External Shocks, Banks and Optimal Monetary Policy: A Recipe for Emerging Market Central Banks[1]

Yasin Mimir[2] Enes Sunel[3]

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Abstract

We document that the 2007-09 Global Financial Crisis exposed emerging market economies to an adverse feedback loop of capital outflows, depreciating exchange rates, deteriorating balance sheets, rising credit spreads and falling real economic activity. We account for these empirical findings, by building 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 implementable 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 rules feature direct and non-negligible responses to the real exchange rate, asset prices and lending spreads. Furthermore, interest rate policy takes a stronger anti-inflationary stance when financial stability considerations are addressed by the monetary policy. We find that a countercyclical reserve requirement rule which responds to fluctuations in credit spreads and is optimized jointly with a conventional interest rate rule dominates augmented Taylor rules under country risk premium shocks.

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[2]Corresponding author. Norges Bank, Monetary Policy Department, Bankplassen 2, 0151 Oslo, Norway, Phone: +4722316811, yasin.mimir@norges-bank.no, Personal homepage: http://www.yasinmimir.com

[3]Sunel & Sunel Law Firm. Soganlik Yeni Mah., Uprise Elite Residence 234, Kartal, 34880 Istanbul, Turkey, Phone: +905334451145, email: enessunel@gmail.com, Personal homepage: https://sites.google.com/site/enessunel/

1 Introduction

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. Furthermore, the unconventional response of advanced economy policymakers to the crisis caused EMEs to sail in uncharted waters from a monetary policymaking perspective. These adverse developments revitalized the previous debate about whether central banks should pay attention to domestic or external financial variables over and above their effects on inflation or real economic activity. Consequently, the lean-against-the-wind (LATW) policies - defined as augmented Taylor-type monetary policy rules that additionally respond to domestic or external financial variables - are now central to discussions in both academic and policy circles.[1] This debate is even more pronounced in EMEs in which banks are the main source of credit extension and their sizeable reliance on non-core debt amplifies the transmission of external shocks, threatening both price and financial stability objectives.[2] In this regard, this paper aims to provide a recipe for EME central banks in rethinking interest rate policy determination.

We study 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 such rules that 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 bank credit, asset prices, credit spreads, the U.S. interest rate and the real exchange rate as additional inputs to policy. We then compare these optimal LATW-type Taylor rules with standard optimized Taylor rules (with and without interest-rate smoothing).

Our model builds on Galí and Monacelli (2005). The main departure from their work 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 demand for debt 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 is additionally affected by fluctuations in the exchange rate.

[1] See the discussion in Angelini et al. (2011).

[2] The median share of bank credit in total credit to the non-financial sector in EMEs was 87% in 2013 while the median share of non-core debt in total liabilities was 33%. For more details, see Ehlers and Víllar (2015). For other related discussions, see Obstfeld (2015) and Rey (2015).

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 investors in recovering assets from banks in case of bankruptcy. This makes foreign debt more risky, creates a wedge between the real costs of domestic and foreign debt, and hence violates the uncovered interest parity (UIP) condition.[3] 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 in total bank liabilities) and analyze 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 utilization and investment adjustment costs.

First, we analytically derive 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 faces in response to shocks. We show that the distortions in the intratemporal wedge are mainly driven by the 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 the variations in the lending spreads over the costs of domestic and foreign deposits together with those in the real exchange rate induced by financial market imperfections and open economy features.

We then conduct our quantitative analysis under five different types of shocks that might be most relevant 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 U.S. interest rate and export demand, which we label as external shocks.[4] Finally, we also analyze 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.

We find that the Ramsey-optimal policy substantially reduces relative volatilities of inflation, markup, the real exchange rate and loan-deposits interest rate spreads, compared to a decentralized economy, in which interest rate policy is a standard Taylor rule calibrated to the data. Morevoer, in comparison with the optimized simple rules, the Ramsey-optimal policy produces fairly smaller degrees of volatility in inflation and the real exchange rate while implying relatively larger degrees of volatility in credit spreads and asset prices. High volatility in credit spreads hints that the Ramsey planner weighs distortions resulting from price dispersion and exchange rate fluctuations more,

[3] We empirically illustrate in the bottom-left panel of Figure 1 that, with the exception of the period 2010:Q2-2011:Q3, 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 2002:Q4 for the average EME in our sample. For a detailed survey on the violation of the UIP, see Engel (2015). For theoretical contributions on domestic funding premium, see Broner et al. (2014) and Fornaro (2015).

[4] A shock to a country's borrowing premium can be justified 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 U.S. interest rate can be justified by the accommodative monetary stance of the Federal Reserve in the aftermath of the crisis or the policy normalization that was expected in late 2015.

compared with stabilizing inefficiencies resulting from credit frictions. Increased volatility in asset prices on the other hand, relates to the mechanism discussed by Faia and Monacelli (2007) that the constrained planner is adjusting asset prices to bring fluctuations in investment closer to efficient fluctuations. This is mainly because asset prices effectively work as a procyclical tax on investment under adjustment costs. The rationale behind this is similar to that in Arseneau and Chugh (2012) in which the Ramsey planner increases the volatility of labor income tax rate under labor market frictions to bring fluctuations in employment closer to the efficient fluctuations.

Under country risk premium shocks, the real exchange rate (RER) augmented rule which displays an aggressive and positive response to fluctuations in the real exchange rate and only mild responses to inflation and output variations implies the largest welfare among all optimized augmented Taylor rules. The implied welfare loss of this policy vis-à-vis the Ramsey-optimal policy is 0.0015% in terms of changes that compensate variation in consumption. This suggests that addressing the financial channel for an EME central bank is crucial (by which exchange rate depreciation hurts the balance sheets of domestic borrowers who face currency mismatch, leading them to curb domestic demand) rather than leaving adjustments to the trade channel that operates via price competitiveness as empirically documented by Kearns and Patel (2016). Since central bank is already fighting the pass-through aggressively, it does not deem useful to take a strong anti-inflationary stance under this policy. This finding is linked to the insights discussed by Monacelli (2005) and Monacelli (2013) that under incomplete exchange rate pass-through, fluctuations in the exchange rate operate as endogenous cost-push shocks which optimal policy pays more attention relative to price stability concerns.

Our results confirm the findings of Faia and Monacelli (2007) that an easing in the policy rate gets the dynamics of investment closer to efficient fluctuations in response to a favorable shock. To that end, we find that optimal policy calls for a negative response to asset prices together with a moderate anti-inflationary stance. The welfare cost implied by this policy rule is 0.0021% against the Ramsey policy. We find that the credit spread-augmented Taylor rule achieves a level of welfare very close to that of the asset price-augmented Taylor rule (the implied cost is 0.0026%). Interest rate policy features a LATW role in this case because credit spreads are countercyclical and the optimized augmented rule calls for an easing in bad times.

An optimized standard Taylor rule calls for a much milder anti-inflationary stance than those obtained under either the asset price- or the credit spread-augmented rules and is welfare inferior. The reason why standard Taylor rules perform suboptimally hinges on the idea that in response to adverse external shocks (which already raise the cost of foreign debt), a strong anti-inflationary stance of interest rate policy would hurt bank balance sheets even more by increasing the cost of domestic deposits. Therefore, we show that using an augmented policy rule with financial stability considerations allows the central bank to take a stronger anti-inflationary stance in line with the insights of Aoki et al. (2016).

When all shocks are switched on, we find that the asset-price augmented rule achieves the highest welfare among alternative optimal simple rules. The welfare cost of implementing this policy relative to the Ramsey-optimal policy rule is 0.0013%. Our findings are broadly in line with the case of external shocks that responding to credit spreads or the exchange rate is welfare superior compared to implementing an optimal standard Taylor rule. We also consider monetary policy responses to the U.S. interest rates motivated by the idea that domestic policy rates in EMEs might partly be driven by changes in the U.S. interest rates over and above what domestic factors would imply. The model suggests that it is optimal to positively respond to the U.S. interest rates in line with the empirical findings and discussions of Takáts and Vela (2014) and Hofmann and Takáts (2015). Although this policy rule dominates an optimal standard Taylor rule, it produces a larger welfare cost than those implied by the RER-, asset price- or credit spread-augmented interest rate policies.

Using the short-term interest rate for LATW purposes might be difficult should hitting multiple stabilization goals necessitate different trajectories for the single policy tool. In this respect, Shin (2013) and Chung et al. (2014) emphasize the usefulness of liability-based macroprudential policy tools alongside conventional monetary policy. To contemplate on those issues, we operationalize reserve requirements as a policy rule that aims to smooth out fluctuations in credit spreads in addition to conventional interest rate policy. We then examine whether an optimized *mix* of these two tools can compete with an optimized *augmented* interest rate rule in maximizing household welfare. We find that optimal reserve requirement policy exhibits LATW as it features a negative response to credit spreads. In addition, such a policy mix is found to produce welfare costs that are even smaller than that implied by the RER-augmented interest rate policy under country risk premium shocks.

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 negatively to asset prices with a Taylor-type interest rate rule is welfare improving. 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 non-financial firms and banks balance sheets. The former study shows that a spread-augmented Taylor rule stabilizes the adverse effects of shocks that widen credit spreads while the latter paper shows that responding to asset prices entails stabilization benefits even in response to supply side shocks. 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. 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 reserve requirements that respond to credit growth have desirable stabilization properties. We differ from these papers by considering the Ramsey-optimal policy rule and investigating optimal, simple and implementable interest rate rules that augment domestic or external financial variables in an open economy framework.

Glocker and Towbin (2012) investigate the interaction of alternative monetary policy rules and reserve requirements within a model of financial accelerator in which firms borrow either only from domestic depositors or foreign investors. Medina and Roldós (2014) focus on the effects of alternative parameterized monetary and macroprudential policy rules in an open economy 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. Akinci and Queralto (2014) consider occasionally binding leverage constraints faced by banks that can also issue new equity within a small open economy model. They show that macroprudential taxes and subsidies are effective in lowering the probability of financial crises and increase welfare. However, they abstract from nominal rigidities and the role of monetary policy in relation to financial stability in EMEs. Kolasa and Lombardo (2014) study optimal monetary policy in a two-country DSGE model of the euro area with financial frictions as in 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.

In a closely related paper, Aoki et al. (2016) consider monetary and financial policies in EMEs using a small open economy New Keynesian setup with banks that are subject to currency risk. They model financial policies as net worth subsidies, which are financed by taxes on risky assets or foreign currency borrowing and show that there are significant gains from combining such measures with monetary policy. Our paper generalizes their finding that from a welfare maximizing point of view; interest rate policy displays a stronger anti-inflationary stance when either it is augmented with a financial stabilization objective or accompanied by an additional financial stabilization tool such as reserve requirements. This finding hinges on the property that all else equal, stronger anti-inflationary stance of interest rate policy hurts bank balance sheets as it increases the cost of funds for banks. Our paper differs from the work of Aoki et al. (2016) in three main ways. First, we model asymmetric financial frictions between domestic and foreign borrowing of banks differently. Second, and most importantly, our paper analyzes optimal Ramsey policy and optimized augmented interest rate rules rather than comparing parameterized alternative policy rules. Third, financial policies in our paper include LATW-type Taylor rules and reserve requirements instead of taxes on foreign debt or risky assets.

Under certain cases, optimal interest rate policy in our work calls for a positive response to exchange rate depreciations. This places our paper within the strand of literature surveyed by Engel (2014) which makes a case for targeting currency mismatches in order to ease financial conditions faced by borrowers (in our case banks). Finally, our analysis also sheds light on the discussions regarding the monetary trilemma and the associated challenges that the EME monetary policymakers face as discussed by Obstfeld (2015) and Rey (2015).

This paper contributes to the literature surveyed above in four main respects. First, in a small open economy setup, we investigate the optimality of responding to developments in domestic financial conditions as well as fluctuations in the exchange rate that are linked to capital flows which are highly relevant for EMEs. Second, we study the role of a banking sector which can raise both domestic and foreign funds in the transmission of augmented interest rate and reserve requirements policies. Third, we derive analytically the intratemporal and intertemporal wedges in the model economy, and characterize the optimal monetary policy rule by solving the Ramsey planner's problem. Finally, we construct optimal and simple augmented interest rate policy rules as well as an optimal policy mix of a conventional Taylor rule and a macroprudential reserve requirements 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 it 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.[5] The top-left panel of the figure illustrates that the sharp reversal of capital inflows to EMEs is accompanied by a roughly 400 basis points increase in the country borrowing premiums (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 ratio (illustrated in the bottom-middle panel) displayed a depreciation and a reversal 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 domestic deposits and disproportionately more reduction in foreign borrowing of banks 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.

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-

[5] 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.

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 the realized severity of the financial crisis. With the intention of mitigating the crisis, EME central banks first raised policy rates to curb accelerating capital outflows in the initial phase, and then gradually eased their policy stances (of about 4 percentage points in 6 quarters) thanks 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 it when there was a sharp upward reversal in capital flows in the aftermath of the crisis.[6]

All in all, it is plausible to argue that 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. 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, non-financial firms, capital producers, and a government. There is a single tradable consumption good which is both produced at home and imported (exported) from (to) the rest of the world. Intermediate goods producers use capital and labor and determine the nominal price of their good in a monopolistically competitive market subject to menu costs as in Rotemberg (1982). Final goods producers on the other hand, repackage the domestically produced and imported intermediate goods in a competitive market in which the prices of aggregated home and foreign goods are determined. Home goods are consumed by workers and capital goods producers, and are exported to the rest of the world. Similarly, foreign goods are consumed by workers and are used by capital goods producers.

Households are composed of worker and banker members who pool their consumption together. Workers earn wages and profit income, save in domestic currency denominated, risk-free bank deposits and derive utility from consumption, leisure and holding money balances. Different from standard open economy models, we assume that workers do not trade international financial assets, since banker members of households carry out the balance of payments operations of this economy by borrowing from abroad.

Intermediate goods producers cannot access to household savings and instead finance their capital expenditures by selling equity claims to bankers. After financing their capital expenditures,

[6] 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.

they buy capital from capital producers who use home and foreign investment goods as inputs, repair the worn out capital and produce new capital.

Financial frictions define bankers as the key agents 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. With their debt and equity, bankers fund their assets that come in the form of firm securities. Finally, the consolidated government makes an exogeneous stream of spending and determines short-term interest rate as well as reserve requirements policy.

The benchmark monetary policy regime is a Taylor rule that aims to stabilize 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 or external financial stability objectives. In addition, we analyze the use of reserve requirements that countercyclically respond to credit spreads over the cost of non-core bank borrowing. Unless otherwise stated, variables denoted by upper (lower) case letters 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 Online Appendix A for detailed descriptions of the optimization problems of workers, firms, capital producers and bankers as well as the definition of the competitive equilibrium.

3.1 Prices

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 charge 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 Online Appendix A.5, 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 from a moral hazard problem between bankers and their funders, leading 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 non-negative 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 an additional 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,

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

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 (1) by the aggregate price index P_t and re-arrange terms to obtain banker j's balance sheet in real terms. Those manipulations imply

$$q_t l_{jt} = b_{jt+1}(1 - rr_t) + b^*_{jt+1}(1 - rr_t) + n_{jt}, \tag{2}$$

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 currency 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 (loans and reserves) and the cost of debt. Therefore we have,

$$n_{jt+1} = R_{kt+1} q_t l_{jt} + rr_t(b_{jt+1} + b^*_{jt+1}) - R_{t+1} b_{jt+1} - R^*_{t+1} b^*_{jt+1}, \tag{3}$$

where R_{kt+1} denotes the state-contingent gross real return earned on the purchased claims issued by the production firms. R_{t+1} is the gross real risk-free deposit rate offered to domestic workers, and R^*_{t+1} is the gross country borrowing rate of foreign debt, denominated in real domestic currency units. The gross real interest rates, R_{t+1} and R^*_{t+1}, are defined as follows,

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

$$R^*_{t+1} = \left\{ \Psi_t (1 + r^*_{nt}) \frac{S_{t+1}}{S_t} \frac{P_t}{P_{t+1}} \right\} \quad \forall t, \tag{4}$$

where r_n denotes the net nominal deposit rate, which is equal to the policy rate set by the central bank, 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.[7] 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 Gaussian innovations ϵ^{Ψ}_{t+1}. Introducing ψ_t enables us to study the domestic business cycle responses to exogenous cycles in capital flows. In order to capture the impact of the U.S. 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 (2), substituting in equation (3), and re-arranging terms imply that bank's net worth evolves as,

$$n_{jt+1} = \left[R_{kt+1} - \hat{R}_{t+1} \right] q_t l_{jt} + \left[R_{t+1} - R^*_{t+1} \right] b^*_{jt+1} + \hat{R}_{t+1} n_{jt}, \tag{5}$$

with $\hat{R}_{t+1} = \frac{R_{t+1} - rr_t}{1 - rr_t}$ representing the required 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 as foreign debt is cheaper in expected terms due to asymmetric financial frictions. 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

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

[7] 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).

where $\Lambda_{t,t+i+1} = \beta^{i+1}\left[\frac{U_c(t+i+1)}{U_c(t)}\right]$ 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 of bankers, 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.

3.2.2 Net worth maximization

Bankers maximize 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,

$$V_{jt} = \max_{l_{jt}, b^*_{jt+1}} E_t\Big\{\Lambda_{t,t+1}[(1-\theta)n_{jt+1} + \theta V_{jt+1}]\Big\}. \tag{6}$$

For a non-negative 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 renege on their liabilities and divert λ fraction of their total divertable assets, where such assets constitute total loans 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,

$$V_{jt} \geq \lambda\Big(q_t l_{jt} - \omega_l b_{jt+1}\Big), \tag{7}$$

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. In equilibrium, bankers never divert (and default on) funds and accordingly adjust their demand for external finance to meet the incentive compatibility constraint in each period.

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 (see Section 4.3 for further details.)

Our methodological approach is to 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 (7) 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 assets 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,

$$V_{jt} = \nu_t^l q_t l_{jt} + \nu_t^* b_{jt+1}^* + \nu_t n_{jt}. \tag{8}$$

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

$$q_t l_{jt} - \omega_l b_{jt+1} = \frac{\nu_t - \frac{\nu_t^*}{1-rr_t}}{\lambda - \zeta_t} n_{jt} = \kappa_{jt} n_{jt}, \tag{9}$$

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 (8) to verify our linear conjecture on bankers' value and using equation (5), we find that ν_t^l, ν_t and ν_t^* should consecutively satisfy,

$$\nu_t^l = E_t\Big\{\Xi_{t,t+1}\Big[R_{kt+1} - \hat{R}_{t+1}\Big]\Big\}, \tag{10}$$

$$\nu_t = E_t\Big\{\Xi_{t,t+1}\hat{R}_{t+1}\Big\}, \tag{11}$$

$$\nu_t^* = E_t\Big\{\Xi_{t,t+1}\left[R_{t+1} - R_{t+1}^*\right]\Big\}, \tag{12}$$

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 (10) 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 (11) shows that marginal value of net worth should be equal to the expected discounted opportunity cost of domestic funds, and lastly, equation (12) 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.13) in Online Appendix A.2 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 none 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 (12), 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 (9) over j and obtain the following aggregate relationship:

$$q_t l_t - \omega_l b_{t+1} = \kappa_t n_t, \tag{13}$$

where $q_t l_t$, b_{t+1}, and n_t represent aggregate levels of bank assets, domestic deposits, and net worth, respectively. Equation (13) shows that the aggregate credit net of non-divertable domestic deposits can only be up to an endogenous multiple of the 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 (13) into the net worth evolution equation (5), 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 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.[8] We consider Taylor-type interest rate rules that respond to deviations of an augmenting variable f_t in addition to inflation and output from their steady state levels,

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

$$\log\left(\frac{1+r_{nt}}{1+\overline{r_n}}\right) = \rho_{r_n}\log\left(\frac{1+r_{nt-1}}{1+\overline{r_n}}\right) + (1-\rho_{r_n})\left[\varphi_\pi \log\left(\frac{1+\pi_t}{1+\overline{\pi}}\right) + \varphi_y \log\left(\frac{y_t}{\overline{y}}\right) + \varphi_f \log\left(\frac{f_t}{\overline{f}}\right)\right], \tag{14}$$

where r_{nt} is the short-term policy rate, π_t is the net CPI inflation rate, y_t is home output, variables with bars denote respective steady state values that are targeted by the central bank, and f_t corresponds to the level of bank credit, asset prices, real exchange rate, credit spreads or the U.S. interest rate in alternative specifications. In each specification, φ_f measures the responsiveness of the interest rate rule to the augmenting 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 in combination with conventional monetary policy to reduce the procyclicality of the financial system. In particular, we assume that required reserves ratios for both domestic and foreign deposits respond to deviations of the loan-foreign deposits spread from its steady state value. That is,

$$\log\left(\frac{1+rr_t}{1+\overline{rr}}\right) = \rho_{rr}\log\left(\frac{1+rr_{t-1}}{1+\overline{rr}}\right) + (1-\rho_{rr})\left[\varphi_{rr}\log\left(\frac{R_{kt+1}-R^*_{t+1}}{\overline{R_k - R^*}}\right)\right], \tag{15}$$

with $0 < |\rho_{rr}| < 1$ and φ_{rr} is a finite real number. Notice that credit spreads are countercyclical, since the magnitude of intermediated funds decline in response to adverse shocks. Therefore, one might conjecture that the reserve requirement rule would support the balance sheet of bankers in bad times by reducing the effective tax on domestic and foreign liabilities as in Glocker and Towbin (2012) and Mimir et al. (2013), implying a negative value for the optimized response coefficient φ_{rr}.

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 in period t. As discussed by Schmitt-Grohé and Uribe (2007), the inclusion of cash balances would not alter the optimality of interest rate policy rules.

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

$$\ln(g^H_{t+1}) = (1-\rho^{g^H})\ln \bar{g}^H + \rho^{g^H}\ln(g^H_t) + \epsilon^{g^H}_{t+1},$$

where $\epsilon^{g^H}_{t+1}$ 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 Online Appendix A.

4 Quantitative analysis

This section analyzes quantitative predictions of the model by studying the results of numerical simulations of an economy calibrated to a typical emerging market, 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 parameterization 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 (CBRT, hereafter) 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 annualized real deposit rate of 7.48% observed in Turkey over the sample period. 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 $\gamma = 0.5$. 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 assets that can be diverted $\lambda = 0.65$, the proportional transfer to newly entering bankers $\epsilon^b = 0.00195$, and the fraction of domestic deposits that cannot be diverted $\omega_l = 0.81$ are jointly calibrated to match the following three 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 bank leverage of 7.94, and the share of foreign funds in total bank liabilities, which is around 40% for commercial banks in Turkey. We also pick the survival probability of bankers θ as 0.925, which implies an average survival duration of nearly three and a half years for bankers.

Regarding the technology parameters, the share of capital in the production function $\alpha = 0.4$ is set to match the share of labor 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 normalized 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 is calibrated to $\psi = 5$, which implies a long-run elasticity of the price of capital with respect to the investment-to-capital ratio of 0.125, which is 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 estimate a standard Taylor rule for the Turkish economy to approximate the monetary policy implemented in Turkey. In the estimation, we use the CBRT's average funding rate, which is the effective policy rate, over the period 2003-2014. The resulting estimated interest rate rule persistence is $\rho_{r_n} = 0.89$ and the inflation rate response is $\varphi_\pi = 2.17$. The estimated response coefficient of output turned out not to be statistically different from zero. We then use these estimated parameters to calibrate the standard Taylor rule parameters in the model of the decentralized economy. Moreover, the long-run value of required reserves ratio $\bar{rr} = 0.09$ is set to its time series average level 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 U.S. 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. We use J.P. Morgan's EMBI Global Turkey data in the estimation of country risk premium 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 interest rate is set to 64 basis points to match quarterly interest rate in the U.S. for the period 1996-2014 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 GDP of the European Union, which are 0.31 and 0.48% respectively.[9] 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 decentralized model economy operating under the standard Taylor calibrated to the Turkish data 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 the 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 rates 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 generate the relative volatilities of model variables of interest that are mostly inline with the data.

When the 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 procyclical. 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.

Table 4 reports asymptotic variance decomposition of main model variables under domestic 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, the 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 drive a negligible part of fluctuations in model variables with the only exception of the spending shocks' declining effect on output as the horizon gets longer. These

[9] We use the GDP of the European Union (EU) for the calibration of export demand shocks because it is the main trading partner of Turkey with the largest share in the data over the past decade. The average share of the EU in Turkey's exports is 46% over the period from 2007 to 2016. The trade data are taken from the Turkish Statistical Agency (www.tuik.gov.tr).

patterns are also confirmed for one-quarter and one-year ahead conditional variance decompositions (reported in Table B.1 in Online Appendix B). Notice that the variance decomposition analysis is sensitive to the calibrated size of individual shocks. However, it is informative in order to sharpen our focus on the importance of external shocks.

We further assess the quantitative performance of the calibrated model by analyzing 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 EMEs 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 calibrated inflation targeting rule. The initial impact of the country borrowing premium shock is reflected on the real exchange rate in the direction of a sharp 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 pass-through from increased nominal exchange rate 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, (13) 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 loan-foreign deposits and -domestic deposits spreads, respectively) reflect the tightened financial conditions in the model. The decline in output and increase in inflation eventually calls for about 55 annualized 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 EMEs fell into in the aftermath of the recent global financial crisis.

For brevity, we do not explain in detail here the impulse responses of model variables under the productivity, government spending, the U.S. interest rate and export demand shocks. Readers may refer to Online Appendix B to see the impulse response functions of model variables under each shock. However, we would like to note that most of the endogenous variables and the policy instruments respond to each shock in a fairly standard way, in line with the previous literature.

4.3 Asymmetric financial frictions and the UIP

Under certain conditions, the UIP may not hold so that the exchange rate dynamics do not align with interest rate differentials.[10] In our framework, the agency problem between bankers and foreign lenders are asymmetrically more intense compared to that between bankers and domestic depositors,

[10] See the Handbook chapter by Engel (2015) which lists a vast survey of contributions that consider departures from the UIP.

which creates a wedge between the real costs of domestic and foreign debt.[11] The analysis in Online Appendix A.2 delivers this result analytically by observing that in equilibrium, the excess value of borrowing from abroad ν^* should be positive so that domestic depositors charge more compared to international lenders. In this regard, asymmetric financial frictions in a small open economy provide a microfoundation to stronger exchange rates than can be explained by the expected real interest rate differentials under the UIP as elaborated by Engel (2016).

Figure 3 provides a graphical illustration of the workings of the asymmetry in financial frictions. We plot the external funds market on the left panel of the figure in which there is 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 compatibility constraint binds and imposes a leverage constraint on banks. Therefore, the supply curve of foreign debt makes a kink and becomes 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. The supply curve in this market originates from the consumption-savings margin of households and 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 demand schedule shifts to the right, as diverted assets constitute a smaller portion of total assets, making banks able to borrow more. This results in a movement along the workers' deposits supply curve until R takes an intermediate value between the loan rate and foreign borrowing rate $R_k > R > R^*$. Lastly, when $\omega_l = 1$, the domestic deposits market becomes frictionless and the deposit 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 $b_{\omega=1}$.

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 of 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 (7) in matching the excess cost of domestic debt.[12] 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,

[11] Broner et al. (2014) show that when domestic borrowers discriminate against foreign creditors, a positive spread between domestic and foreign interest rates emerges. Fornaro (2015) obtains a similar result in a setup with collateral constraints by assuming that domestic borrowing does not require collateral.

[12] 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.

we find that the volatility of macroeconomic and financial variables, as well as monetary variables gets smaller as the fraction of non-divertable 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.[13] 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

$$\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = 1 \tag{16}$$

The model counterpart of the consumption-leisure margin is found by combining and manipulating equations (A.2), (A.8), (A.22), (A.23) and (A.28) listed in Online Appendix A, which yields

$$\frac{MRS_t}{MPL_t} = \frac{-U_h(t)/U_c(t)}{W_t/P_t} = \frac{(p_t^H + \eta_t)}{X}, \tag{17}$$

with the expressions,

$$p_t^H = \left[\frac{\omega}{1-(1-\omega)(p_t^F)^{(1-\gamma)}}\right]^{-\frac{1}{(1-\gamma)}}, \tag{18}$$

$$p_t^F = Xs_t + \frac{\varphi^F}{\epsilon-1}\frac{\pi_t^F(\pi_t^F-1)}{y_t^F} - \frac{\varphi^F}{\epsilon-1}E_t\left\{\Lambda_{t,t+1}\frac{\pi_{t+1}^F(\pi_{t+1}^F-1)}{y_t^F}\right\}, \tag{19}$$

$$X = \frac{\epsilon}{\epsilon-1}, \tag{20}$$

$$\eta_t = \frac{\varphi^H}{\epsilon-1}\frac{\pi_t^H(\pi_t^H-1)}{y_t^H} - \frac{\varphi^H}{\epsilon-1}E_t\left\{\Lambda_{t,t+1}\frac{\pi_{t+1}^H(\pi_{t+1}^H-1)}{y_t^H}\right\}. \tag{21}$$

The first expression (18), 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

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

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 stabilize the fluctuations in p_t^H to smooth this wedge, which creates a misallocation between consumption demand and labor supply.

The second expression (19), 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 fluctuations in the real exchange rate (which are equivalent to endogenous cost-push shocks as discussed by Monacelli (2005)) to stabilize 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.

The final expression (21), 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 stabilizing 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

$$\beta E_t R_{kt+1} \left[\frac{U_c(t+1)}{U_c(t)} \right] = 1. \tag{22}$$

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 (4), (A.12), (A.13), and (10) under no reserve requirements $rr_t = 0$, implies

$$\beta E_t R_{kt+1} \left[\frac{U_c(t+1)}{U_c(t)} \right] = (1 + \tau^1_{t+1} - \tau^2_{t+1}) > 1, \tag{23}$$

with the expressions

$$\tau^1_{t+1} = \frac{\left[cov[\Xi_{t,t+1}, (R_{kt+1} - R_{t+1})] + cov[\Xi_{t,t+1}, (R_{t+1} - R^*_{t+1})] - \lambda\frac{\mu_t}{(1+\mu_t)}\right]}{E_t[\Xi_{t,t+1}]} > 0, \tag{24}$$

$$\tau^2_{t+1} = E_t[R^*_{nt+1}]E_t\left[\Psi_{t+1}\frac{S_{t+2}}{S_{t+1}}\frac{P_{t+1}}{P_{t+2}}\right] + cov\left\{R^*_{nt+1}, \left[\Psi_{t+1}\frac{S_{t+2}}{S_{t+1}}\frac{P_{t+1}}{P_{t+2}}\right]\right\} < 0, \tag{25}$$

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. In particular, the first term in τ^1_{t+1} is the risk premium associated with the credit spread over the domestic cost of borrowing, the second term is the risk premium associated with the funding spread, and the last term is the liquidity premium associated with binding leverage constraints of banks. When credit frictions are completely eliminated $\lambda = 0$, both covariances and the last term in the numerator of τ^1_{t+1} become zero.[14] The Ramsey planner has an incentive to contain the fluctuations in credit spreads over both domestic and foreign deposits 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 second term in this wedge is the risk premium associated with the U.S. interest rate and the real exchange rate movements. It 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 the 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. This channel is typically referred to as the financial channel by which exchange rate depreciation hurts the balance sheets of borrowers who suffer from liability dollarization, leading them to curb domestic demand as discussed by Kearns and Patel (2016).

Overall, in an open economy with financial frictions, financial stability requires an optimal balance between stabilizing 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 stabilizing credit spreads by reducing the policy rate and resort to some degree of exchange rate stabilization by increasing the policy rate in response to adverse external shocks.

[14] 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.

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 rise in the inflation rate 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 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 Long-run and cyclical properties of the decentralized and Ramsey economies

We assume that the Ramsey planner chooses state-contingent allocations, prices and policies to maximize lifetime utility of households, taking the private sector equilibrium conditions (except the monetary policy rule) and exogenous stochastic processes $\{A_t, g_t^H, \psi_t, r_{nt}^*, y_t^*\}_{t=0}^{\infty}$ as given. She uses the short-term nominal interest rates as her 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.

We compare the non-stochastic steady states of decentralized and Ramsey economies in Table 5 to understand the sources of long-run welfare costs. Most strikingly, the Ramsey planner reduces the exchange rate risk that bankers are exposed to by significantly lowering the ratio of foreign debt to total liabilities. This relaxes financial constraints of banks since domestic debt is diverted less. Consequently, the long run levels of bank leverage, credit, investment, consumption and output are higher in the Ramsey economy. In this regard, our work places in the strand of literature surveyed by Engel (2014) that calls for a direct targeting of currency for financial stability goals as well as its indirect impact on inflation gap. Finally, the Ramsey steady state features a negative inflation rate of -0.52% per annum compared to the decentralized economy, which is calibrated to an inflation rate of zero.[15] This results in a lower steady state markup and larger real money balances in the Ramsey economy with respect to the decentralized economy. Resembling the findings of Schmitt-Grohé and Uribe (2007), although the second-best economy exhibits deflation, we observe that the Ramsey steady state emerges closer to eliminating price rigidity, rather than driving nominal interest rates down to zero, since the Friedman rule suggests a deflation rate of 6.97% per annum.

We then analyze the dynamics of the decentralized and Ramsey economies in order to gauge the source of short-run welfare costs. The intratemporal and intertemporal wedges in the model fluctuate due to movements in the credit spreads over domestic and foreign deposits, the real exchange rate, and the aggregate markup. Table 6 displays the relative volatilities of real, financial, external and monetary variables in the decentralized and the planner's economies. The results suggest that the planner is able to smooth the fluctuations in variables that are related to the distortionary wedges. In particular, she reduces the relative volatilities of the CPI inflation, aggregate markup, and the

[15] Schmitt-Grohé and Uribe (2007) finds a Ramsey steady-state inflation of -0.55% per annum, which is fairly close to our case.

real exchange rate by 68%, 36%, and 63% compared to the decentralized economy, respectively. Moreover, the planner is able to reduce the relative volatilities of lending spreads over domestic and foreign deposits by 10% and 62% relative to the decentralized 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.

4.6 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 emphasize 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

$$V_0^R = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^R, h_t^R, m_t^R), \tag{26}$$

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

$$V_0^A = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^A, h_t^A, m_t^A), \tag{27}$$

where 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 changes that compensate 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. 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

$$V_0^A = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1-\lambda^c)c_t^R, h_t^R, m_t^R\right). \tag{28}$$

Hence, a positive value for λ^c implies that the Ramsey policy achieves a higher welfare relative to the particular policy regime.

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

$$V_{0,t} = U(c_t, h_t, m_t) + \beta E_t V_{0,t+1}. \tag{29}$$

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

$$V_{0,t} = \overline{V_0} + \frac{1}{2}\Delta(V_0), \tag{30}$$

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 (30) is an approximation to the welfare $V_{0,t}$, capturing the fluctuations of endogenous variables at the stochastic steady state.

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 $\rho_{r_n} \in [0, 0.995]$, $\varphi_\pi \in [1.001, 3]$, $\varphi_y \in [0, 3]$, $\varphi_f \in [-3, 3]$ for $f \in \{credit, q, spr, s, R_n^*\}$, $\rho_{rr} \in [0, 0.995]$, and $\varphi_{rr} \in [-3, 3]$. Each interval includes 15 evenly distributed grid points except for the intervals for the response coefficients of external and financial variables as well as the interval for the response coefficient of the reserve requirement rule to credit spreads. Those intervals include 30 evenly distributed grid points since we span both positive and negative territories for their response coefficients. 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. Following Schmitt-Grohé and Uribe (2007), 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. We search for optimal set of policy coefficients for each shock separately and under simultaneous 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 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. Section 4.8 covers optimal reserve requirement policies in addition to the interest rate policy. In the interest of space, we left the discussion of optimal policy responses to domestic shocks in isolation to the Online Appendix C.

4.7.1 External shocks

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

Optimized Taylor rules with and without smoothing feature no response to output variations under external shocks with the exception of the rule without smoothing under export demand shocks. This confirms the results discussed by Schmitt-Grohé and Uribe (2007) that positive response to output is detrimental to welfare. The levels of the inflation coefficients on the other hand, are at their lowest levels. This finding resembles the discussion of Aoki et al. (2016) that in response to adverse external shocks (which already raise the cost of foreign debt) strong anti-inflationary stance of interest rate policy would hurt bank balance sheets even more by increasing the cost of domestic deposits. Since these policy rules do not target any financial stabilization objective, the volatilities of inflation, credit spreads and the real exchange rate under these two optimized rules are much higher than those under the Ramsey policy, which justifies relatively higher welfare costs associated with these rules.

Table 7 indicates that under country risk premium shocks (which is the most relevant shock as discussed in Section 4.2 for EMEs), the RER augmented rule which displays an aggressive and positive response to fluctuations in the real exchange rate and only mild responses to inflation and output variations implies the largest welfare among all optimized *augmented* Taylor rules (the top panel). This optimal simple policy implies a welfare loss of 0.0015% vis-à-vis the Ramsey policy. This suggests that considering the financial channel for an EME central bank is crucial when domestic borrowers face currency mismatch. For this reason, the real exchange rate volatility is smaller under this rule, than those implied by the other optimized Taylor rules. Since central bank is already fighting the pass-through aggressively, it does not deem useful to take a strong anti-inflationary stance. This is evident from the small degree of inflation volatility achieved under this rule. This finding is also linked to the insights discussed by Monacelli (2005) and Monacelli (2013) that under incomplete exchange rate pass-through, fluctuations in the exchange rate operate as endogenous cost-push shocks (see equation (19)) and optimal policy deviates from maintaining price stability towards exchange rate stability.

Lining up next is the optimized simple rule that augments asset prices. Our results confirm the findings of Faia and Monacelli (2007) that optimal policy calls for a negative response to asset prices together with a moderate anti-inflationary stance (with respective coefficients of -1.07 and 1.43). The welfare cost implied by this policy rule is 0.0021% against the Ramsey policy. While the absolute magnitude of the asset prices coefficient of optimal interest policy depends on the amplification created by financial frictions, the intuition behind its negative sign primarily hinges on the existence of investment adjustment costs. As discussed in the Online Appendix A.3, capital producers buy the depreciated capital from intermediate goods firms and incur an investment adjustment cost that is scaled up by the asset price q. This causes Tobin's-q to operate as a procyclical tax on investment and limits the expansion in investment to be smaller than the efficient magnitude in response to favorable shocks. Therefore, an *easing* in the policy rate boosts investment demand of intermediate goods producers and gets the dynamics of investment closer to the Ramsey allocation.[16] Stronger investment demand stimulated by the asset price-augmented interest rate policy rises equilibrium asset prices more than the case with no policy response. Indeed, Table 7 and Figure 4 illustrate that both the Ramsey policy and the asset price-augmented interest rate rule suggest a sharp increase in the volatility of asset prices.[17] Finally, the surge in demand by accommodative monetary policy calls for an increase in the inflation rate under this rule compared to the optimized standard Taylor rule (with respective coefficients of 1.43 and 1.001). Therefore, using an augmented policy rule with financial stability considerations allows the central bank to take a stronger anti-inflationary stance.

We find that the loan-deposits spread-augmented Taylor rule achieves a level of welfare very close to that of the asset price-augmented Taylor rule (the implied cost is 0.0026%). Interest rate policy features a LATW role in this case because credit spreads are countercyclical and the optimized augmented rule calls for an easing in bad times. Consequently, this rule justifies a higher inflation response coefficient than the optimized standard Taylor rule. Under this rule, the volatility of credit spreads is even lower than that in the Ramsey policy whereas the volatilities of the inflation rate and the real exchange rate are much higher.

Our findings also show that optimized credit-augmented interest rate rules feature a negative response to the level of credit. This result is mainly due to the fact that the decentralized economy in the model features underborrowing rather than overborrowing compared to the Ramsey planner's economy as in Benigno et al. (2013). These authors show that introducing production might transform the *overborrowing* observed in endowment economies to *underborrowing*, which in turn

[16] Our results seem to contrast with the findings of Gambacorta and Signoretti (2014) who find that an interest rate policy rule that is augmented with a positive response to asset prices performs better than a standard Taylor rule. However, they do not consider the negative range for the asset price response coefficient while searching for policy rules that minimize loss functions, which depend on inflation and output variability. Indeed, they obtain the minimum loss levels when this coefficient hits its lower bound of zero.

[17] This insight is akin to the Ramsey planner's optimal policy of increasing volatility in labor income tax rate under the existence of labor market distortions in order to bring fluctuations in employment closer to the efficient fluctuations. For a detailed elaboration, see Arseneau and Chugh (2012).

suggests that macroprudential taxes that are intended to reduce borrowing are detrimental to welfare. Our steady state comparisons that are reported in Table 5 confirm this underborrowing result. The table shows that the planner's economy features a higher leverage compared to the decentralized economy, which is achieved by collecting more deposits (higher borrowing of banking sector). By having a higher leverage, the planner extends more credit to non-financial firms, leading to more capital accumulation, higher investment and thus higher output in the economy. In this environment, optimized credit-augmented monetary policy rule reduces the policy rate in response to positive deviations of credit from its steady state level over the business cycle. This further increases deposit issuance and credit extension, stimulates investment more and finally increases output. Reducing policy rate in response to higher credit brings allocations in the decentralized economy closer to those in the second best economy (i.e. the Ramsey planner's economy). This finding is consistent with that discussed by Benigno et al. (2013) since the macroprudential tax on borrowing in their paper is akin to a policy rate hike in our model, which increases the cost of borrowing for banks. While the optimized credit-augmented interest rules achieve a higher level of welfare compared to the optimized standard Taylor rules, their implied welfare cost is larger than those of the optimized RER- or credit spread-augmented interest rate rules.

Optimized augmented Taylor rules under the U.S. interest and 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 optimized 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 deterioration in 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 *qualitatively* 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 an orthogonalized 100 basis points increase in the U.S. policy rate, we find that the EME central bank should raise its policy rate by 257 basis points. However, the welfare cost implied by this policy rules is an order of magnitude larger than those implied by the credit spread and the RER-augmented Taylor rules. On the other hand, when compared to the optimized standard Taylor rules, the welfare cost implied by this policy is much smaller (0.0096% vs. 0.3014%).

4.7.2 All shocks

Table 8 displays the response coefficients of optimized conventional and augmented Taylor rules, the absolute volatilities of key macroeconomic variables under these rules, and the associated consumption-equivalent welfare costs relative to the optimal Ramsey policy under domestic (TFP and government spending) and external shocks hitting the economy simultaneously.

The optimized Taylor rules with and without smoothing still display zero response to output deviations under all shocks. The magnitudes of the inflation response coefficients are at their lower bounds and the optimized standard Taylor rule with smoothing still features a high degree of inertia. Furthermore, these two optimized rules imply much more volatility in the CPI inflation rate and the RER together with much less volatility in asset prices in comparison with the Ramsey policy, which explains relatively higher welfare losses associated with these rules.

The findings associated with the optimized augmented Taylor rules suggest that a strong negative response to asset prices together with an aggressive response to inflation achieves the highest welfare possible. The associated welfare cost vis-à-vis the Ramsey policy is 0.0013%. It appears that the gains are mainly linked to stimulating investment demand as this policy generates more asset price volatility than that implied by the Ramsey policy. What follows the asset price augmenting rule is the optimal rule that negatively responds to the credit spreads with an implied welfare cost of 0.0027%. As in the case of external shocks, the gains associated with this rule depend on the significant reduction in the volatility of credit spreads. Finally, we observe that the RER-augmented Taylor rule implies a welfare cost in the same order of magnitude with the aforementioned policies (0.0093%) and suggests a positive response to fluctuations in the real exchange rate with a mild anti-inflationary stance. We also confirm our previous findings under other external shocks that it is optimal to negatively respond to the level of credit and positively respond to the U.S. interest rates, whereas these policy rules are dominated by the asset price-augmented interest rate policy. Nevertheless, we find that in response to a 100 basis points increase in the U.S. policy rate, the EME policy rate should be raised by 21 basis points (under simultaneous shocks), which is *quantitatively* in line with the empirical findings of Hofmann and Takáts (2015).

4.7.3 Optimal policy rules versus Ramsey-optimal policy

Figure 4 compares the impulses responses to a one standard deviation country risk premium shock under the Ramsey planner's economy (dashed plots) with the selected optimal simple interest rate rules. In particular, we select the optimal real exchange rate-augmented interest rate rule (straight plots) since it produces the smallest welfare cost vis-à-vis the Ramsey-optimal policy and the optimal standard Taylor rule with smoothing (straight plots with asterisks) in order to highlight the departures of *conventional wisdom* from optimality in our setup. We highlight the country risk premium shock due to its strong explanatory power that emerged in the variance decomposition analysis. For brevity, we do not plot the impulse responses to other domestic or external shocks, which are available from the authors upon request.

The planner increases the policy rate by about 250 basis points per annum on impact in response to a 127 basis points annualized increase in the country borrowing premium. Accordingly, both the nominal and real exchange rates depreciate only about 2 percent, which contains the pass-through to CPI inflation via imported goods. 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 decentralized economy (see straight plots in Figure 2). The Ramsey planner also contains inefficient movements in the credit spreads over the cost of foreign debt and ensures that the credit spreads increase by less than 100 basis points in annualized terms. This enables the planner to substantially reduce the reversal in the current account balance. Notice that the second-best equilibrium warrants increased volatility in asset prices and investment compared to the decentralized economy. In that respect, the Ramsey planner trades-off a smoother path of the real exchange rate and credit spreads against a more volatile trajectory for investment and output in order to achieve a more stable path of the CPI inflation rate.

The optimal RER-augmented rule calls for an increase of 30 basis points in the policy rate in annualized terms under the country borrowing premium shock. This results in 3 percent more depreciation in the real exchange rate and 1 percentage point higher increase in the inflation rate compared to the Ramsey-optimal policy. As a result, credit spreads rise more and there is a stronger reversal in the current account balance in comparison to the second-best economy. However, this optimized rule approximates the Ramsey-optimal policy fairly well in terms of bringing fluctuations in the asset price, investment and output closer to efficient fluctuations. Recall that the real exchange rate response coefficient of this optimized rule hits its upper bound of 3 (see the top panel of Figure 7) suggesting that this policy could approximate the Ramsey-optimal policy even better should we allowed the response coefficient to take a larger value.

Since optimal Taylor rule with smoothing exhibits no response to the real exchange rate and displays only a mild response to inflation, it calls for a negligible rise (by about only 2 basis points per annum) in the short-term policy rate when the country risk premium shock hits the economy. While the on-impact depreciation under this rule resembles that implied by the optimal RER-augmented rule, currency exchanges at about a 1 percent more depreciated level under this rule for 12 consecutive quarters. This results in 1.4 percentage point rise in the CPI inflation rate on impact due to the pass-through and underpins the relatively larger welfare loss implied by this rule. Since the tightening in the policy rate is much smaller under this rule, credit spreads rise even less than the Ramsey-optimal policy. Consequently, the dynamics of investment and asset prices implied by this rule deviate substantially from those produced by either the second-best economy or the optimal exchange rate-augmented policy.

4.7.4 Optimal policy rules versus data

Figure 5 illustrates the comparison of trajectories for the optimal simple and implementable short term policy rules with the empirical trajectory of the policy rate determined by the CBRT. In order to obtain the model implied trajectories, we feed in the empirical time series for policy targets into the optimized augmented Taylor rules. We find that a combination of the optimized U.S. interest rate- and credit spread-augmented interest rate rules resembles the actual policy rate fairly well. In particular, the former (the plot with full squares) captures the trend of the empirical series, while the latter (the plot with empty squares) captures its cyclical properties. Recall that the optimal standard Taylor rule (the plot with triangles) is not successful in capturing neither the absolute level, nor the cyclicality of the empirical time series of the short term policy rate.

4.8 Optimal interest rate and reserve requirement policies

Augmenting the interest rate policy with a LATW goal might be cumbersome for a central bank if it aims to simultaneously achieve price and financial stability targets, which imply different trajectories for interest rates in certain cases. To that end, Shin (2013) and Chung et al. (2014) emphasize the usefulness of liability-based policy tools, such as reserve requirements, in meeting financial stability targets alongside conventional monetary policy.[18] In addition, Cordella et al. (2014) provide empirical evidence on the use of reserve requirements as a countercyclical monetary policy tool in developing countries. They emphasize that due to the procyclical behavior of the exchange rate over the business cycle in developing countries, the countercyclical use of interest rates proves to be complicated due its impact on the exchange rate. In this regard, reserve requirements can be useful as a second policy tool in response to capital inflows or outflows.

In this section, we aim to address these issues by operationalizing reserve requirements as a policy rule that tries to smooth out fluctuations in credit spreads over the cost of foreign borrowing together with a typical short-term policy rate. We then examine whether the optimal mix of this time-dependent rule with a conventional Taylor rule can compete with an optimal LATW-type monetary policy rule in maximizing household welfare. The seventh row in each panel of Tables 7 and 8 reports the optimal simple interest rate and reserve requirement rule mix that is pinned down by using a similar methodology to that in the previous section. Specifically, we jointly optimize one persistence coefficient for each policy tool, the inflation and output response coefficients of the interest rate policy, and the credit spread response coefficient of the reserve requirement rule.

Two important results stand out. First, 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, the central bank uses this tool to LATW. Consequently, the welfare costs compared to the Ramsey policy always emerge as strictly smaller than that implied by the optimized simple Taylor rule, which does not LATW. This is because the reserve requirement rule calls for a decline in the effective 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 standard Taylor rule.

[18] Instead of using reserve requirements additionally, one might also consider a single optimal tool, the short-term interest rate, augmenting a few number of financial response variables, simultaneously. Although the practical implementability of such a policy would arguably be cumbersome, we think that such a policy would move in the direction implied by our overall analysis in regards to the augmenting variables that we consider.

Thus, as expected, the results suggest that employing the two rules in response to multiple wedges is better than using only the short-term policy rate, which does not LATW.

Second, under country risk premium shocks, the jointly optimized Taylor and reserve requirement rules attains a smaller welfare cost (0.0006%) than the best optimized augmented interest rate rule, which responds to the real exchange rate (0.0015%). This result derives from the fact that the jointly optimized Taylor and reserve requirement rules reduce the volatility of credit spreads an order of magnitude more compared to the real exchange rate-augmented Taylor rule. In addition, this policy mix performs fairly well under domestic, other external and all shocks. This suggests that should the central bank find it hard to introduce a LATW role for the short term interest policy, it might rely on the use of reserve requirements as an additional tool without foregoing substantial stabilization gains.

5 Conclusion

This paper contributes to the previous literature by investigating the quantitative performances of lean-against-the-wind-type monetary policy rules and reserve requirement policies in mitigating the negative impact of external shocks on macroeconomic or 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 adverse macro-financial feedback loop that EMEs endured during and after the Global Financial Crisis. On the normative side, we take the Ramsey equilibrium as a benchmark and search for optimal, simple and implementable short-term interest rules that aim at minimizing welfare losses against the planner's economy.

Our analysis highlights three main results. First, we find that the optimized augmented monetary policy rules, in particular, the policy rate specifications that respond to the real exchange rate, asset prices and credit spreads in addition to inflation and output gaps outperform the optimized standard Taylor rules under both domestic and external shocks. In addition, the optimized standard Taylor rule displays at best a mild anti-inflationary stance. This finding supports the idea that it might be desirable to deviate from price stability in favor of external or financial stability in small open economies. Second, we show that interest rate policy displays a stronger anti-inflationary stance when financial stability considerations are addressed by monetary policy. Lastly, we find that an optimized policy mix that is comprised of a reserve requirement rule (which responds to credit spreads) and a standard Taylor rule improves upon an optimized standard Taylor rule under both domestic and external shocks.

We abstract 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 reserve requirements in a gradual build-up of macro-financial risks. 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.

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

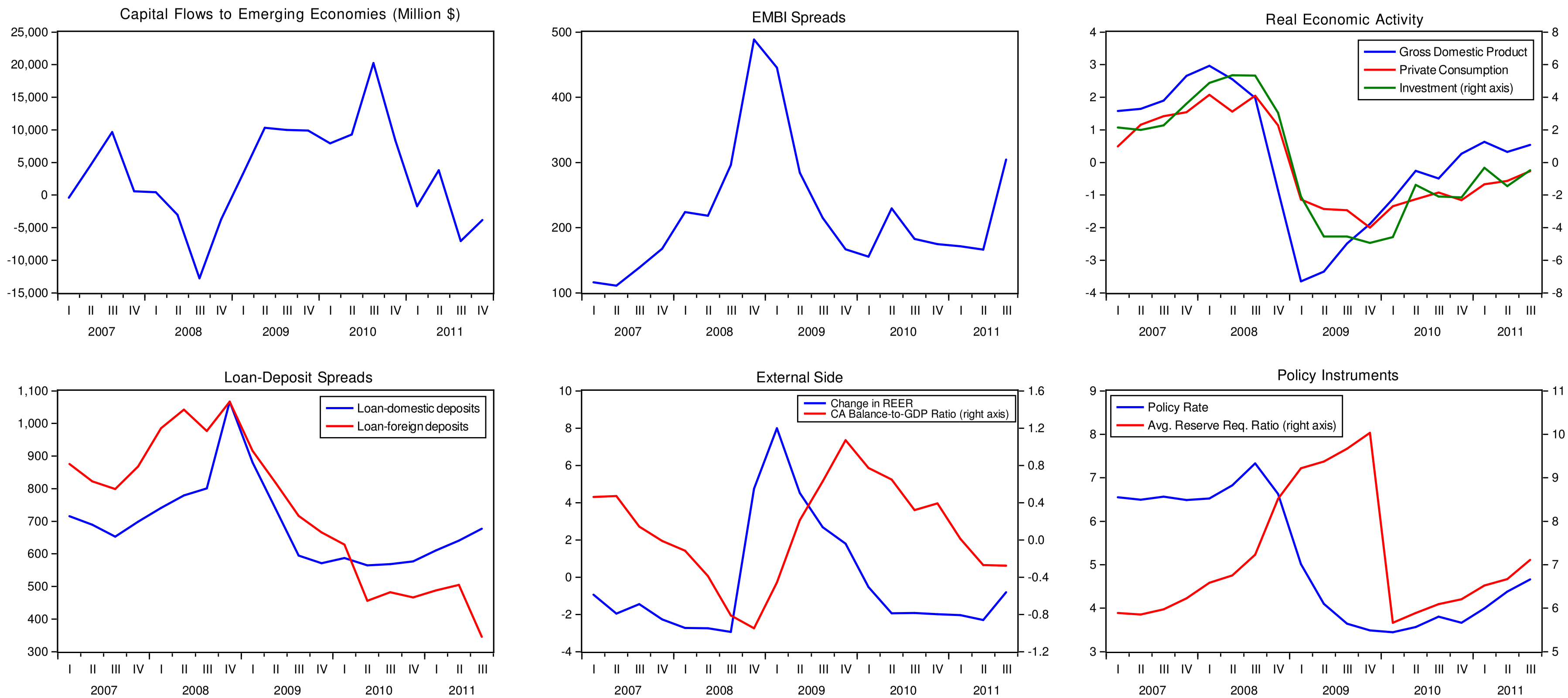

Figure 2: Role of asymmetric frictions in the decentralized economy - Impulse response functions driven by 127 annualized basis points increase in country risk premium

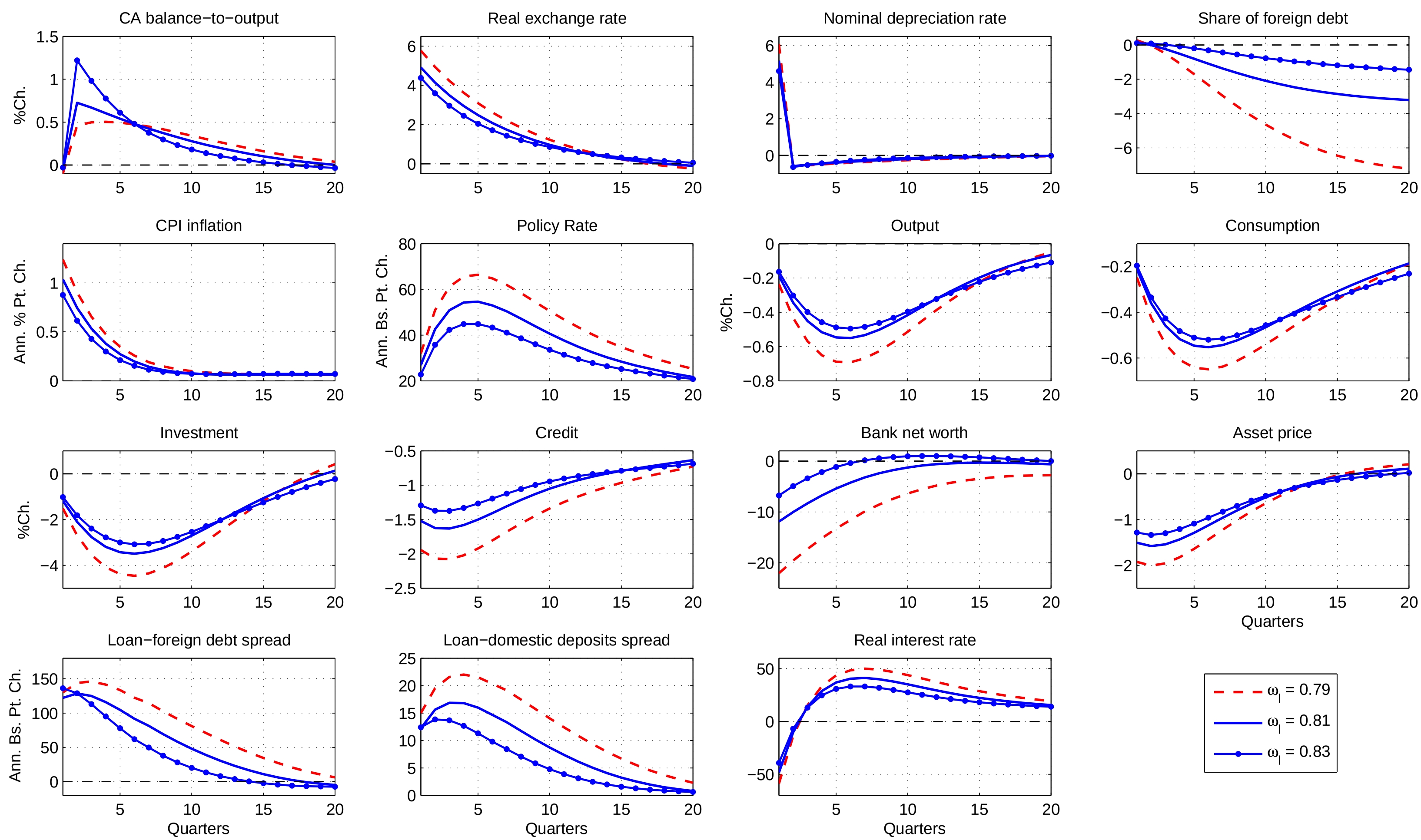

Figure 3: Financial frictions and spreads

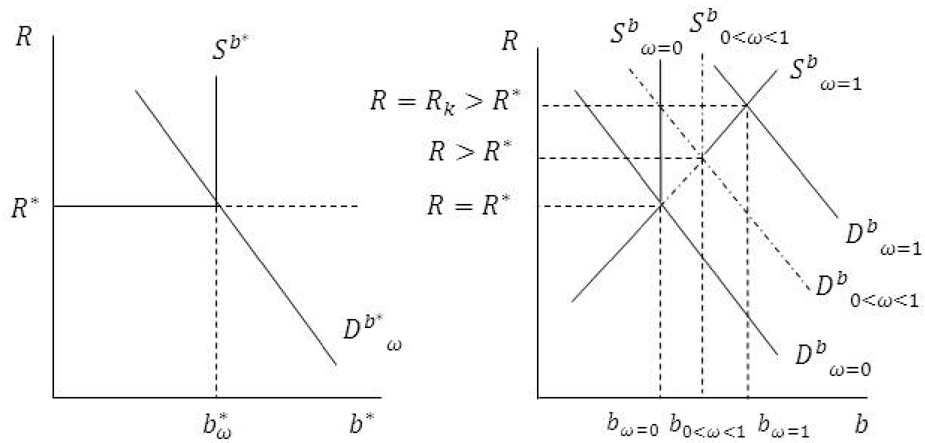

Figure 4: Optimal simple rules versus Ramsey planner under country risk premium shocks

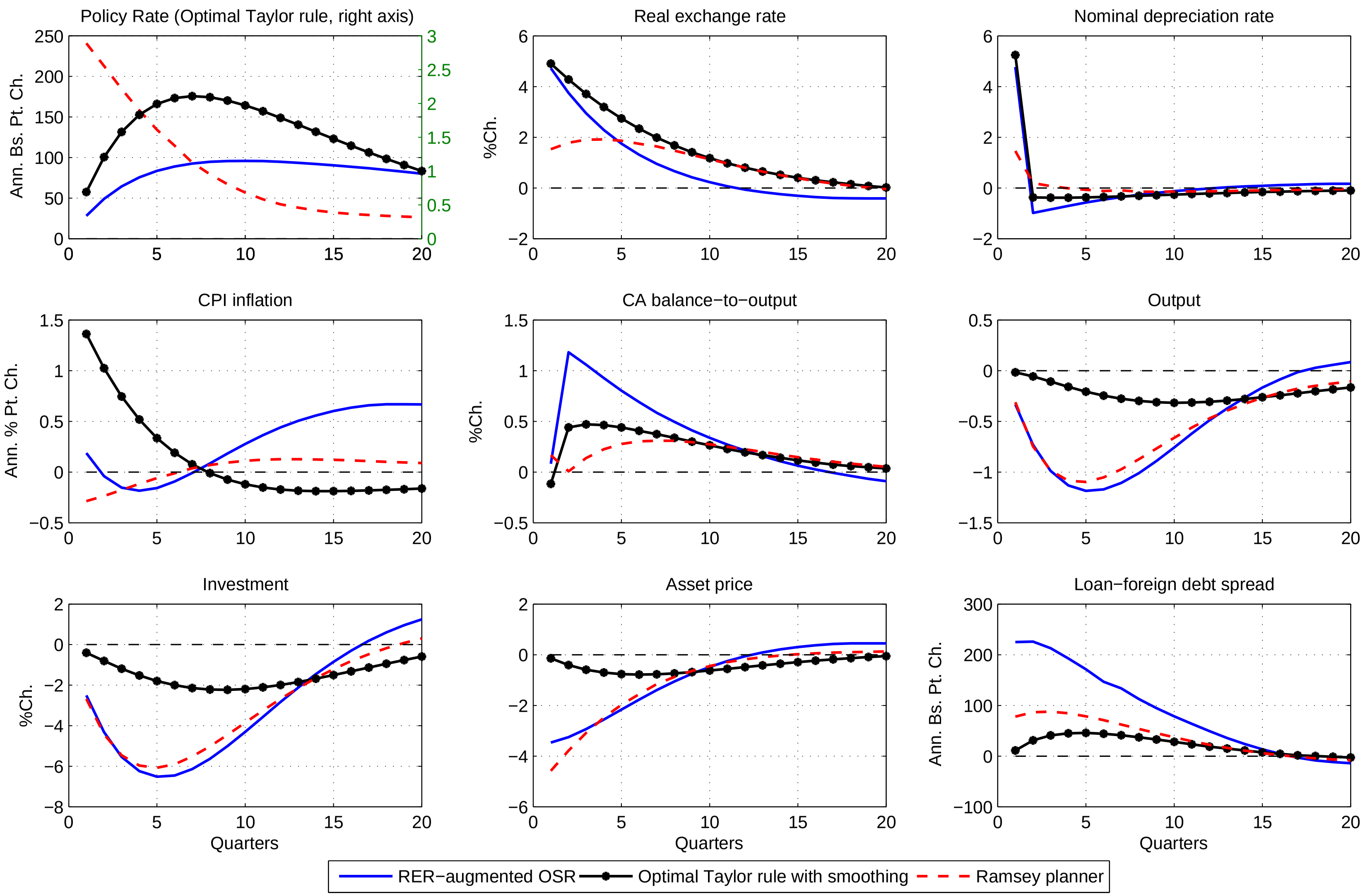

Figure 5: Optimal and empirical interest rate trajectories

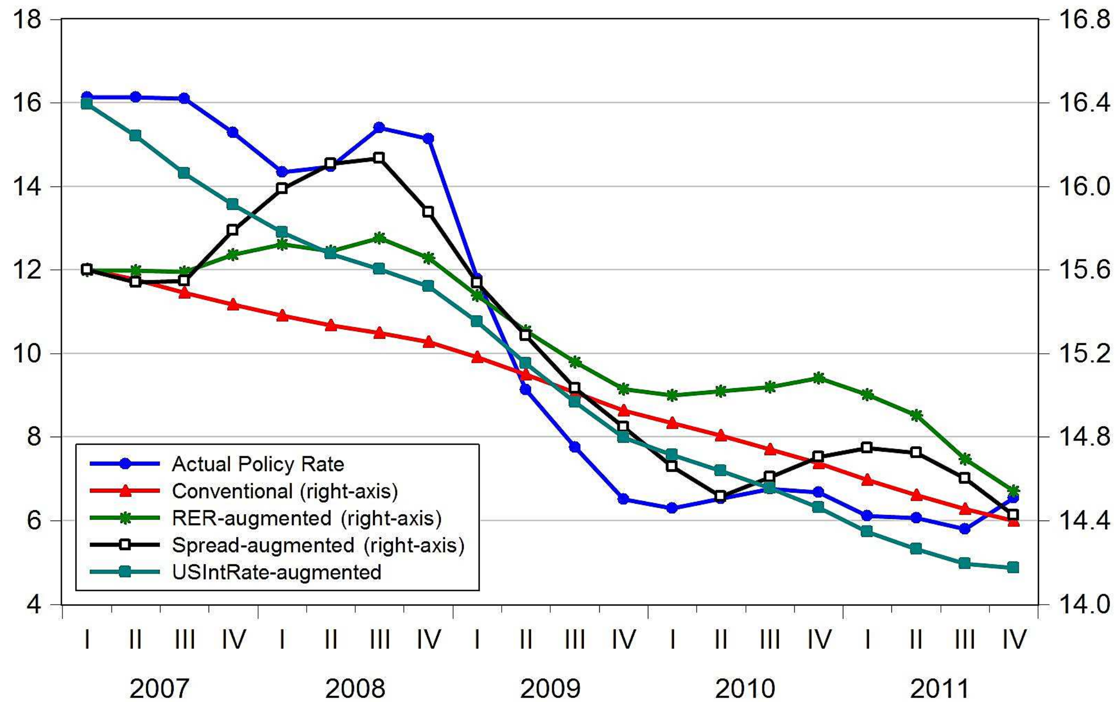

Table 1: Macroeconomic dynamics in 2007:Q1-2011:Q3 episode (peak-to-trough)

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[a] (%)	Spread over dom. (bps)	Spread over for. (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

[a] An increase in the real effective exchange rate corresponds to a depreciation.

Table 2: Model parameters

Description	Parameter	Value	Target
Preferences			
Quarterly discount factor	β	0.9821	Annualized 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	Commercial bank leverage = 7.94
Fraction of non-diverted domestic deposits	ω_l	0.81	Banks' foreign debt share = 40.83%
Survival probability of bankers	θ	0.925	Survival duration of 3.33 years for bankers
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	Elasticity of price of capital w.r.t. $\frac{I}{K}$ ratio = 0.125
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	Average 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	$corr(TB/Y, Y) = -0.76$
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	Estimated for 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 the EU GDP = 0.31
Standard deviation of export demand shocks	σ^{y^*}	0.0048	Standard deviation of the EU GDP = 0.0048

Table 3: Business cycle statistics: Data vs. model economy

	$\frac{\sigma_x}{\sigma_y}$		$corr(x,y)$		$corr(x_t, x_{t-1})$	
Variable	Data	D.E.[a]	Data	D.E.	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
Loan-domestic deposit spread	0.23	0.20	-0.55	-0.65	0.65	0.83
Loan-foreign deposit 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 decentralized economy.

Table 4: Asymptotic variance decomposition in the decentralized economy (%)

Variables	TFP	Government spending	Country risk premium	U.S. interest rate	Export demand
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
Foreign debt share	9.99	0.08	77.40	12.49	0.04
Loan-domestic d. spread	1.36	0.01	84.31	14.24	0.09
Loan-foreign d. 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: Steady states

Variable	Decentralized economy	Ramsey planner
Real variables		
Output	0.7552	0.7569
Consumption	0.5731	0.5842
Investment	0.1447	0.1477
Hours worked	0.3333	0.3328
Financial variables		
Credit	2.7410	2.8220
Liability composition (Foreign)	0.4083	0.1330
Leverage	7.9312	13.875
Asset price	0.6627	0.6701
External variables		
Real Exchange Rate	2.0894	2.0480
Trade Balance to GDP (%)	0.9136	0.2906
Monetary variables		
Inflation Rate (% annualized)	0	-0.5270
Markup	2.3530	2.2940
Real Money Balances	0.3357	0.3760

Table 6: Relative volatilities

Variable	Decentralized 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
Loan-domestic deposit spread	0.20	0.18
Loan-foreign deposit 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 7: Optimal simple policy rules under external shocks

Country risk premium	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}	σ_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)[a]
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	1.0010	0	-	-	-	0.7878	1.4067	0.2464	7.3900	1.2141	4.5849
Standard (with smoothing)	0.9950	1.0010	0	-	-	-	0.0032	0.4044	0.1129	6.0891	1.0429	0.2912
Optimized augmented TR												
Credit	0.6396	1.0010	1.0714	-0.4286	-	-	0.5565	0.2489	0.8716	6.7310	5.0710	0.0096
Asset price	0.6396	1.4294	0.6429	-1.0714	-	-	3.1285	0.6709	1.3206	7.4468	10.2921	0.0021
Credit spread	0.9239	1.4294	0.4286	-2.1429	-	-	0.5134	1.1540	0.0265	6.9217	0.4592	0.0026
Real exchange rate	0.9950	1.0010	0.4286	3.0000	-	-	0.1381	0.1837	0.8079	5.8538	5.0637	0.0015
Optimized TR and RRR	0.3554	1.1438	2.3571	-	0.4264	-2.5714	0.2322	0.5677	0.0281	6.2455	0.9535	0.0006
Ramsey policy	-	-	-	-	-	-	0.3610	0.0668	0.2211	3.3243	5.0007	0

U.S. interest rate	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}	σ_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	1.0010	0	-	-	-	0.3479	0.6212	0.1072	2.8912	0.5296	2.3948
Standard (with smoothing)	0.9950	1.0010	0	-	-	-	0.013	0.1622	0.0427	2.3181	0.4070	1.7815
Optimized augmented TR												
Credit	0.4975	1.0010	2.3571	-1.0714	-	-	0.8100	0.2149	0.4128	1.6112	2.6099	0.0011
Asset price	0.2132	3.0000	2.1429	-2.1429	-	-	2.6984	0.1644	0.4259	3.2054	3.3204	0.0009
Credit spread	0.9239	1.0010	3.0000	-3.0000	-	-	0.2784	0.5925	0.0123	2.7718	0.2092	0.0050
Real exchange rate	0.1421	1.2866	1.0714	1.2857	-	-	1.3936	0.3017	2.0838	4.1775	12.566	0.0025
U.S. interest rate	0.7818	1.0010	0	2.5714	-	-	0.9770	3.3691	2.2266	3.0112	13.368	0.0121
Optimized TR and RRR	0.4264	1.1438	1.9286	-	0.2843	-2.7857	0.0821	0.2120	0.0161	2.3449	0.3698	0.0004
Ramsey policy	-	-	-	-	-	-	0.1333	0.0308	0.0901	1.3029	1.9737	0

Export demand	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}	σ_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	3.0000	0.6429	-	-	-	0.0028	0.0084	0.0153	0.1041	0.0323	2.0777
Standard (with smoothing)	0.9950	1.0010	0	-	-	-	0.0001	0.0049	0.0139	0.1058	0.0340	2.0769
Optimized augmented TR												
Credit	0.9950	3.0000	0.6429	-2.7857	-	-	0.0298	0.2260	0.2939	0.5507	1.8000	0.0794
Asset price	0.2843	1.0010	0.4286	-2.1429	-	-	0.9875	0.1947	0.2077	1.7078	1.2732	0.0047
Credit spread	0.0711	1.0010	1.7143	-2.5714	-	-	0.4595	0.7643	0.0014	0.9428	0.2299	0.0001
Real exchange rate	0.2843	1.1438	0	1.7143	-	-	0.1597	0.0753	0.2641	0.2027	1.7710	0.0063
Optimized TR and RRR	0.9950	1.0010	1.7143	-	0.5686	-3.0000	0.0068	0.1101	0.0573	0.1529	0.8350	0.0021
Ramsey policy	-	-	-	-	-	-	0.0062	0.0042	0.0140	0.0610	0.0564	0

[a] The reported welfare figures include both long-run and dynamic costs.

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_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)[a]
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	1.0010	0	-	-	-	0.9424	1.6829	0.2734	7.9497	1.3517	6.0616
Standard (with smoothing)	0.9239	1.0010	0	-	-	-	0.0614	0.5532	0.1757	6.5809	1.3472	2.1345
Optimized Augmented TR												
Credit	0.9239	1.0010	1.7143	-0.6429	-	-	0.2401	0.3229	0.7744	6.4310	4.7299	0.0450
Asset price	0.8529	2.4289	1.9286	-2.7857	-	-	3.8831	0.9414	0.8868	10.716	11.529	0.0013
Credit spread	0.9950	1.0010	2.7857	-1.500	-	-	0.0908	0.5682	0.0579	6.7198	0.8986	0.0027
Real exchange rate	0.9950	1.0010	0.4286	2.7857	-	-	0.1391	0.3735	0.8674	6.3262	5.3979	0.0093
U.S. interest rate	0.9239	1.0010	0	0.2143	-	-	0.0593	0.5302	0.2976	6.5545	1.9367	0.1332
Optimized TR and RRR	0.5686	1.4294	2.1429	-	0.3554	-1.7143	0.4565	0.9267	0.3220	6.6794	1.9311	0.0040
Ramsey policy	-	-	-	-	-	-	0.4460	0.1861	0.2472	3.8810	5.4933	0

[a]The reported welfare figures include both long-run and dynamic costs.

Online Appendix for "External Shocks, Banks and Optimal Monetary Policy: A Recipe for Emerging Market Central Banks". Not Intended for Publication.[1]

Yasin Mimir[2] Enes Sunel[3]

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[2]Corresponding author. Norges Bank, Monetary Policy Department, Bankplassen 2, 0151 Oslo, Norway, Phone: +4722316811, yasin.mimir@norges-bank.no, Personal homepage: http://www.yasinmimir.com

[3]Sunel & Sunel Law Firm. Soganlik Yeni Mah., Uprise Elite Residence 234, Kartal, 34880 Istanbul, Turkey, Phone: +905334451145, email: enessunel@gmail.com, Personal homepage: https://sites.google.com/site/enessunel/

A Model derivations

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

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

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.

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 (A.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 minimizing 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

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

Therefore, the expenditure minimization problem of households subject to the consumption aggregator (A.1) produces the domestic consumer price index (CPI),

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

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

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

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.[1] 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

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

where U is a CRRA type period utility function given by

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

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.[2]

Households face the flow budget constraint,

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

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.

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

[2] 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 condition except the consumption-money optimality condition.

Households choose c_t, h_t, B_{t+1}, and M_t to maximize preferences in (A.5) subject to (A.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 households are given by

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

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

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

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

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

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

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

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 (A.9) and (A.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 (7). Since,

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

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

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,

$$\max_{l_{jt}, b^*_{jt+1}} L = \nu^l_t q_t l_{jt} + \nu^*_t b^*_{jt+1} + \nu_t n_{jt} \tag{A.11}$$

$$+\mu_t \left[\nu^l_t q_t l_{jt} + \nu^*_t b^*_{jt+1} + \nu_t n_{jt} - \lambda \left(q_t l_{jt} - \omega_l \left[\frac{q_t l_{jt} - n_{jt}}{1 - rr_t} - b^*_{jt+1} \right] \right) \right],$$

where the term in square brackets represents the incentive compatibility constraint, (7) combined with the balance sheet (2), to eliminate b_{jt+1}. The first-order conditions for l_{jt}, b^*_{jt+1}, and the Lagrange multiplier μ_t are:

$$\nu^l_t (1 + \mu_t) = \lambda \mu_t \Big(1 - \frac{\omega_l}{1 - rr_t} \Big), \tag{A.12}$$

$$\nu^*_t (1 + \mu_t) = \lambda \mu_t \omega_l, \tag{A.13}$$

and

$$\nu^l_t q_t l_{jt} + \nu^*_t \left[\frac{q_t l_{jt} - n_{jt}}{1 - rr_t} - b_{jt+1} \right] + \nu_t n_{jt} - \lambda (q_t l_{jt} - \omega_l b_{jt+1}) \geq 0, \tag{A.14}$$

respectively. We are interested in cases in which the incentive constraint of banks is always binding, which implies that $\mu_t > 0$ and (A.14) holds with equality.

An upper bound for ω_l is determined by the necessary condition for a positive value of making loans $\nu^l_t > 0$, 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.12).

Combining (A.12) and (A.13) yields,

$$\frac{\frac{\nu^*_t}{1 - rr_t}}{\nu^l_t + \frac{\nu^*_t}{1 - rr_t}} = \frac{\omega_l}{1 - rr_t}.$$

Re-arranging the binding version of (A.14) leads to equation (9).

We replace V_{jt+1} in equation (6) by imposing our linear conjecture in equation (8) and the borrowing constraint (9) to obtain,

$$\tilde{V}_{jt} = E_t\Big\{\Xi_{t,t+1} n_{jt+1}\Big\}, \tag{A.15}$$

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

Replacing the left-hand side to verify our linear conjecture on bankers' value (8) and using equation (5), 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^l_t, ν_t, and ν^*_t should consecutively satisfy equations (10), (11) and (12) 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 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

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

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

$$\frac{i^H_t}{i^F_t} = \frac{\omega_i}{1-\omega_i}\left(\frac{P^H_t}{P^F_t}\right)^{-\gamma_i}.$$

The resulting aggregate investment price index P^I_t 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 maximize its discounted profits represented by

$$\max_{i_{t+i}} \sum_{i=0}^{\infty} E_0 \left[\Lambda_{t,t+1+i} \left(q_{t+i} i_{t+i} - \Phi\left(\frac{i_{t+i}}{i_{t+i-1}}\right) q_{t+i} i_{t+i} - \frac{P_{t+i}^I}{P_{t+i}} i_{t+i} \right)\right]. \tag{A.16}$$

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

$$\frac{P_t^I}{P_t} = q_t \left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right) - \Phi'\left(\frac{i_t}{i_{t-1}}\right)\frac{i_t}{i_{t-1}}\right] + E_t\left[\Lambda_{t,t+1} q_{t+1} \Phi'\left(\frac{i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right)^2\right].$$

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

$$k_{t+1} = (1-\delta_t)k_t + \left[1 - \Phi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t, \tag{A.17}$$

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

A.4 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 sells 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 of final goods producers are represented by

$$\max_{y_t^H(i)} \; P_t^H \left[\int_0^1 y_t^H(i)^{1-\frac{1}{\epsilon}} di\right]^{\frac{1}{1-\frac{1}{\epsilon}}} - \left[\int_0^1 P_t^H(i) y_t^H(i) di\right]. \tag{A.18}$$

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.

A.5 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

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

with zero mean and constant variance innovations ϵ_{t+1}^A.

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

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

which depends on the aggregate home output y_t^H. 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

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

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 maximize the present discounted real profits. We confine our interest to symmetric equilibrium, in which all intermediate producers choose the same price level that is, $P_t^H(i) = P_t^H \;\; \forall i$.

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

$$\max_{P_t^H(i)} E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left[\frac{D_{t+j}^H(i)}{P_{t+j}} \right] \tag{A.19}$$

subject to the nominal profit function

$$D_{t+j}^H(i) = P_{t+j}^H(i) y_{t+j}^H(i) + S_{t+j} P_{t+j}^{H*} c_{t+j}^{H*}(i) - MC_{t+j} y_{t+j}(i) - P_{t+j} \frac{\varphi^H}{2} \left[\frac{P_{t+j}^H(i)}{P_{t+j-1}^H(i)} - 1 \right]^2, \tag{A.20}$$

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,

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

$$+ \varphi^H E_t \left\{ \Lambda_{t,t+1} \left[\frac{P_{t+1}^H(i)}{P_t^H(i)} - 1 \right] \frac{P_{t+1}^H(i)}{P_t^H(i)^2} \right\}. \tag{A.21}$$

Imposing the symmetric equilibrium condition to the first order condition of the profit maximization problem and using the definitions $rmc_t = \frac{MC_t}{P_t}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, and $p_t^H = \frac{P_t^H}{P_t}$ yield

$$p_t^H = \frac{\epsilon}{\epsilon - 1} rmc_t - \frac{\varphi^H}{\epsilon - 1} \frac{\pi_t^H (\pi_t^H - 1)}{y_t^H} + \frac{\varphi^H}{\epsilon - 1} E_t \left\{ \Lambda_{t,t+1} \frac{\pi_{t+1}^H (\pi_{t+1}^H - 1)}{y_t^H} \right\}. \tag{A.22}$$

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, $P_t^H = \frac{\epsilon}{\epsilon-1} MC_t$.

The remaining part of the intermediate goods is exported as $c_t^{H*}(i)$ 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

$$c_t^{H*} = \left[\left(\frac{P_t^{H*}}{P_t^*} \right)^{-\Gamma} y_t^* \right]^{\nu^H} (c_{t-1}^{H*})^{1-\nu^H},$$

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

$$\ln(y_{t+1}^*) = \rho^{y^*} \ln(y_t^*) + \epsilon_{t+1}^{y^*},$$

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,

$$p_t^F = \frac{\epsilon}{\epsilon - 1} s_t - \frac{\varphi^F}{\epsilon - 1} \frac{\pi_t^F(\pi_t^F - 1)}{y_t^F} + \frac{\varphi^F}{\epsilon - 1} E_t \left\{ \Lambda_{t,t+1} \frac{\pi_{t+1}^F(\pi_{t+1}^F - 1)}{y_t^F} \right\}, \tag{A.23}$$

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 minimize

$$\min_{u_t, k_t, h_t} q_{t-1} r_{kt} k_t - (q_t - q_{t-1}) k_t + p_t^I \delta(u_t) k_t + w_t h_t + rmc_t \Big[y_t - A_t \Big(u_t k_t \Big)^{\alpha} h_t^{1-\alpha} \Big] \tag{A.24}$$

subject to the endogeneous depreciation rate function,

$$\delta(u_t) = \delta + \frac{d}{1 + \varrho} u_t^{1+\varrho}, \tag{A.25}$$

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

$$p_t^I \delta'(u_t) k_t = \alpha \Big(\frac{y_t}{u_t} \Big) rmc_t, \tag{A.26}$$

$$R_{kt} = \frac{\alpha \Big(\frac{y_t}{k_t} \Big) rmc_t - p_t^I \delta(u_t) + q_t}{q_{t-1}}, \tag{A.27}$$

and

$$w_t = (1 - \alpha) \Big(\frac{y_t}{h_t} \Big) rmc_t. \tag{A.28}$$

A.6 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

$$y_t^H = c_t^H + c_t^{H*} + i_t^H + g_t^H y_t^H + \left(p_t^H\right)^{-\gamma} \frac{\varphi^H}{2} \left(\pi_t \frac{p_t^H}{p_{t-1}^H} - 1\right)^2. \tag{A.29}$$

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

$$y_t^F = c_t^F + i_t^F + \left(p_t^F\right)^{-\gamma} \frac{\varphi^F}{2} \left(\pi_t \frac{p_t^F}{p_{t-1}^F} - 1\right)^2. \tag{A.30}$$

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

$$R_t^* b_t^* - b_{t+1}^* = c_t^{H*} - y_t^F. \tag{A.31}$$

Finally, the national income identity that reflects investment adjustment costs built in capital accumulation condition (A.17) would read,

$$y_t = y_t^H - y_t^F. \tag{A.32}$$

A.7 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 (A.5)-(A.6), the net worth maximization problem of bankers (6)-(7), and the profit maximization problems of capital producers (A.16), final goods producers (A.18), and intermediate goods producers (A.19)-(A.20) and (A.24)-(A.25).

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.31) and (A.32) hold.

B Impulse responses under domestic and other external shocks

This section presents the impulse responses of real, financial and external variables under the productivity, government spending, U.S. policy rate and export demand shocks. For brevity, we do not explain the dynamics of model variables under each shock in detail. We note that most of the endogenous variables and the policy instruments respond to each shock in a fairly standard way, which were already extensively studied in the previous literature. In this section, we also report one-quarter and one-year ahead variance decomposition results.

Figure B.1: Impulse response functions driven by 1 s.d. increase in productivity

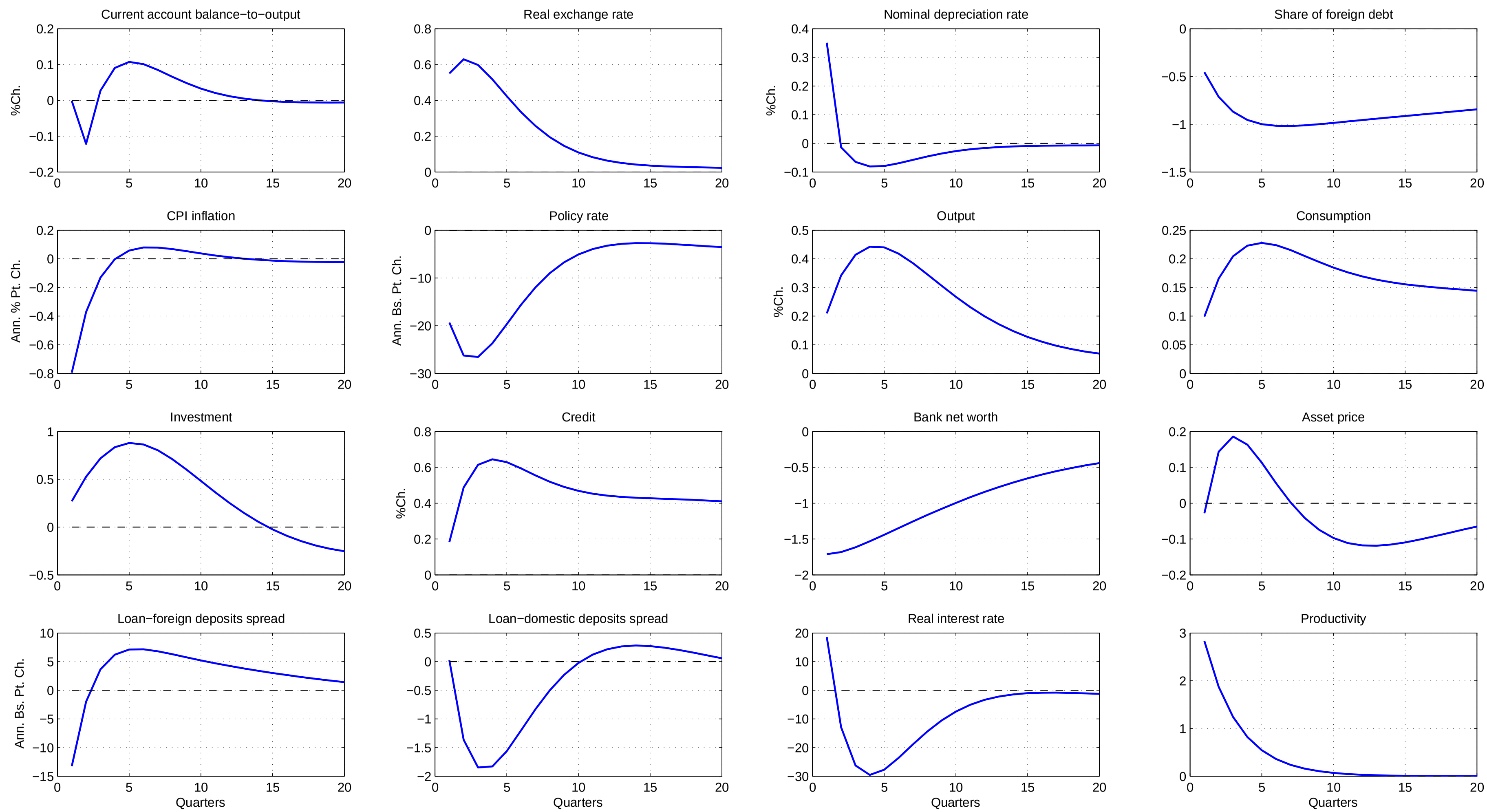

Figure B.2: Impulse response functions driven by 1 s.d. increase in government spending

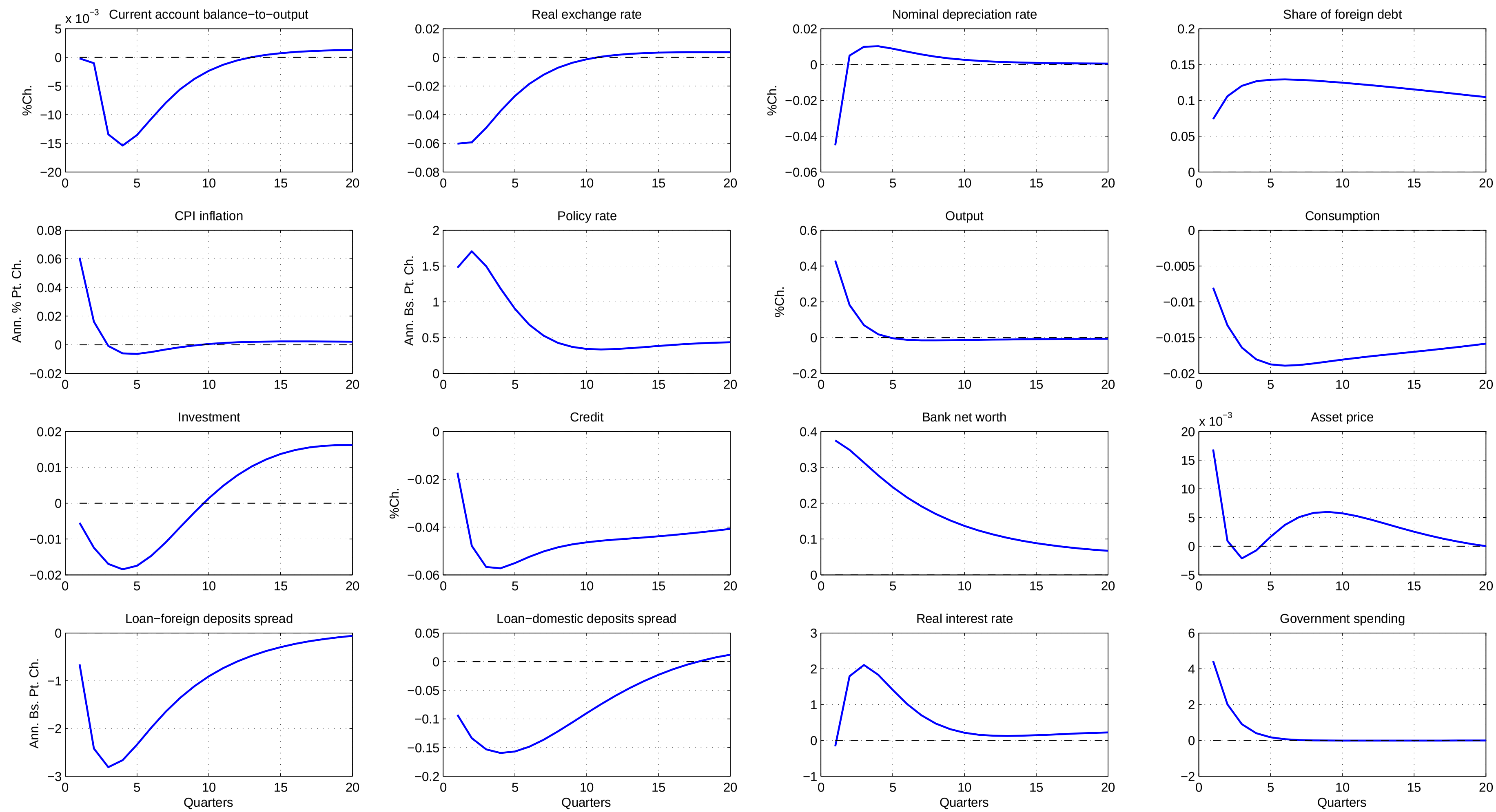

Figure B.3: Impulse response functions driven by 40 annualized basis points increase in the U.S. policy rate

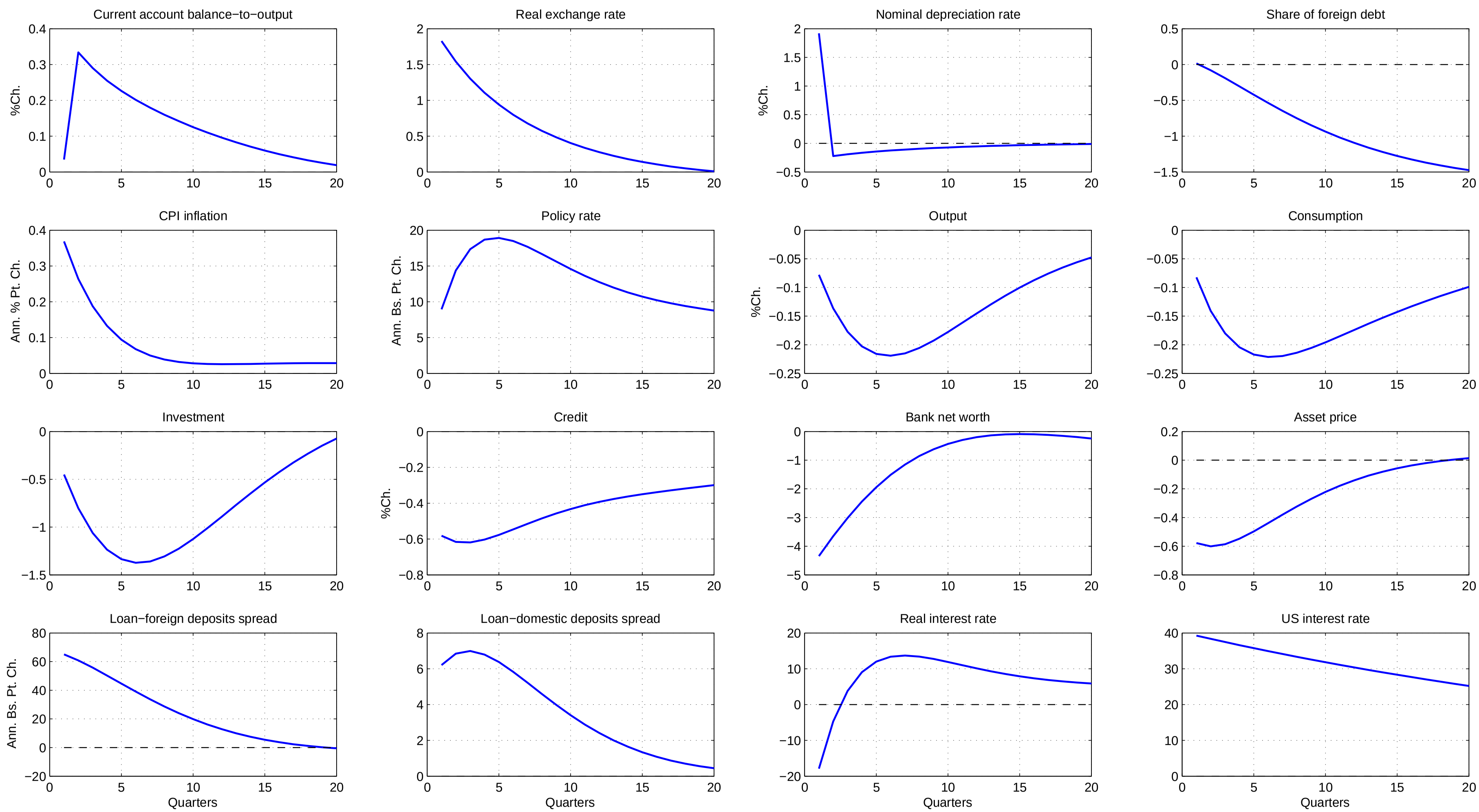

Figure B.4: Impulse response functions driven by 1 s.d. increase in foreign output

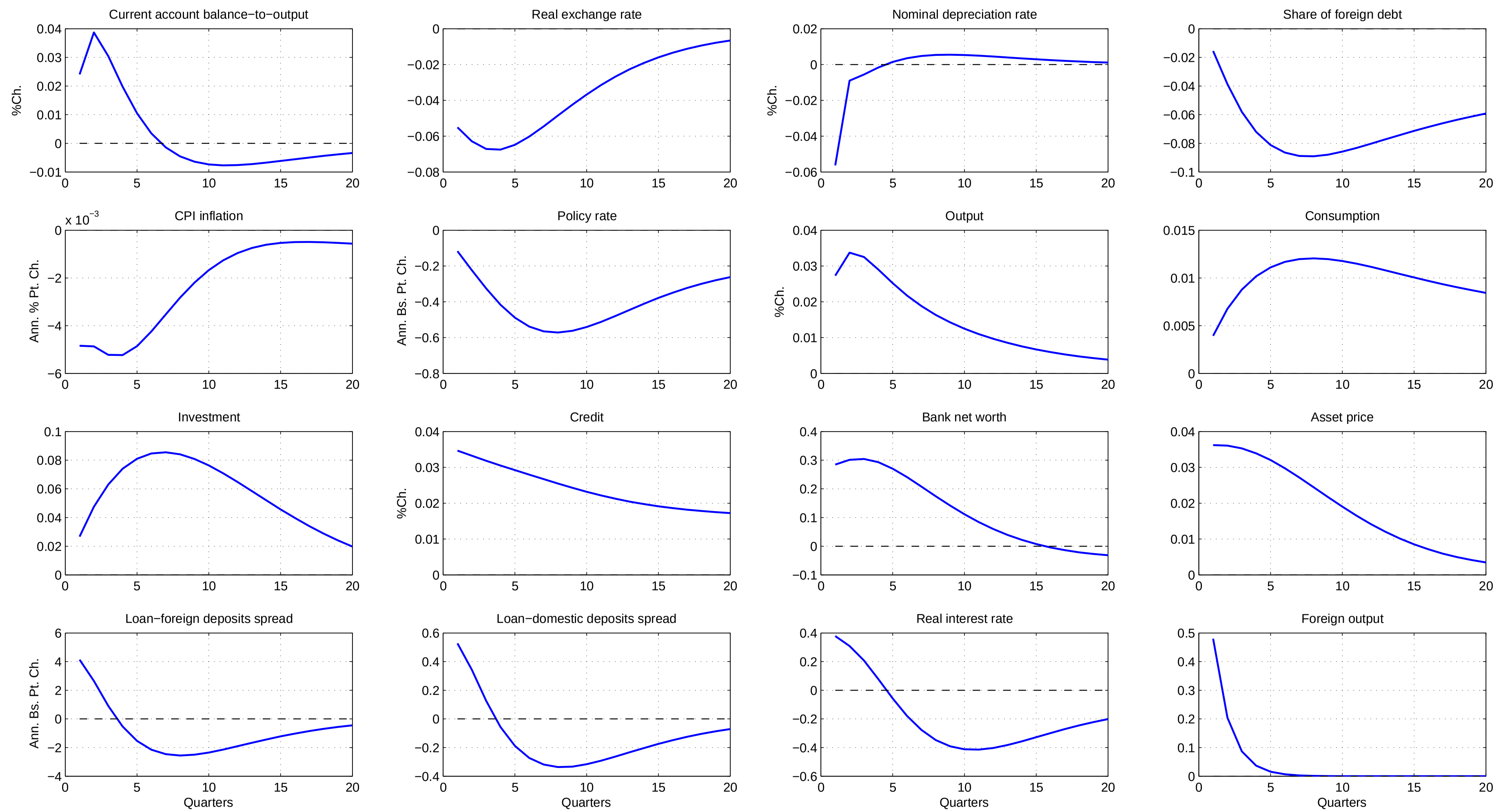

Table B.1: Variance decomposition in the decentralized economy (%)

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
Loan-domestic deposit spread	0.04	0.00	84.50	15.36	0.10
Loan-foreign deposit 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
Loan-domestic deposit spread	0.91	0.00	84.48	14.58	0.03
Loan-foreign deposit 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

C Optimal simple rules under domestic shocks

Table C.1 reports the response coefficients of optimized conventional and augmented Taylor rules, the absolute volatilities of policy rate, inflation, lending spread over foreign debt and the real exchange rate under these rules, and the corresponding consumption-equivalent welfare costs relative to the Ramsey-optimal policy under productivity and government spending shocks.

The optimized 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 (2013) 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. Higher volatilities of inflation and credit spreads together with a lower volatility of asset prices compared to the Ramsey policy indicate that these two optimized Taylor rules can only partially stabilize the intratemporal and intertemporal wedges, explaining the welfare losses associated with these rules.

Under productivity shocks, optimized augmented Taylor rules suggest that a negative response to credit spreads together with a moderate response to inflation and a strong response to output deviations achieve the highest welfare possible. In response to 100 basis points increase in credit spreads, the policy should be reduced by 150 basis points, all else equal. This policy substantially reduces the volatility of spreads in comparison to that in the Ramsey policy. Moreover, the optimized augmented Taylor rules that respond to credit, asset prices or the real exchange rate also achieve a level of welfare very close to that implied by the spread-augmented Taylor rule. Both rules feature a lower degree of volatility of the real exchange rate in comparison to that in the Ramsey policy. We also observe that it is optimal to negatively respond to bank credit under productivity shocks. In addition, comparing 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 volatility in the CPI inflation rate. In addition, the optimized 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 against the Ramsey-optimal policy.

Optimized 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.

Table C.1: Optimal simple policy rules under domestic shocks

TFP	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}	σ_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)[a]
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	1.5721	0	-	-	-	0.2701	0.3071	0.0830	0.4714	0.4155	2.2690
Standard (with smoothing)	0.9950	1.0010	0	-	-	-	0.0015	0.2559	0.1183	0.9274	0.6568	1.3583
Optimized augmented TR												
Credit	0.7818	1.2866	2.7857	-1.7143	-	-	0.4441	0.4697	0.1008	1.1231	1.0792	0.0010
Asset price	0.4264	3.0000	2.7857	-3.0000	-	-	2.9289	0.7777	0.4339	4.5204	3.5392	0.0009
Credit spread	0.9239	1.2866	1.2857	-1.5000	-	-	0.2268	0.3903	0.0234	1.3792	0.4942	0.0001
Real exchange rate	0.7107	1.0010	1.9286	2.7857	-	-	0.3718	0.4431	0.8391	1.1026	5.2674	0.0014
Optimized TR and RRR	0.1421	2.8572	1.0714	-	0.7107	-2.7857	0.4204	0.5282	14.5650	12.8479	4.3218	0.0008
Ramsey policy	-	-	-	-	-	-	0.2248	0.1703	0.0623	1.5168	1.1261	0

Government spending	ρ_{r_n}	φ_π	φ_y	φ_f	ρ_{rr}	φ_{rr}	σ_{r_n}	σ_π	σ_{spread}	σ_{RER}	σ_q	CEV(%)
Optimized Taylor rules (TR)												
Standard (without smoothing)	-	1.0010	0.2143	-	-	-	0.0725	0.0427	0.0290	0.1186	0.1641	2.0672
Standard (with smoothing)	0.9950	1.0010	0.4286	-	-	-	0.0009	0.0145	0.0064	0.0949	0.0616	2.0106
Optimized augmented TR												
Credit	0.9950	1.1438	1.5000	-0.8571	-	-	0.0089	0.2327	0.2649	0.4117	1.7141	0.0332
Asset price	0.9950	2.4289	1.2857	-2.3571	-	-	0.0278	0.1991	0.2551	0.4078	1.6741	0.0010
Credit spread	0.3554	1.2866	0.2143	-2.5714	-	-	0.3014	0.4829	0.0007	0.6864	0.2662	0.0147
Real exchange rate	0.1421	1.2866	2.3571	-2.7857	-	-	0.3445	0.3008	0.4325	1.2370	3.3088	0.0005
Optimized TR and RRR	0.9950	1.1438	0.8571	-	0.2843	-3.0000	0.0040	0.1182	0.0521	0.2786	0.8837	0.0001
Ramsey policy	-	-	-	-	-	-	0.0144	0.0146	0.0060	0.0961	0.0508	0

[a] The reported welfare figures include both long-run and dynamic costs.