclusion, the model performs considerably well in replicating the adverse feedback loop (illustrated in Figure 1) that emerging open economies fell into in the aftermath of the recent global financial crisis.

4.3 Asymmetric financial frictions and the UIP

The UIP condition might be violated when domestic financial markets are repressed, which curbs the access to international debt markets and pushes up domestic interest rates above country borrowing rates.[13] We establish this result analytically by observing that in equilibrium, the excess value of borrowing from abroad ν^* should be positive so that domestic depositors are expected to charge more compared to international lenders. This finding posits asymmetry in financial frictions as a microfoundation to the violation of the UIP condition.

Figure 3 illustrates how financial frictions are modified when asymmetry in financial frictions is introduced. We plot the external funds market on the left panel of the figure in which there is

[13] See Munro (2014) on the conditions regarding the measurement of the deviation from the UIP condition.

an almost perfectly elastic supply curve, and a downward sloped demand curve for foreign funds, absent financial frictions. Indeed, the slope of the supply curve is slightly positive since the country risk premium increases with the foreign debt. When $\lambda > 0$, the incentive constraint binds and the supply curve for external funds become vertical at the equilibrium level of foreign debt b^*_ω.

The panel on the right displays the domestic funds market and covers three cases regarding the asymmetry in financial frictions. Notice that as opposed to the chart on the left, the supply curve in this market, which originates from the consumption-savings margin of households, is upward sloped. When $\omega_l = 0$, financial frictions are symmetric in both markets and the supply curve makes a kink at the equilibrium domestic debt level $b_{\omega=0}$, and becomes vertical. This case corresponds to the UIP condition so that there is no arbitrage between the two sources of external finance, yielding $R_k > R = R^*$. When ω_l takes an intermediate value between zero and one, the kink on the supply curve shifts to the right (the dotted-dashed curve). Since $R_k > R$, the demand curve of bankers shifts to the right until the value of relaxing the incentive constraint becomes equal to the excessive cost of domestic deposits on the margin, resulting in $R_k > R > R^*$. Lastly, when $\omega_l = 1$, the domestic deposits market becomes frictionless and the supply curve becomes continuous rendering banks a veil from the perspective of households. In this case, $R_k = R > R^*$, implying that depositing at a financial intermediary is no different than directly investing in physical capital for households. This shifts the equilibrium level of domestic debt further to the right to $b_{\omega=1}$. Therefore, the existence of asymmetry in external financing is instrumental in the determination of the liability composition of bankers.

For simplicity, we did not plot the impact of changes in ω_l on the amount of foreign debt. Indeed, one shall expect that the share foreign debt increases with ω_l despite the increase in domestic deposits. This is because ω_l levers up bankers so that it facilitates smaller amounts of domestic borrowing to bring enough relaxation of the financial constraint (17) in matching the excess cost of domestic debt.[14] Finally, in Figure 2 we explore the impact of the asymmetry in financial frictions by using different ω_l values. The value of ω_l increases as we move along the dashed, straight, and dotted-straight plots in which the straight plots correspond to the benchmark economy. As expected, we find that the volatility of macroeconomic and financial variables, as well as monetary variables gets smaller as the fraction of non-diverted domestic deposits increases.

4.4 Model frictions and optimal monetary policy

The model economy includes six key ingredients that generate deviations from a first-best flexible price economy apart from the real rigidities such as habit persistence, variable capacity utilization and investment adjustment costs. Among these, monopolistic competition and price rigidities are standard in canonical closed-economy New-Keynesian models, whereas open-economy New-Keynesian models additionally consider home bias and incomplete exchange rate pass-through.[15] These frictions distort the intratemporal consumption-leisure margin. Our model also includes credit frictions in the banking sector and a risk premium in the country borrowing rate. These additional frictions distort the intertemporal consumption-savings margin.

intratemporal wedge: In the closed, first-best flexible price economy, the intratemporal efficiency requires that

[14] Steady state comparisons for different levels of asymmetry confirm this conjecture that liability composition of bankers becomes more biased towards foreign debt as ω_l increases.

[15] Galí (2008), Monacelli (2005), and Faia and Monacelli (2008) elaborate on these distortions in New Keynesian models in greater detail.

$$\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = 1 \tag{35}$$

The model counterpart of the consumption-leisure margin is found by combining and manipulating equations (2), (8), (26), (27) and (32), which yields

$$\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = \frac{(p_t^H + \eta_t)}{X} \tag{36}$$

with the expressions,

$$p_t^H = \left[\frac{\omega}{1-(1-\omega)(p_t^F)^{(1-\gamma)}}\right]^{-\frac{1}{(1-\gamma)}}, \tag{37}$$

$$p_t^F = \frac{\epsilon}{\epsilon-1}s_t + \frac{\varphi^F}{\epsilon-1}\frac{\pi_t^F(\pi_t^F-1)}{y_t^F} - \frac{\varphi^F}{\epsilon-1}E_t\left\{\Lambda_{t,t+1}\frac{\pi_{t+1}^F(\pi_{t+1}^F-1)}{y_t^F}\right\}, \tag{38}$$

$$X = \frac{\epsilon}{\epsilon-1}, \tag{39}$$

$$\eta_t = \frac{\varphi^H}{\epsilon-1}\frac{\pi_t^H(\pi_t^H-1)}{y_t^H} - \frac{\varphi^H}{\epsilon-1}E_t\left\{\Lambda_{t,t+1}\frac{\pi_{t+1}^H(\pi_{t+1}^H-1)}{y_t^H}\right\}. \tag{40}$$

The first expression (37), is the relative price of home goods with respect to the aggregate price level and it depends on ω, the home bias parameter. Under flexible home goods prices $\varphi^H = 0$, complete exchange rate pass-through $\varphi^F = 0$, and no monopolistic competition $X = 1$, the intratemporal wedge becomes $\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = p_t^H$. The case of $p_t^H < 1$ leads to an inefficiently low level of employment and output as $\frac{MRS_t}{MPL_t} < 1$. The case of $\omega = 1$ corresponds to the closed economy in which consumption basket only consists home goods and $p_t^H = 1$, restoring intratemporal efficiency. Therefore, the Ramsey planner has an incentive to stabilise the fluctuations in p_t^H to smooth this wedge, which creates a misallocation between consumption demand and labor supply.

The second expression (38), is the relative price of foreign goods with respect to the aggregate price level, which depends on the gross markup X, the real exchange rate s_t, and an expression representing incomplete exchange rate pass-through that originates from sticky import prices $\varphi^F > 0$. If import prices are fully flexible $\varphi^F = 0$, and there is perfect competition $X = 1$, then $p_t^F = s_t$ so that there is complete exchange rate pass-through. However, even if that is the case, the existence of the real exchange rate in the intratemporal efficiency condition still generates a distortion, depending on the level of home bias ω. The Ramsey planner would then want to contain the fluctuations in the real exchange rate to stabilise this wedge. Furthermore, if import prices are sticky $\varphi^F > 0$, the law-of-one-price-gap might potentially reduce p_t^H below 1, creating an additional distortion in the intratemporal wedge. Therefore, optimal policy requires stabilization of the deviations from the law of one price, inducing smoother fluctuations in exchange rates.[16]

[16]The fourth expression (39), is the gross markup which represents the market power of retailers, who can set their prices above their marginal costs. Therefore, even under closed-economy, flexible prices and no credit frictions, the intratemporal wedge becomes $\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = \frac{1}{X} < 1$, implying that the output produced is suboptimal due to an inefficiently low level of labor. If the Ramsey planner has access to a wage subsidy, she may use it to offset this distortion. However, we do not adopt this assumption of ad-hoc wage subsidies to study the model dynamics around a distorted non-stochastic steady state in the spirit of Schmitt-Grohé and Uribe (2007).

The final expression (40), stems from the price stickiness of home goods. Unless η_t is always equal to X, the intratemporal efficiency condition will not hold, leading to a welfare loss. $\eta_t = X$ for all t is not possible since price dispersion across goods, which depends on inflation, induces consumers to demand different levels of intermediate goods across time. Moreover, menu costs that originate from sticky home goods and import prices generate direct output losses. Consequently, the planner has an incentive to reduce inflation volatility, which helps contain the movements in the price dispersion.

Overall, in an open economy, price stability requires an optimal balance between stabilising domestic markup volatility induced by monopolistic competition and sticky prices and containing exchange rate volatility induced by home bias and incomplete exchange rate pass-through.

intertemporal wedge: In the closed, first-best flexible price economy with no financial frictions, the intertemporal efficiency requires that

$$\beta E_t R_{kt+1} \left[\frac{U_c(t+1)}{U_c(t)} \right] = 1. \tag{41}$$

Volatile credit spreads, the endogenous leverage constraint, fluctuations in the exchange rate, and the existence of country risk premium result in deviations of the model counterpart of the consumption-savings margin from what the efficient allocation suggests. Specifically, combining conditions (14), (A.2), (A.3), and (20) under no reserve requirements $rr_t = 0$, implies

$$\beta E_t R_{kt+1} \left[\frac{U_c(t+1)}{U_c(t)} \right] = (1 + \tau^1_{t+1} - \tau^2_{t+1}) > 1, \tag{42}$$

with the expressions

$$\tau^1_{t+1} = \frac{\left[cov[\Xi_{t,t+1}, (R_{kt+1} - R_{t+1})] + cov[\Xi_{t,t+1}, (R_{t+1} - R^*_{t+1})] - \lambda \frac{\mu_t}{(1+\mu_t)} \right]}{E_t[\Xi_{t,t+1}]} > 0, \tag{43}$$

$$\tau^2_{t+1} = E_t[R^*_{nt+1}] E_t \left[\Psi_{t+1} \frac{S_{t+2}}{S_{t+1}} \frac{P_{t+1}}{P_{t+2}} \right] + cov \left\{ R^*_{nt+1}, \left[\Psi_{t+1} \frac{S_{t+2}}{S_{t+1}} \frac{P_{t+1}}{P_{t+2}} \right] \right\} < 0, \tag{44}$$

where μ_t is the Lagrange multiplier of the incentive compatibility constraint faced by bankers and the signs of τ^1_{t+1} and τ^2_{t+1} are confirmed by simulations.

The first expression τ^1_{t+1}, which contributes to the intertemporal wedge, originates from the financial frictions in the banking sector. When credit frictions are completely eliminated $\lambda = 0$, both covariances and the last term in the numerator of τ^1_{t+1} become zero.[17] The Ramsey planner has an incentive to contain the fluctuations in both domestic and foreign lending spreads to smooth this wedge by reducing movements in the Lagrange multiplier of the endogenous leverage constraint.

The second expression τ^2_{t+1} is the remaining part of the intertemporal wedge, stemming from openness and the country borrowing premium. The covariance term in this wedge is strictly negative because increases in the foreign interest rate R^*_{nt+1} reduces foreign borrowing and diminishes the debt elastic country risk premium Ψ_{t+1}. Furthermore, the magnitude of real exchange rate depreciation gradually declines after the initial impact of shocks. Consequently, the optimal policy requires containing inefficient fluctuations in the exchange rate, which would reduce fluctuations in foreign debt and the country borrowing premium, accordingly.

[17] When the UIP holds $\omega_l = 0$, the second covariance disappears. Nevertheless, the overall wedge would increase substantially, since more of the total external finance can be diverted. On the other hand, when none of domestic deposits are diverted $\omega_l = 1$, the first covariance term disappears, leading the wedge to be smaller.

Overall, in an open economy with financial frictions, financial stability requires an optimal balance between stabilising credit spreads volatility induced by financial frictions, which distorts the dynamic allocation between savings and investment, and containing exchange rate volatility induced by openness, incomplete exchange rate pass-through and financial frictions, which leads to balance sheet deterioration. Therefore, the policymaker may want to deviate from fully stabilising credit spreads by reducing the policy rate and resort to some degree of exchange rate stabilization by increasing the policy rate.

Finally, there exists an inherent trade-off between price stability and financial stability. The policymaker may want to hike the policy rate in response to adverse external shocks to contain the inflation volatility coming from the exchange rate depreciation and the fall in the production capacity of the economy at the expense of not being able to smooth fluctuations in domestic and foreign lending spreads and to reduce the cost of funds for banks. Below we validate this discussion by solving the Ramsey planner's problem and quantitatively shed light on how she optimally balances the tensions across these trade-offs.

4.5 Welfare analysis

We assess the performances of alternative policy regimes by calculating the welfare cost associated with a particular monetary policy rule relative to the time-invariant stochastic equilibrium of the Ramsey policy. Before going into the details of the welfare computation, we want to emphasise that our model economy features distortions due to monopolistic competition and financial frictions in the banking sector even at its non-stochastic steady state. Following Schmitt-Grohé and Uribe (2007), we do not assume any subsidy to factor inputs that removes the inefficiency introduced by monopolistic competition. In addition, the distortions due to credit frictions are also present at the deterministic steady state of the model. Therefore, we conduct our welfare analysis around a distorted steady state and the constrained Ramsey planner can only achieve the second-best allocation.

Conducting welfare evaluations around an inefficient steady state requires us to implement a second-order approximation to the policy functions and the aggregate welfare in order to correctly rank alternative policy regimes and to obtain accurate welfare costs. Otherwise, aggregate welfare values would be the same across different policy rules since the mean values of endogenous variables are equal to their non-stochastic steady state levels under a first-order approximation to the policy functions.

We first define the welfare associated with the time-invariant equilibrium associated with the Ramsey policy conditional on a particular state of the economy in period 0 as:

$$V_0^R = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^R, h_t^R, m_t^R) \tag{45}$$

where E_0 denotes conditional expectation over the initial state, and c_t^R, h_t^R, and m_t^R stand for the contingent plans for consumption, labor, and real money balances under the Ramsey policy. Moreover, the welfare associated with the time-invariant equilibrium associated with a particular policy regime conditional on a particular state of the economy in period 0 as

$$V_0^A = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^A, h_t^A, m_t^A) \tag{46}$$

where E_0 denotes conditional expectation over the initial state, and c_t^A, h_t^A, and m_t^A stand for the contingent plans for consumption, labor and real money balances under a particular alternative policy rule.

We then compute the welfare cost for each alternative monetary policy rule in terms of compensating consumption variation relative to the Ramsey policy. Let λ^c stand for the welfare cost of implementing a particular monetary policy rule instead of the Ramsey policy conditional on a particular state in period 0.[18] We define λ^c as the proportional reduction in the Ramsey planner's consumption plan that a household must forgo to be as well off under policy regime A. Therefore, λ^c is implicitly defined by

$$V_0^A = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1-\lambda^c)c_t^R, h_t^R, m_t^R\right) \tag{47}$$

Hence, a positive value for λ^c implies that the Ramsey policy achieves a higher welfare relative to the particular policy regime. We undertake a discrete grid search over smoothing and response coefficients of alternative interest rate rules that minimise λ^c in order to find optimal simple and implementable policies.

Finally, we define aggregate welfare in the following recursive form to conduct a second-order approximation to V_0:

$$V_{0,t} = U(c_t, h_t, m_t) + \beta E_t V_{0,t+1}. \tag{48}$$

Schmitt-Grohé and Uribe (2007) show that V_0 can also be represented as

$$V_{0,t} = \overline{V_0} + \frac{1}{2}\Delta(V_0), \tag{49}$$

where $\overline{V_0}$ is the level of welfare evaluated at the non-stochastic steady-state and $\Delta(V_0)$ is the constant correction term, denoting the second-order derivative of the policy function for $V_{0,t}$ with respect to the variance of shock processes. Therefore, equation (49) is an approximation to the welfare $V_{0,t}$, capturing the fluctuations of endogenous variables at the stochastic steady state.

4.6 Ramsey optimal policy

We assume that the Ramsey planner chooses state-contingent allocations, prices and policies to maximise (4) taking the private sector equilibrium conditions (except the monetary policy rule) and exogenous stochastic processes $\left\{A_t, g_t^H, \psi_t, r_{nt}^*, y_t^*\right\}_{t=0}^{\infty}$ as given. The Ramsey planner uses the short-term nominal interest rates as its policy tool to strike an optimal balance across different distortions analyzed in the previous section and can only achieve second-best allocations. We solve the optimal policy problem from a timeless perspective following Woodford (2003). We compute a second-order approximation to the solution of the Ramsey planner's problem.

The intratemporal and intertemporal wedges in the model fluctuate due to movements in the domestic and foreign lending spreads, the real exchange rate, and the aggregate markup. Table 5 displays the relative volatilities of macroeconomic, financial, external, and monetary variables in the decentralised and the planner's economies. The results suggest that the planner is able to smooth the fluctuations for variables that are related to the distortionary wedges. In particular, the planner is able to reduce the relative volatilities of the CPI inflation, aggregate markup, and the real exchange rate by 68%, 36%, and 63% compared to the decentralised economy, respectively.

[18] Both the decentralised and Ramsey planner economies take their deterministic steady states as their initial condition. Therefore, the welfare gains that we calculate include both long-run and dynamic gains.

Moreover, the planner is able to reduce the relative volatilities of domestic and foreign lending spreads by 10% and 62% relative to the decentralised economy, respectively. Taking these into account together with lower volatility in the real exchange rate, the results indicate that the planner is able to contain fluctuations in both wedges. Finally, we observe a substantial decline in the relative volatilities of bank leverage and bank net worth, mainly due to the lower volatilities of lending spreads and the real exchange rate.

Finally, Figure 4 compares the impulses responses to a one standard deviation country risk premium shock under the Ramsey planner's economy with the decentralised one. The reason why we highlight this particular shock relies on its strong explanatory power that emerged in the variance decomposition analysis. For brevity, we do not plot the impulse responses to other conventional and external shocks.[19] The planner increases the policy rate by a bit more than 200 basis points per annum on impact in response to a 127 basis points annualised increase in the country borrowing premium, while in the decentralised economy, the policy rate is raised by about 25 basis points. The planner would like to smooth the fluctuations in the exchange rate (both real and nominal) to contain the exchange rate pass-through to CPI inflation. Accordingly, the real exchange rate depreciates a bit less than 2 percent in the planner's economy, against the depreciation of about 5 percent in the decentralised economy. As a result, the annual CPI inflation rate falls a quarter of a percentage point on impact in the planner's economy, while it increases by 1 percentage point in the decentralised economy. By containing the fluctuations in the real exchange rate, inefficient movements in the foreign lending spread are smoothed by 50 basis points per annum on impact, relative to the private equilibrium. Moreover, the current account reversal in the planner's economy is much more contained. Although asset prices decline 2 percent more in the planner's economy, bank net worth falls 7% less relative to the decentralised economy. Most remarkably, the Ramsey planner trade-offs a smoother path of the real exchange rate against a more volatile trajectory for output in order to achieve a more stable path of CPI inflation.

4.7 Optimal simple and implementable policy rules

We search for optimal simple and implementable rules by following the methodology adopted by Schmitt-Grohé and Uribe (2007). Specifically, we run a discrete grid search for alternative optimal policy coefficients over the intervals $\rho_{r_n} \in [0, 0.995]$, $\varphi_\pi \in [1.001, 3]$, $\varphi_f \in [0, 3]$ for $f \in \{y, credit, q, s, R_n^*\}$, $\rho_{rr} \in [0, 0.995]$, $\varphi_{rr} \in [0, 3]$, and $\varphi_{spr} \in [-3, 0]$. Each interval includes 15 evenly distributed grid points. The boundary points of intervals are chosen by following the literature and respecting technical constraints. In particular, we confine the smoothing parameter of the interest rate rule to be positive and less than one to center our analysis on the optimal responses to inflation, output and financial or external variables. We also choose the inertia parameter of the reserve requirement rule to be positive and less than one. The lower bound for inflation response is chosen to ensure determinacy. The policy coefficient interval of credit spreads is chosen as negative since credit spreads are always countercyclical in our model. The upper bounds of the remaining response coefficients are chosen arbitrarily, but in the interest of policymakers' convenience in communicating policy responses, they are fixed at arguably not very large magnitudes. Due to curse of dimensionality, while searching for simultaneous optimal interest rate and reserve requirement policies, we fix ρ_{r_n} to its optimal value under the Taylor rule, in which policy rate responds to only inflation and output. We search for optimal set of policy coefficients for each shock separately and under all shocks. The former experiment is informative for policymakers since it shows how the optimal set of policy coefficients changes with the underlying set of disturbances. However, the

[19] The comparisons of impulse responses for other shocks are available from the authors upon request.

latter experiment might be more appealing in terms of actual policymaking because, in the real world, the monetary authority cannot perfectly disentangle the different sources of business cycle fluctuations.

4.7.1 Domestic shocks

Table 6 reports the response coefficients of optimised conventional and augmented Taylor rules, the relative volatilities of policy rate, inflation, foreign lending spread and the real exchange rate (RER) under these rules, and the corresponding consumption-equivalent welfare costs relative to the optimal Ramsey policy under productivity and government spending shocks. The reason why we choose to display the relative volatilities of the variables above hinges on the fact that they are the main variables that affect the intratemporal and intertemporal wedges mentioned in the previous section and we want to show how optimal simple rules affect these volatilities compared to the Ramsey planner.

The optimised Taylor rules with and without smoothing feature no response to output variations under productivity shocks, which is consistent with the results of Schmitt-Grohé and Uribe (2007) in a canonical closed-economy New Keynesian model without credit frictions. The optimal simple rule with smoothing displays a large degree of inertia and a limited response to the CPI inflation. The latter result is in line with Schmitt-Grohé and Uribe (2007) in the sense that the level of the response coefficient of inflation plays a limited role for welfare and it matters to the extent that it affects the determinacy. It is also inline with Monacelli (2005), Faia and Monacelli (2008), and Monacelli (forthcoming) since open economy features such as home bias and incomplete exchange rate pass-through may cause the policymaker to deviate from strict domestic markup stabilization and resort to some degree of exchange rate stabilization. Large relative volatilities of inflation, credit spread and real exchange rate compared to the Ramsey policy indicates that these two optimised Taylor rules with and without smoothing can only partially stabilise the intratemporal and intertemporal wedges, explaining the welfare losses associated with these rules.

Under productivity shocks, optimised augmented Taylor rules suggest that a strong response to credit spreads together with moderate responses to inflation and output deviations achieves the highest welfare possible. In response to 100 basis points increase in credit spreads, the policy should be reduced by 150 basis points. This policy substantially reduces the relative volatility of spread in comparison to that in the Ramsey policy. Moreover, the optimised augmented Taylor rules that respond to asset prices and real exchange rate also achieve a level of welfare very close to the spread-augmented Taylor rule. Both rules feature a lower degree of relative volatility of the real exchange rate in comparison to that in the Ramsey policy. We also observe that it is not optimal to respond to bank credit under productivity shocks. In addition, comparing the relative volatilities of key variables under these augmented Taylor rules displays the nature of the policy trade-offs that the central bank faces. For instance, although the spread-augmented rule features a lower volatility of the credit spreads relative to the Ramsey policy as can be expected, it displays a much higher relative volatility in the CPI inflation. In addition, RER-augmented rule features a lower volatility in the real exchange rate as expected but it displays much larger variations in the inflation rate and the credit spread.

Optimised augmented Taylor rules under government spending shocks suggest similar results in general except the following. In response to this domestic demand shock, which pushes inflation and output in the same direction, the optimal Taylor rules with or without smoothing display a positive response to output. The best policy on the other hand, is to respond to the RER instead of credit spreads, noting that the welfare costs implied by either policy rule relative to the Ramsey policy are quite similar.

4.7.2 External shocks

Table 7 displays the response coefficients of optimised conventional and augmented Taylor rules, the relative volatilities of key macroeconomic variables under these rules, and the associated consumption-equivalent welfare costs relative to the optimal Ramsey policy under country borrowing premium, the U.S. interest rate and export demand shocks.

The optimised Taylor rules with and without smoothing still feature no response to output variations under external shocks with the exception of export demand shocks and the rule without smoothing. The levels of the inflation coefficients are at their lowest levels and the optimised Taylor rule with smoothing still displays a high degree of inertia. In addition, the relative volatilities of inflation, credit spreads and the RER under these two optimised rules are much higher than those under the Ramsey policy, which justifies relatively higher welfare costs associated with these rules.

The results associated with the optimised augmented Taylor rules indicate that an aggressive response to the RER together with mild responses to inflation and output variations achieves the highest welfare possible. The relative volatility of the RER in comparison to those in other optimised Taylor rules and that in the Ramsey policy is substantially reduced. Furthermore, the spread-augmented Taylor rule achieves a level of welfare virtually identical to the RER-augmented Taylor rule. Under this rule, the relative volatility of credit spreads is lower than that in the Ramsey policy whereas the relative volatilities of the inflation rate and the real exchange rate are much higher. Finally, we also find that it is not optimal to respond to bank credit and asset price movements under these shocks.

Optimised augmented Taylor rules under the U.S. interest and the export demand shocks display very similar results as in the case of the country borrowing premium shocks. For brevity, we do not discuss the results here in detail. We just would like to focus on the results of a particular augmented Taylor rule. Specifically for the U.S. interest rate shocks, we also consider another optimised augmented Taylor rule that directly responds to the U.S. policy rate movements in addition to inflation and output variations. This rule is of particular interest for EME policymakers as domestic policy rates in EMEs might be driven by the changes in the U.S. policy rate over and above domestic factors would imply, which is also empirically shown by Takáts and Vela (2014), and Hofmann and Takáts (2015). The latter paper suggests two reasons as to why EME policy rates might follow those in the U.S. First, they might want to eliminate high interest differentials resulting from the U.S policy rate movements, which may potentially cause exchange rate appreciation and hence a loss of trade competitiveness. Second, they might want to prevent excessive short-term capital inflows by eliminating large interest rate differentials in order to maintain financial stability. The model results confirm their empirical findings, suggesting that it is optimal for an EME policymaker to positively respond to the U.S. policy rate. In response to 100 basis points increase in the U.S. policy rate, the EME central bank should raise its policy rate by 257 basis points. This policy particularly reduces the relative volatility of the real exchange rate in comparison to the Ramsey policy. The welfare cost of implementing this policy is very close to those of implementing the spread and the RER-augmented Taylor rules.

4.7.3 All shocks

Table 8 displays the response coefficients of optimised conventional and augmented Taylor rules, the relative volatilities of key macroeconomic variables under these rules, and the associated consumption-equivalent welfare costs relative to the optimal Ramsey policy under all shocks together.

The optimised Taylor rules with and without smoothing still display zero response to output deviations under all shocks. The magnitudes of the inflation coefficients are at their lower bounds and the optimised Taylor rule with smoothing still feature a high degree of inertia. Furthermore, the relative volatilities of the CPI inflation, the credit spread and the RER under these two optimised rules are much larger in comparison to those in the Ramsey policy, which explains relatively higher welfare losses associated with these rules.

The findings associated with the optimised augmented Taylor rules suggest that a strong response to credit spread together with a mild response to inflation and an aggressive response to output variations achieves the highest welfare possible. In response to 100 basis points increase in credit spreads, the policy rate should be reduced by 150 basis points. This policy substantially reduces the relative volatilities of the credit spread and the real exchange rate compared to those under the Ramsey policy whereas it increases the relative volatility of the inflation rate. In addition, the RER-augmented Taylor rule also achieves a level of welfare very close to the spread-augmented Taylor rule. This rule feature much lower level of relative volatility of the inflation rate in comparison to that in the spread-augmented Taylor rule. Moreover, we find that in response to 100 basis points increase in the U.S. policy rate, the EME policy rate should be raised by 21 basis points, which is quantitatively inline with the empirical findings of Hofmann and Takáts (2015). We also confirm our previous findings under other external shocks that it is not optimal to respond to bank credit and asset prices under all shocks.

4.8 Extension: Optimal interest rate and reserve requirement policies

Coordination of policymaking among monetary and supervisory authorities has been a central issue since the aftermath of the recent global financial crisis.[20] Furthermore, adding a LATW role to the short-term interest rate might confuse the policy targets of a central bank if it aims to achieve price and financial stability by itself, simultaneously. In this section, we aim to address these issues by operationalising reserve requirements as a policy rule that tries to smooth out fluctuations in the credit spreads over the cost of foreign borrowing.[21] Finally, we investigate whether a supervisory authority should separately optimise a reserve requirement policy or coordinate with the central bank in maximising the welfare of households. The short term interest rate rule in these experiments correspond to a standard Taylor rule.

Rows 7 and 8 in Tables 6 to 8 report optimal simple interest rate and reserve requirement rules that are pinned down by using a similar methodology to that in the previous section. Specifically in row 7, we solve for the case with coordination, in which the Taylor rule and the reserve requirement rule are jointly optimised. To avoid the curse of dimensionality, we fix the persistence parameter of the Taylor rule in these experiments to its value under the optimal simple Taylor rule (reported in the second row of each table). In row 8, we solve for the case with lack of coordination, in which all of Taylor rule parameters are fixed to their optimal simple rule values and the optimal reserve requirement rule is searched for separately.

Two important results stand out. Under domestic, external and all shocks, we always find a negative response of reserve requirements to the credit spreads over the cost of foreign debt. That is, regardless of whether an independent supervisory body or the central bank itself, the authorities use this tool to LATW. Consequently, the welfare costs compared to the Ramsey policy always emerge as strictly smaller than that implied by the optimal simple Taylor rule, which does not LATW. This

[20] Angelini et al. (2011) find that inadequate coordination between monetary and macroprudential policies might result in sub-optimal results.

[21] Shin (2013) and Chung et al. (2014) argue that reserve requirements might prove useful in the managing non-core liabilities of banks. Nevertheless, share of non-core debt in our framework does not explicitly distort the efficiency conditions, whereas credit spreads do. Therefore, we model the reserve requirement rule as responding to the spreads over the cost of non-core debt.

is because the reserve requirement rule calls for a decline in the tax levied on banks' external finance in bad times, since credit spreads are countercyclical. This partly offsets the negative impact of declining asset prices and depreciating exchange rate on the balance sheet of banks, and reduces the welfare cost obtained under the Taylor rule. Lastly, except for the case of all shocks, welfare costs under coordination are always strictly lower than those with lack of coordination. Indeed, the welfare cost under under joint optimization of the two rules is very close to those implied by the best optimal simple LATW type interest rate rules for the case productivity, country risk premium and US interest rate shocks. Therefore, our results confirm that lack of coordination among authorities, or sub-branches within a central bank might be detrimental for welfare. Most importantly, under certain shocks, if central bank finds it hard to introduce a LATW role for the short term interest policy, it might rely on reserve requirements as an additional tool for that objective without foregoing substantial stabilization gains.

5 Conclusion

This paper contributes to the previous literature by investigating the quantitative performance of LATW-type monetary policy rules and RR policies in mitigating the negative impacts of external shocks on macroeconomic, domestic and external financial stability. To this aim, we build a New-Keynesian small open economy model that includes a banking sector with domestic and foreign borrowing and for which external and financial conditions influence macroeconomic dynamics. We show that the model is reasonably successful in explaining the observed dynamics of the real, financial and external sides of EMEs during the Global Financial Crisis. On the normative side, we solve for the Ramsey equilibrium problem and search for optimal, simple and implementable rules that aim at replicating the dynamics of the planner's economy.

Our analysis highlights three main results. First, we find that LATW-type monetary policy rules, in particular spread- and real exchange rate-augmented Taylor rules, outperform standard or credit/asset price-augmented interest rate rules under both domestic and external shocks. Second, a US interest rate-augmented optimal Taylor rule calls for a positive response to US interest rates and achieves welfare costs that are similar to the best optimal rule. Lastly, a countercyclical RR rule that aims at stabilising credit spreads proves effective in reducing welfare costs in coordination with a standard Taylor-type rule, especially under external financial shocks.

It is crucial to disentangle the various shocks that drive the business cycles in EMEs while designing the optimal monetary policy response. One caveat is that our model does not provide a prescription for EME central banks in the exact determination of the source of shocks. EME policymakers might have to solve a signal extraction problem to determine which variable is driven by which shock, bearing in mind that embedding such a problem into this framework might be a daunting task. We also exclude systemic risk by abstracting from irrational exuberance or asset price bubbles. The framework might be extended in those dimensions to explore any macroprudential role for LATW-type interest rate rules or countercyclical RRs. Lastly, future research might consider an explicit account of non-financial firms' balance sheets to study how the policy prescriptions of the model are affected by this additional source of financial amplification.

6 References

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A Appendix - Model derivations

A.1 Households

The expenditure minimization problem of households

$$\min_{c_t^H, c_t^F} P_t c_t - P_t^H c_t^H - P_t^F c_t^F$$

subject to (1) yields the demand curves $c_t^H = \omega \left(\frac{P_t^H}{P_t} \right)^{-\gamma} c_t$ and $c_t^F = (1-\omega) \left(\frac{P_t^F}{P_t} \right)^{-\gamma} c_t$, for home and foreign goods, respectively.

The final demand for home consumption good c_t^H, is an aggregate of a continuum of varieties of intermediate home goods along the [0,1] interval. That is, $c_t^H = \left[\int_0^1 (c_{it}^H)^{1-\frac{1}{\epsilon}} di \right]^{\frac{1}{1-\frac{1}{\epsilon}}}$, where each variety is indexed by i, and ϵ is the elasticity of substitution between these varieties. For any given level of demand for the composite home good c_t^H, the demand for each variety i solves the problem of minimising total home goods expenditures, $\int_0^1 P_{it}^H c_{it}^H di$ subject to the aggregation constraint, where P_{it}^H is the nominal price of variety i. The solution to this problem yields the optimal demand for c_{it}^H, which satisfies

$$c_{it}^H = \left(\frac{P_{it}^H}{P_t^H} \right)^{-\epsilon} c_t^H,$$

with the aggregate home good price index P_t^H being

$$P_t^H = \left[\int_0^1 (P_{it}^H)^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}.$$

First order conditions (7) and (9) that come out of the utility maximization problem can be combined to obtain the consumption-savings optimality condition,

$$\left(c_t - h_c c_{t-1} - \frac{\chi}{1+\xi} h_t^{1+\xi} \right)^{-\sigma} - \beta h_c E_t \left(c_{t+1} - h_c c_t - \frac{\chi}{1+\xi} h_{t+1}^{1+\xi} \right)^{-\sigma}$$

$$= \beta E_t \left[\left\{ \left(c_{t+1} - h_c c_t - \frac{\chi}{1+\xi} h_{t+1}^{1+\xi} \right)^{-\sigma} - \beta h_c \left(c_{t+2} - h_c c_{t+1} - \frac{\chi}{1+\xi} h_{t+2}^{1+\xi} \right)^{-\sigma} \right\} \frac{(1+r_{nt+1}) P_t}{P_{t+1}} \right].$$

The consumption-money optimality condition,

$$\frac{\upsilon/m_t}{\varphi_t} = \frac{r_{nt}}{1+r_{nt}}.$$

on the other hand, might be derived by combining first order conditions (9) and (10) with m_t denoting real balances held by consumers.

A.2 Banks' net worth maximization

Bankers solve the following value maximization problem,

$$\begin{aligned} V_{jt} &= \max_{l_{jt+i}, b^*_{jt+1+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\ n_{jt+1+i} \\ &= \max_{l_{jt+i}, b^*_{jt+1+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i} \Big(\left[R_{kt+1+i} - \hat{R}_{t+1+i}\right] q_{t+i} l_{jt+i} \\ &\quad + \left[R_{t+1+i} - R^*_{t+1+i}\right] b^*_{jt+1+i} + \hat{R}_{t+1+i} n_{jt+i} \Big). \end{aligned}$$

subject to the constraint (17). Since,

$$\begin{aligned} V_{jt} &= \max_{l_{jt+i}, b^*_{jt+1+i}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\ n_{jt+1+i} \\ &= \max_{l_{jt+i}, b^*_{jt+1+i}} E_t \left[(1-\theta)\Lambda_{t,t+1} n_{jt+1} + \sum_{i=1}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i}\ n_{jt+1+i} \right], \end{aligned}$$

we have

$$V_{jt} = \max_{l_{jt}, b^*_{jt+1}} E_t \Big\{ \Lambda_{t,t+1} [(1-\theta) n_{jt+1} + \theta V_{jt+1}] \Big\}.$$

The Lagrangian which solves the bankers' profit maximization problem reads,

$$\begin{aligned} \max_{l_{jt}, b^*_{jt+1}} L &= \nu^l_t q_t l_{jt} + \nu^*_t b^*_{jt+1} + \nu_t n_{jt} \\ &\quad + \mu_t \left[\nu^l_t q_t l_{jt} + \nu^*_t b^*_{jt+1} + \nu_t n_{jt} - \lambda \left(q_t l_{jt} - \omega_l \left[\frac{q_t l_{jt} - n_{jt}}{1 - rr_t} - b^*_{jt+1} \right] \right) \right], \end{aligned} \tag{A.1}$$

where the term in square brackets represents the incentive compatibility constraint, (17) combined with the balance sheet (12), to eliminate b_{jt+1}. The first-order conditions for l_{jt}, b^*_{jt+1}, and the Lagrange multiplier μ_t are:

$$\nu^l_t (1+\mu_t) = \lambda \mu_t \Big(1 - \frac{\omega_l}{1 - rr_t} \Big), \tag{A.2}$$

$$\nu_t^*(1+\mu_t) = \lambda\mu_t\omega_l \tag{A.3}$$

and

$$\nu_t^l q_t l_{jt} + \nu_t^* \left[\frac{q_t l_{jt} - n_{jt}}{1-rr_t} - b_{jt+1}\right] + \nu_t n_{jt} - \lambda(q_t l_{jt} - \omega_l b_{jt+1}) \geq 0 \tag{A.4}$$

respectively. We are interested in cases in which the incentive constraint of banks is always binding, which implies that $\mu_t > 0$ and (A.4) holds with equality.

An upper bound for ω_l is determined by the necessary condition for a positive value of making loans $\nu_t^l > 0$, implying $\omega_l < 1 - rr_t$. Therefore, the fraction of non-diverted domestic deposits has to be smaller than one minus the reserve requirement ratio, as implied by (A.2).

Combining (A.2) and (A.3) yields,

$$\frac{\frac{\nu_t^*}{1-rr_t}}{\nu_t^l + \frac{\nu_t^*}{1-rr_t}} = \frac{\omega_l}{1-rr_t}.$$

Re-arranging the binding version of (A.4) leads to equation (19).

We replace V_{jt+1} in equation (16) by imposing our linear conjecture in equation (18) and the borrowing constraint (19) to obtain,

$$\tilde{V}_{jt} = E_t\Big\{\Xi_{t,t+1} n_{jt+1}\Big\}, \tag{A.5}$$

where $\tilde{V}_{jt}$ stands for the optimised value.

Replacing the left-hand side to verify our linear conjecture on bankers' value (18) and using equation (15), we obtain the definition of the augmented stochastic discount factor $\Xi_{t,t+1} = \Lambda_{t,t+1}\Big[1-\theta+\theta\Big(\zeta_{t+1}\kappa_{t+1}+\nu_{t+1}-\frac{\nu_{t+1}^*}{1-rr_{t+1}}\Big)\Big]$ and find that ν_t^l, ν_t, and ν_t^* should consecutively satisfy equations (20), (21) and (22) in the main text.

Surviving bankers' net worth n_{et+1} is derived as described in the main text and is equal to

$$n_{et+1} = \theta\left(\left[R_{kt+1} - \hat{R}_{t+1} + \frac{R_{t+1} - R_{t+1}^*}{1-rr_t}\right]\kappa_t - \left[\frac{R_{t+1} - R_{t+1}^*}{1-rr_t}\right] + \hat{R}_{t+1}\right) n_t$$

$$+ \left(\left[R_{kt+1} - \hat{R}_{t+1} + \frac{R_{t+1} - R_{t+1}^*}{1-rr_t}\right]\omega_l - \left[\frac{R_{t+1} - R_{t+1}^*}{1-rr_t}\right]\right) b_{t+1}.$$

A.3 Final goods producers

The profit maximization problem of final goods producers are represented by

$$\max_{y_t^H(i)} \quad P_t^H \left[\int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon}} di \right]^{\frac{1}{1-\frac{1}{\epsilon}}} - \left[\int_0^1 P_t^H(i) y_t^H(i) di \right]. \tag{A.6}$$

A.4 Intermediate goods producers

Domestic intermediate goods producers' profit maximization problem can be represented as follows:

$$\max_{P_t^H(i)} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[\frac{D_{t+j}^H(i)}{P_{t+j}} \right] \tag{A.7}$$

subject to the nominal profit function

$$D_{t+j}^H(i) = P_{t+j}^H(i) y_{t+j}^H(i) + S_{t+j} P_{t+j}^{H*} c_{t+j}^{H*}(i) - MC_{t+j} y_{t+j}(i) - P_{t+j} \frac{\varphi^H}{2} \left[\frac{P_{t+j}^H(i)}{P_{t+j-1}^H(i)} - 1 \right]^2, \tag{A.8}$$

and the demand function $y_t^H(i) = \left(\frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon} y_t^H$. Since households own these firms, any profits are remitted to consumers and future streams of real profits are discounted by the stochastic discount factor of consumers, accordingly. Notice that the sequences of the nominal exchange rate and export prices in foreign currency $\{S_{t+j}, P_{t+j}^{H*}\}_{j=0}^{\infty}$ are taken exogenously by the firm, since it acts as a price taker in the export market. The first-order condition to this problem becomes,

$$(\epsilon - 1) \left(\frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon} \frac{y_t^H}{P_t} = \epsilon \left(\frac{P_t^H(i)}{P_t^H} \right)^{-\epsilon-1} MC_t \frac{y_t^H}{P_t P_t^H} - \varphi^H \left[\frac{P_t^H(i)}{P_{t-1}^H(i)} - 1 \right] \frac{1}{P_{t-1}^H(i)}$$

$$+ \varphi^H E_t \left\{ \Lambda_{t,t+1} \left[\frac{P_{t+1}^H(i)}{P_t^H(i)} - 1 \right] \frac{P_{t+1}^H(i)}{P_t^H(i)^2} \right\}. \tag{A.9}$$

A.5 Resource constraints

The resource constraint for home goods equates domestic production to the sum of domestic and external demand for home goods and the real domestic price adjustment costs, so that

$$y_t^H = c_t^H + c_t^{H*} + i_t^H + g_t^H y_t^H + \left(p_t^H \right)^{-\gamma} \frac{\varphi^H}{2} \left(\pi_t \frac{p_t^H}{p_{t-1}^H} - 1 \right)^2. \tag{A.10}$$

A similar market clearing condition holds for the domestic consumption of the imported goods, that is,

$$y_t^F = c_t^F + i_t^F + \left(p_t^F\right)^{-\gamma} \frac{\varphi^F}{2} \left(\pi_t \frac{p_t^F}{p_{t-1}^F} - 1\right)^2. \tag{A.11}$$

The balance of payments vis-à-vis the rest of the world defines the trade balance as a function of net foreign assets

$$R_t^* b_t^* - b_{t+1}^* = c_t^{H*} - y_t^F. \tag{A.12}$$

Finally, the national income identity that reflects investment adjustment costs built in capital accumulation condition (25) would read,

$$y_t = y_t^H - y_t^F. \tag{A.13}$$

A.6 Definition of competitive equilibrium

A competitive equilibrium is defined by sequences of prices $\left\{p_t^H, p_t^F, p_t^I, \pi_t, w_t, q_t, s_t, R_{kt+1}, R_{t+1}, R_{t+1}^*\right\}_{t=0}^{\infty}$, government policies $\{r_{nt}, rr_t, M_{0t}, T_t\}_{t=0}^{\infty}$, allocations $\left\{c_t^H, c_t^F, c_t, h_t, m_t, b_{t+1}, b_{t+1}^*, \varphi_t, l_t, n_t, \kappa_t, \nu_t^l, \nu_t^*, \nu_t, i_t, i_t^H, i_t^F, k_{t+1}, y_t^H, y_t^F, y_t, u_t, rmc_t, c_t^{H*}, D_t^H, \Pi_t, \delta_t\right\}_{t=0}^{\infty}$, initial conditions, $b_0, b_0^*, k_0, m_-, n_0$ and exogenous processes $\left\{A_t, g_t^H, \psi_t, r_{nt}^*, y_t^*\right\}_{t=0}^{\infty}$ such that;

i) Given exogenous processes, initial conditions, government policy, and prices; the allocations solve the utility maximization problem of households (5)-(6), the net worth maximization problem of bankers (16)-(17), and the profit maximization problems of capital producers (24), final goods producers (A.6), and intermediate goods producers (A.7)-(A.8) and (28)-(29).

ii) Home and foreign goods, physical capital, investment, security claims, domestic deposits, money, and labor markets clear. The balance of payments and GDP identities (A.12) and (A.13) hold.

Figure 1: Macroeconomic dynamics around the 2007-09 crisis in emerging markets

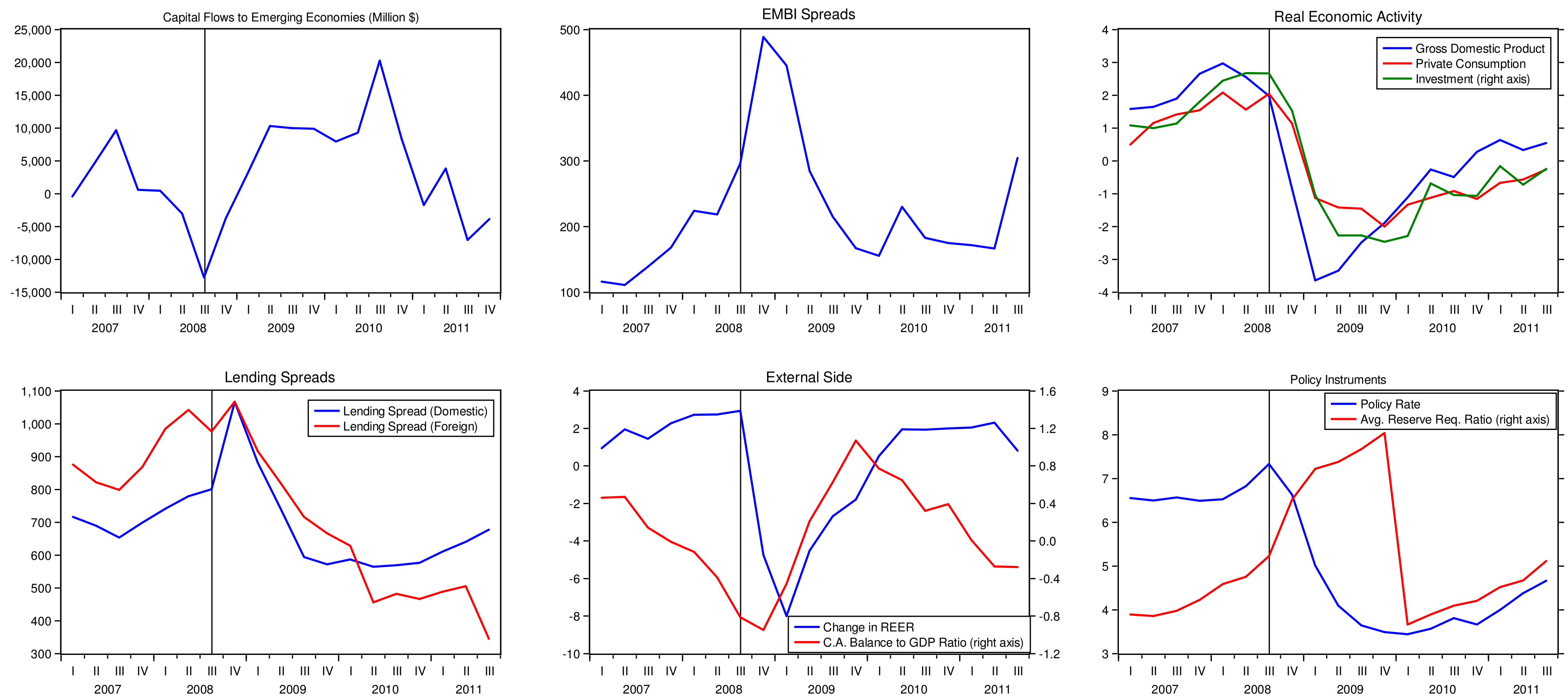

Figure 2: Role of asymmetric frictions in the decentralised economy - Impulse response functions driven by 127 annualised basis points increase in country risk premium.

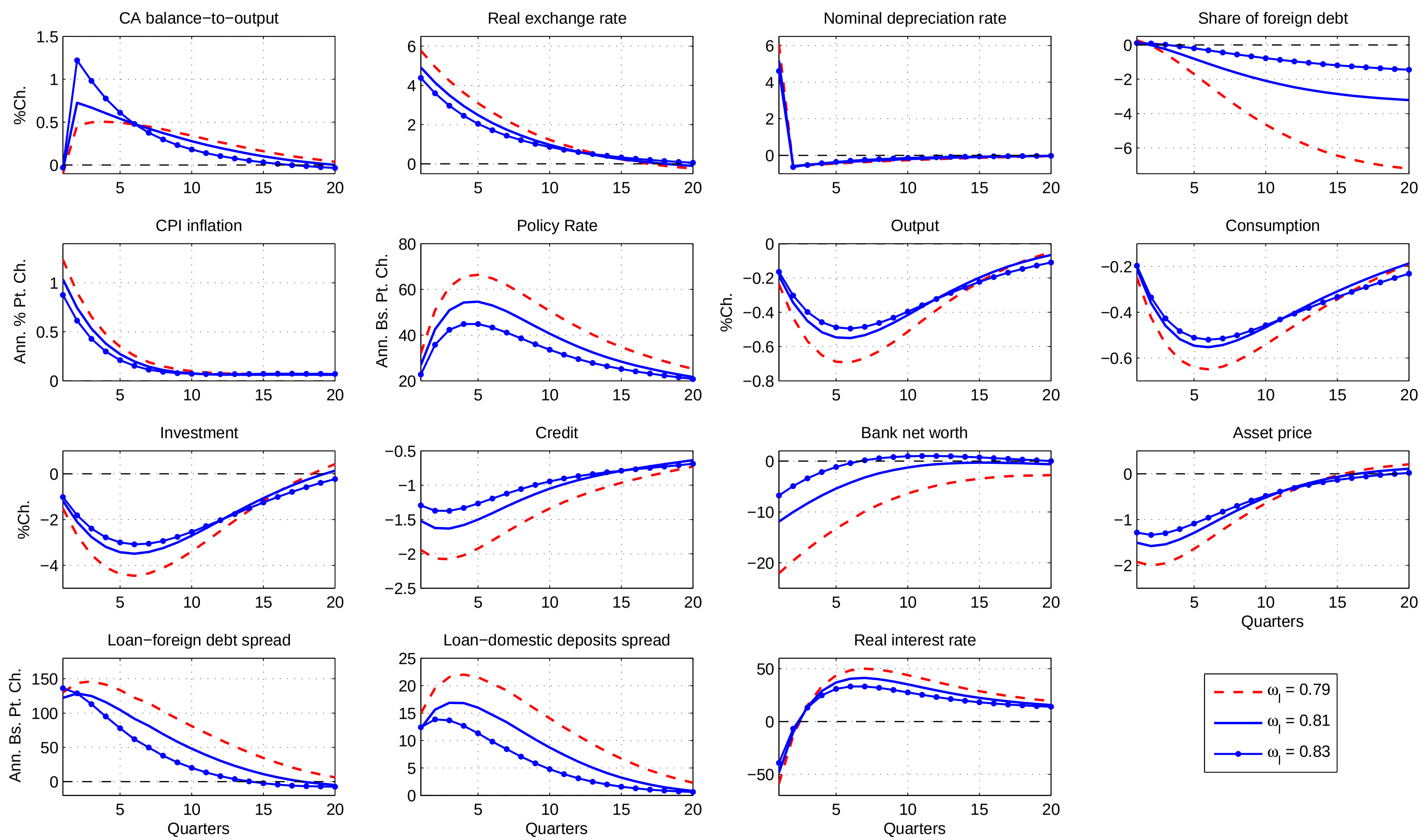

Figure 3: Financial frictions and spreads

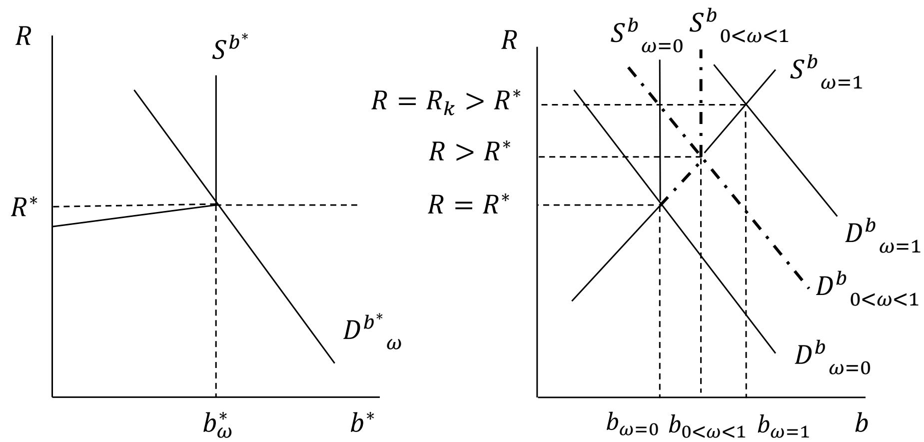

Figure 4: Decentralised economy versus Ramsey planner

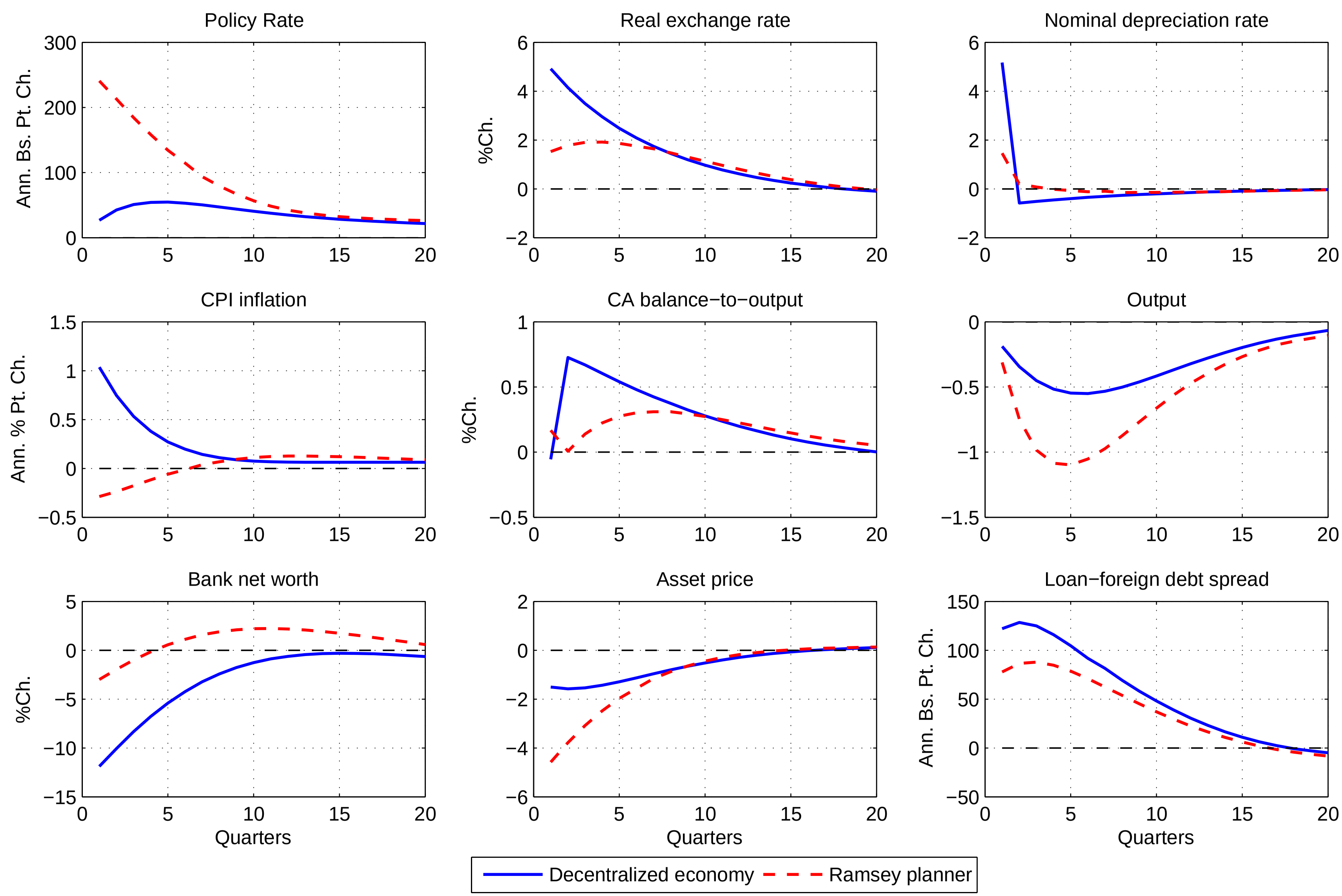

Table 1: Macroeconomic dynamics in 2007:Q1-2011:Q3 episode: peak-to-trough

Country	EMBI Spread (bps)	Output (%)	Consumption (%)	Investment (%)	CAD/Output (pp)
Brazil	279	-7.6	-4.8	-23.0	1.43
Chile	260	-8.2	-15.0	-29.2	–
China	175	-3.6	–	–	2.70
Colombia	379	-6.5	-4.9	-17.3	1.53
Czech Rep.	–	-7.5	-6.3	-19.8	2.50
Hungary	477	-7.5	-10.2	-17.1	5.60
India	–	-1.8	-4.3	-11.3	1.53
Indonesia	597	-1.8	-7.7	-5.1	2.38
Israel	–	-4.1	-7.9	-20.4	8.70
Korea Rep.	–	-6.0	-7.8	-5.2	4.80
Malaysia	297	-10.2	-7.2	-17.7	3.20
Mexico	330	-9.8	-9.6	-14.0	1.87
Peru	392	-7.1	-8.0	-21.6	4.60
Philippines	391	-5.3	-5.7	-14.7	4.90
Poland	266	-3.8	-3.2	-19.3	2.80
Russia	703	-13.6	-10.6	-20.0	–
Singapore	162	-15.5	–	–	3.10
S. Africa	489	-5.2	-8.5	-26.1	6.30
Thailand	–	-10.6	-8.7	-27.0	7.40
Turkey	345	-19.7	-19.4	-41.0	4.90
Average	369	-7.7	-8.3	-19.4	3.90

Country	REER (%)	Dom. Spread (bps)	For. Spread (bps)	Policy rate (pp)	Res. req. (pp)
Brazil	-24.7	970	1000	-5.00	-3.33
Chile	-20.0	700	1140	-7.80	0.00
China	-12.3	900	1240	-1.89	-2.50
Colombia	-21.9	830	1030	-7.00	-16.0
Czech Rep.	-12.6	–	–	-3.00	0.00
Hungary	-19.8	190	260	-4.70	-1.00
India	-15.0	–	–	-4.20	-4.00
Indonesia	-22.1	86	410	-2.75	–
Israel	-8.3	–	–	-3.75	0.00
Korea Rep.	-37.3	–	–	-3.25	–
Malaysia	-7.5	41	188	-1.50	-3.00
Mexico	-22.0	183	440	-3.75	0.00
Peru	-8.1	120	330	-5.20	-9.00
Philippines	-12.6	107	254	-3.50	-2.00
Poland	-27.2	221	-225	-2.50	-0.50
Russia	-16.3	380	460	-5.00	-3.00
Singapore	-5.2	–	–	-2.43	0.00
S. Africa	-29.0	-98	460	-6.50	–
Thailand	-9.3	–	–	-3.25	0.00
Turkey	-19.9	1480	340	-11.5	-1.50
Average	-17.5	436	523	-4.4	-2.69

Table 2: Model parameters

Description	Parameter	Value	Target
Preferences			
Quarterly discount factor	β	0.9821	Annualised real deposit rate of 7.48%
Relative risk aversion	σ	2	Literature
Scaling parameter for labor	χ	199.35	Steady state hours worked of 0.33
Labor supply elasticity	ξ	3	Literature
Habit persistence	h_c	0.7	Literature
Scaling parameter for money	υ	0.0634	$Y/M2 = 2.25$
Elasticity of substitution for consumption composite	γ	0.5	Faia and Monacelli (2007)
Elasticity of substitution for investment composite	γ_i	0.25	Gertler et al. (2007)
Share of domestic consumption goods	ω	0.62	$C/Y = 0.57$
Financial Intermediaries			
Fraction of diverted bank loans	λ	0.65	Domestic credit spread = 34 bp.
Proportional transfer to the entering bankers	ϵ^b	0.00195	Foreign credit spread = 152 bp.
Fraction of non-diverted domestic deposits	ω_l	0.81	Banks' foreign debt share = 40.83%
Survival probability of bankers	θ^b	0.925	Commercial bank leverage = 7.94
Firms			
Share of capital in output	α	0.4	Labor share of output = 0.60
Share of domestic goods in the investment composite	ω_i	0.87	$I/Y = 0.15$
Steady-state utilization rate	$\overline{u}$	1	Literature
Depreciation rate of capital	δ	0.035	$I/K = 14.8\%$
Utilization elasticity of marginal depreciation rate	ϱ	1	Gertler et al. (2007)
Investment adjustment cost parameter	ψ	5	Literature
Elasticity of substitution between varieties	ϵ	11	Steady state mark-up of 1.1
Menu cost parameter for domestic intermediate goods	φ_H	113.88	Price inertia likelihood = 0.75
Menu cost parameter for foreign intermediate goods	φ_F	113.88	Price inertia likelihood = 0.75
Foreign price elasticity of export demand	Γ	1	Literature
Share of foreign output in export demand	ν^F	0.25	Gertler et al. (2007)
Average foreign output	$\bar{y^*}$	0.16	$X/Y = 0.18$
Monetary Authority and Government			
Policy rate persistence	ρ_{r_n}	0.89	Estimated for 2003:Q1-2014:Q4
Policy rate inflation response	φ_π	2.17	Estimated for 2003:Q1-2014:Q4
Required reserves ratio	rr	0.09	Required reserves ratio for 1996 - 2015
Steady state government expenditure to GDP ratio	$\bar{g}^H$	0.10	$G/Y = 10\%$
Shock Processes			
Persistence of government spending shocks	ρ^{g^H}	0.457	Estimated for 2002-2014
Standard deviation of government spending shocks	σ^{g^H}	0.04	Estimated for 2002-2014
Persistence of risk premium shocks	ρ^Ψ	0.963	Estimated from EMBI Global for 1996:Q2-2014:Q4
Standard deviation of risk premium shocks	σ^Ψ	0.0032	Estimated from EMBI Global for 1996:Q2-2014:Q4
Foreign debt elasticity of risk premium	ψ_1	0.015	$corr(TB/Y, Y) = -76\%$
Persistence of U.S interest rate shocks	$\rho^{R_n^*}$	0.977	Estimated for 1996:Q2-2014:Q4
Standard deviation of U.S. interest rate shocks	$\sigma^{R_n^*}$	0.00097	1996:Q2-2014:Q4
Persistence of TFP shocks	ρ^A	0.662	Bahadir and Gumus (2014)
Standard deviation of TFP shocks	σ^A	0.0283	Bahadir and Gumus (2014)
Persistence of export demand shocks	ρ^{y^*}	0.425	Persistence of euro area GDP = 0.31
Standard deviation of export demand shocks	σ^{y^*}	0.0048	Standard deviation of euro area GDP = 0.0048

Table 3: Business cycle statistics: Data vs. Model Economy

	Variable	$\frac{\sigma_x}{\sigma_y}$ Data	D.E.	$corr(x,y)$ Data	D.E.	$corr(x_t, x_{t-1})$ Data	D.E.
Real Variables	Output	1.00	1.00	1.00	1.00	0.84	0.83
	Consumption	0.76	0.70	0.92	0.86	0.72	0.93
	Investment	2.58	4.93	0.96	0.83	0.87	0.95
Financial Variables	Liability Composition (Foreign)	1.16	1.95	-0.03	-0.20	0.53	0.95
	Credit	1.78	2.25	0.54	0.72	0.69	0.79
	Domestic Lending Spread	0.23	0.20	-0.55	-0.65	0.65	0.83
	Foreign Lending Spread	0.81	0.37	-0.37	-0.48	0.55	0.74
External Variables	Real Exchange Rate	1.20	5.95	-0.26	-0.34	0.50	0.66
	CA Balance to GDP	0.38	1.05	-0.67	-0.50	0.90	0.71
	Trade Balance to GDP	0.46	0.33	-0.79	-0.76	0.72	0.94
Monetary Variables	Inflation Rate	0.16	0.34	-0.32	-0.18	0.73	0.50
	Policy Rate	0.18	0.11	-0.17	-0.83	0.78	0.89

[a]D.E. denotes the decentralised economy.

Table 4: Variance decomposition in the decentralised economy (%)

One quarter ahead	TFP	Government spending	Country risk premium	U.S. interest rate	Export demand
Output	16.41	67.89	13.05	2.38	0.27
Consumption	17.69	0.12	69.81	12.36	0.03
Investment	5.11	0.00	80.86	13.98	0.05
Credit	96.45	2.54	0.77	0.12	0.11
Liability composition (foreign)	1.64	0.01	83.97	14.32	0.05
Domestic lending spread	0.04	0.00	84.50	15.36	0.10
Foreign lending spread	0.75	0.00	84.70	14.49	0.05
Real exchange rate	1.12	0.01	86.41	12.45	0.01
CA balance to GDP	0.04	0.00	79.93	13.72	6.31
Trade balance to GDP	0.18	0.25	79.87	13.73	5.98
Inflation rate	36.25	0.21	56.00	7.55	0.00
Policy rate	36.25	0.21	56.00	7.55	0.00
One year ahead					
Output	37.33	15.59	39.67	7.14	0.27
Consumption	15.98	0.10	71.23	12.66	0.03
Investment	6.17	0.00	79.89	13.90	0.05
Credit	70.40	1.40	23.71	4.19	0.31
Liability composition (foreign)	9.34	0.08	77.57	12.98	0.04
Domestic lending spread	0.91	0.00	84.48	14.58	0.03
Foreign lending spread	0.28	0.02	85.06	14.61	0.02
Real exchange rate	1.90	0.02	85.50	12.56	0.02
CA balance to GDP	1.30	0.02	84.33	14.17	0.18
Trade balance to GDP	0.94	0.02	83.12	14.46	1.45
Inflation rate	27.13	0.14	64.14	8.60	0.00
Policy rate	23.32	0.09	67.55	9.05	0.00
Asymptotic					
Output	32.66	16.38	43.39	7.39	0.18
Consumption	12.67	0.08	74.65	12.57	0.03
Investment	7.17	0.00	79.58	13.20	0.04
Credit	27.35	0.50	61.64	10.31	0.21
Liability composition (foreign)	9.99	0.08	77.40	12.49	0.04
Domestic lending spread	1.36	0.01	84.31	14.24	0.09
Foreign lending spread	0.63	0.02	84.93	14.34	0.07
Real exchange rate	1.95	0.02	85.69	12.32	0.02
CA balance to GDP	3.61	0.04	82.63	13.50	0.23
Trade balance to GDP	1.25	0.03	83.65	13.85	1.21
Inflation rate	33.99	0.18	58.10	7.73	0.00
Policy rate	24.07	0.08	67.12	8.73	0.01

Table 5: Relative volatilities

	Variable	Decentralised economy	Ramsey planner
Real Variables	Output	1.00	1.00
	Consumption	0.70	0.70
	Investment	4.93	5.06
	Hours Worked	2.09	1.32
Financial Variables	Credit	2.25	2.97
	Liability Composition (Foreign)	1.95	4.42
	Domestic Lending Spread	0.20	0.18
	Foreign Lending Spread	0.37	0.14
	Leverage	12.43	2.51
	Net Worth	14.13	3.11
External Variables	Real Exchange Rate	5.95	2.21
	CA Balance to GDP	1.05	0.27
	Trade Balance to GDP	0.33	0.32
Monetary Variables	Inflation Rate	0.34	0.11
	Policy Rate	0.11	0.25
	Markup	7.97	5.13

Table 6: Optimal simple policy rules under domestic shocks

Productivity Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	1.572	0	-	-	-	0.55	0.63	0.17	0.96	2.541
Standard (with smoothing)	0.995	1.001	0	-	-	-	0.35	0.60	0.27	2.16	1.633
Optimised Augmented Taylor Rules											
Credit	0.995	1.001	0	0	-	-	0.35	0.60	0.27	2.16	1.633
Asset price	0.639	1.286	0.643	3.000	-	-	0.27	0.54	0.08	1.52	0.295
Spread	0.924	1.286	1.285	-1.500	-	-	0.30	0.51	0.03	1.81	0.279
Real exchange rate	0.710	1.001	1.928	2.785	-	-	0.42	0.50	0.95	1.25	0.280
Optimised TR and RRR (joint)	0.995*	3.000	3.000	-	0.995	-3.000	0.04	1.21	0.02	1.32	0.282
Optimised TR and RRR (separate)	0.995*	1.001*	0*	-	0.852	-3.000	0.003	0.62	0.04	0.84	0.360
Ramsey Policy	-	-	-	-	-	-	0.28	0.22	0.08	1.92	0

Government Spending Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	1.001	0.214	-	-	-	0.17	0.09	0.07	0.28	2.081
Standard (with smoothing)	0.995	1.001	0.428	-	-	-	0.002	0.02	0.02	0.20	1.817
Optimised Augmented Taylor Rules											
Credit	0.995	1.001	0.428	0	-	-	0.002	0.02	0.02	0.20	1.817
Asset price	0.995	1.001	1.500	2.571	-	-	0.005	0.04	0.03	0.20	0.380
Spread	0.355	1.286	0.214	-2.571	-	-	0.62	1.00	0.001	1.43	0.029
Real exchange rate	0.213	1.143	0.214	2.142	-	-	0.20	0.09	0.33	0.29	0.016
Optimised TR and RRR (joint)	0.995*	1.143	1.285	-	0.995	-0.643	0.009	0.13	0.09	0.21	0.143
Optimised TR and RRR (separate)	0.995*	1.001*	0.428*	-	0.995	-0.428	0.002	0.04	0.02	0.20	1.817
Ramsey Policy	-	-	-	-	-	-	0.03	0.02	0.01	0.23	0

Table 7: Optimal simple policy rules under external shocks

Country Risk Premium Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	1.001	0	-	-	-	2.38	4.27	0.75	22.39	5.188
Standard (with smoothing)	0.995	1.001	0	-	-	-	0.94	1.17	0.33	17.91	0.894
Optimised Augmented Taylor Rules											
Credit	0.995	1.001	0	0	-	-	0.94	1.17	0.33	17.91	0.894
Asset price	0.995	1.001	0	0	-	-	0.94	1.17	0.33	17.91	0.894
Spread	0.923	1.429	0.428	-2.142	-	-	0.92	2.07	0.04	12.37	0.596
Real exchange rate	0.995	1.001	0.428	3.000	-	-	0.08	0.10	0.47	3.40	0.595
Optimised TR and RRR (joint)	0.995*	1.715	0	-	0.284	-2.785	0.02	1.34	0.02	17.71	0.595
Optimised TR and RRR (separate)	0.995*	1.001*	0*	-	0.995	-0.857	0.009	1.16	0.19	16.88	0.671
Ramsey Policy	-	-	-	-	-	-	0.26	0.05	0.16	2.37	0

U.S. Interest Rate Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	1.001	0	-	-	-	2.89	5.16	0.89	24.08	2.501
Standard (with smoothing)	0.995	1.001	0	-	-	-	0.009	1.14	0.30	16.57	1.888
Optimised Augmented Taylor Rules											
Credit	0.995	1.001	0	0	-	-	0.009	1.14	0.30	16.57	1.888
Asset price	0.995	1.001	0	0	-	-	0.009	1.14	0.30	16.57	1.888
Spread	0.923	1.001	3.000	-3.000	-	-	1.16	2.50	0.05	11.54	0.113
Real exchange rate	0.142	1.286	1.071	1.285	-	-	0.47	0.10	0.71	1.43	0.111
U.S. interest rate	0.781	1.001	0	2.571	-	-	0.29	0.98	0.64	0.88	0.120
Optimised TR and RRR (joint)	0.995*	2.857	3.000	-	0.995	-2.785	0.07	1.66	0.60	19.08	0.150
Optimised TR and RRR (separate)	0.995*	1.001*	0*	-	0.995	-2.785	0.009	1.13	0.87	15.06	1.071
Ramsey Policy	-	-	-	-	-	-	0.24	0.05	0.16	2.32	0

Export Demand Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	3.000	0.642	-	-	-	0.07	0.25	0.38	2.50	2.080
Standard (with smoothing)	0.995	1.001	0	-	-	-	0.003	0.25	0.38	2.75	2.079
Optimised Augmented Taylor Rules											
Credit	0.995	1.001	0	-	-	-	0.003	0.25	0.38	2.75	2.079
Asset price	0.995	1.001	0	-	-	-	0.003	0.25	0.38	2.75	2.079
Spread	0.071	1.001	1.714	-2.571	-	-	2.08	3.45	0.006	4.27	0.003
Real exchange rate	0.284	1.143	0	1.714	-	-	0.31	0.15	0.52	0.39	0.009
Optimised TR and RRR (joint)	0.995*	1.001	1.714	-	0.995	-0.643	0.02	0.33	0.25	0.55	0.093
Optimised TR and RRR (separate)	0.995*	1.001*	0*	-	0.995	-2.785	0.003	0.03	0.37	2.66	2.030
Ramsey Policy	-	-	-	-	-	-	0.12	0.02	0.28	1.20	0

Table 8: Optimal simple policy rules under all shocks

All Shocks	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}/σ_Y	σ_π/σ_Y	σ_{spread}/σ_Y	σ_{RER}/σ_Y	CEV(%)
Optimised Taylor Rules											
Standard (without smoothing)	-	1.001	0	-	-	-	1.40	2.50	0.40	11.86	6.992
Standard (with smoothing)	0.923	1.001	0	-	-	-	0.08	0.75	0.24	9.01	3.100
Optimised Augmented Taylor Rules											
Credit	0.923	1.001	0	0	-	-	0.08	0.75	0.24	9.01	3.100
Asset price	0.923	1.001	0	0	-	-	0.08	0.75	0.24	9.01	3.100
Spread	0.995	1.001	2.785	-1.500	-	-	0.10	0.68	0.07	0.07	0.987
Real exchange rate	0.995	1.001	0.428	2.785	-	-	0.07	0.20	0.47	3.44	0.993
U.S. interest rate	0.923	1.001	0	0.2143	-	-	0.07	0.63	0.35	7.79	1.116
Optimised TR and RRR (joint)	0.923*	1.001	0	-	0.995	-0.857	0.005	0.70	0.14	9.01	2.855
Optimised TR and RRR (separate)	0.923*	1.001*	0*	-	0.995	-0.857	0.09	0.77	0.14	8.89	2.855
Ramsey Policy	-	-	-	-	-	-	0.25	0.11	0.14	2.21	0

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