Macroprudential Regulation and Financial Stability in Open Economies

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Abstract

In the aftermath of the global financial crisis, researchers and policymakers have shown a renewed interest in the role of capital controls as a macroprudential instrument as well as the international dimensions of macroprudential policies. This thesis discusses macroprudential regulation and financial stability in open economies. Chapter 1 studies the performance of time-varying capital controls on cross-border bank borrowing in an open-economy, dynamic stochastic general equilibrium model with credit market frictions and imperfect capital mobility. The model is parameterized for a middle-income country and is shown to replicate the stylized facts associated with a fall in world interest rates (capital inflows, real appreciation, credit boom, asset price pressures, and output expansion). A capital controls rule, which is fundamentally macroprudential in nature, is defined in terms of either changes in bank foreign borrowing or cyclical output. An optimal, welfare-maximizing rule is established numerically. In addition, the optimal simple rule is shown to perform well relative to the Ramsey policy. The analysis is then extended to solve jointly for optimal countercyclical reserve requirements and capital controls rules. These instruments are complements in the sense that both are needed to maximize welfare. At the same time, a more aggressive credit-based reserve requirement rule also induces less reliance on capital controls. Thus, at the margin, countercyclical reserve requirements and capital controls are partial substitutes in maximizing welfare.

Chapter 2 evaluates, using a game-theoretic approach, the benefits of coordinating macroprudential policy (in the form of reserve requirements) in a two-country model of a currency union with credit market imperfections. Financial stability is first defined in terms of the volatility of the credit-to-output ratio. The gains from coordination are measured by comparing outcomes under a centralized regime, where a common regulator sets the required reserve ratio to minimize union-wide financial volatility, and a decentralized (Nash) regime, where each country regulator sets that ratio to minimize its own policy loss. Experiments show that, under asymmetric real and financial shocks, the gains from coordination are significant at the union level. Moreover, these gains are higher when the common and national regulators have asymmetric preferences with respect to output stability, when financial markets are more integrated, and when the degree of asymmetry in credit markets between members is larger.
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Dedication

To my beloved parents Shunde Jia and Lihua Gao for their love and support
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Introduction

The 2008 global financial crisis led to the worst recession since World War II. The sources of the crisis are several and complex, including country-specific factors, yet a combination of loose monetary and regulatory structures encouraged excessive credit growth, asset price pressures, and leverage and procyclicality in the financial sector. One legacy of the crisis, however, is the adoption of macroprudential policy as a new policy paradigm and part of the standard crisis prevention policy toolkit. The policymakers in charge of financial stability missed the mark before the crisis because they failed to perceive and contain the financial vulnerabilities that were building up during the boom. Macroprudential policy—designed to safeguard systemic financial stability—fills this gap by restraining the factors of systemic risk in the balance sheets of the banking and real sectors before the crisis.

Studies have shown that large swings in capital flows into emerging markets can potentially lead to excessive volatility in asset prices and credit supply. Indeed, capital flows have been extensively blamed for episodes of booms and busts, in particular the financial and macroeconomic instability in emerging markets. In order to lessen the impact of capital flows on financial instability, a number of researchers and policymakers have recently proposed the use of capital controls as a prudential tool. For instance, Schmitt-Grohé and Uribe (2012) argued that the combination of downward nominal wage rigidity, a fixed exchange rate, and free capital mobility creates a negative aggregate-demand externality. The existence of the externality creates a rationale for government intervention. They showed that optimal capital controls are highly effective at curbing overborrowing during booms and reducing unemployment during busts, therefore enhancing welfare.

In addition, the large economic costs associated with the global financial crisis have generated renewed interest in the international dimensions of macroprudential policies. This is largely driven by the fact that increased interconnectedness of fi-
nancial institutions and markets, and more highly correlated financial shocks, have intensified cross-border spillovers and risks. The unprecedented speed and scale with which the financial crisis was amplified and propagated internationally, has led to renewed calls to strengthen prudential regulation and supervision of financial institutions, both within and between countries. If policymakers could internalize the adverse effects of cross-border spillovers, cross-country coordination of macroprudential policies may be desirable and welfare-improving (see Bengui (2014), Jeanne (2014), Korinek (2014, 2017), and Kara (2016)). The thesis consists of two substantive chapters, with the content of each chapter briefly discussed below.

Chapter 1 studies the performance of time-varying capital controls on cross-border bank borrowing in an open-economy, dynamic stochastic general equilibrium model with credit market frictions and imperfect capital mobility. The analysis differs from existing studies in several important ways. First, as in Escudé (2014), Kitano and Takaku (2014), Chang et al. (2015) and Davis and Presno (2017), this study uses an open-economy stochastic general equilibrium model to examine the benefits of time-varying capital controls; however, unlike these contributions, this study does so in a model with financial frictions, a feature that is important to understand some of the negative externalities associated with capital flows from the perspective of financial volatility. Second, in contrast to all existing contributions, which tend to focus on controls on households or the nonfinancial sector, this study focuses on capital controls on bank-related short-term capital flows. Such flows have been an important component of cross-border capital flows in recent years. Third, the optimal, welfare-maximizing capital controls simple rule is solved, using a second-order approximation of the utility function and the model itself. Fourth, this study investigates the joint optimal determination of simple, implementable countercyclical rules in terms of both reserve requirements and capital controls.

Parameterized for a middle-income country, this study first replicates the stylized facts associated with a fall in world interest rates (capital inflows, real appreciation,
credit boom, asset price pressures, and output expansion). A capital controls rule is defined in terms of either changes in bank foreign borrowing or cyclical output. An optimal, welfare-maximizing rule is established numerically. In addition, the optimal simple rule is shown to perform well relative to the Ramsey policy. Finally, this study solves jointly for optimal countercyclical reserve requirements and capital controls rules. The results show that these instruments are complements in the sense that both are needed to maximize welfare. At the same time, a more aggressive credit-based reserve requirement rule also induces less reliance on capital controls. Thus, at the margin, countercyclical reserve requirements and capital controls are partial substitutes in maximizing welfare.

Chapter 2 evaluates, using a game-theoretic approach, the benefits of coordinating macroprudential policy (in the form of reserve requirements) in a two-country model of a currency union with credit market imperfections. A key question in this context has been the level (national or supranational) at which macroprudential regulation should be conducted. This issue is particularly important in a currency union with a one-size-fits-all monetary policy and business cycles are not fully synchronized. Specifically, the purpose of this chapter is twofold. First, it aims to contribute to a better understanding of the cross-border spillover effects of macroprudential policy in a currency union where credit and capital markets are imperfect and housing plays a key role as collateral. Second, it aims to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in a currency union, relative to the case where countries pursue independently their own policies.

In contrast to the existing literature, this study focuses on reserve requirements as the instrument of macroprudential regulation. This is because in recent years policymakers in a number of countries have indeed used reserve requirements to mitigate credit fluctuations and promote macroeconomic and financial stability—not only in middle-income countries, where time and again they have been used
aggressively, but in some advanced economies as well (see, e.g., Cerutti et al. (2017)).
Also in contrast with most existing contributions, this study addresses this issue
in an explicit game-theoretic framework. This allows us to account for strategic
interactions between countries when they choose their policies in the absence of
cooperation.

A numerical comparison of the decentralized regime (in which regulators in each
country set the required reserve ratio to minimize own financial volatility) and the
centralized regime (where the common regulator sets either a uniform ratio or sep-

erate ratios to minimize union-wide financial volatility) shows that the gains from
coordination from the perspective of the home country (where the shocks occur) or
the union as a whole are significant in response to financial shocks. Moreover, when
member countries are faced with asymmetric shocks, a one-size-fits-all policy of set-
ing a uniform required reserve ratio is suboptimal compared to separate instrument
setting. However, when shocks are real in nature the country of origin may be worse
off under cooperation even if at the same time the union as a whole benefits from it.
If transfers from winners to losers cannot be enforced, cooperation in such conditions
can be sustained only with a collective binding political commitment.

This study also finds that the gains from coordination are stronger when the
national and common regulators are both concerned with output stability as well,
but the common regulator attaches a higher weight to financial stability than the
national regulators. The gains from coordination, at both the union and each coun-
try’s levels, tend to increase also with the degree of financial market integration,
because the common regulator is able to internalize the effects of greater integration
on cross-border spillovers through financial markets. Finally, this study finds that
the relative gain from coordination, from the perspective of the home country, tends
to increase with the degree of asymmetry in credit markets between the member
where the shocks originate and the other member of the union.
Chapter 1

Capital Controls and Welfare with Bank Capital Flows

1.1 Introduction

Recent experience has shown that surges in capital inflows and outflows can lead to financial instability—in the form of excessive credit growth, asset price pressures and, in some extreme cases, banking crises—even in countries with a floating exchange rate and an independent monetary policy. Temporary capital controls have been increasingly viewed by some economists and policymakers (especially in middle-income countries), as well as international financial institutions like the International Monetary Fund (2012), as a useful instrument for managing financial risks associated with large swings in capital flows, alongside monetary and macroprudential policies.

The case for imposing capital controls is often made on second-best grounds (see Dooley (1996)). Distortions in the domestic financial system, for instance, may cause resources borrowed from abroad to be allocated in socially unproductive ways in the domestic economy. In the absence of a well developed regulatory framework or adequate risk management practices in the financial sector, overborrowing can increase financial vulnerability. If the distortion causing the problem cannot be removed, a second-best option may be to limit foreign borrowing by the financial and nonfinancial sectors.
More recent analytical contributions have focused on the role of capital controls as a prudential instrument, or as a tool to reduce the probability of financial crises. These contributions include Bianchi (2011), Bianchi and Mendoza (2011), Farhi and Werning (2012), Schmitt-Grohé and Uribe (2012), De Paoli and Lipinska (2013), Costinot et al. (2014), Heathcote and Perri (2014), Kitano and Takaku (2014), Korinek and Sandri (2014), Brunnermeier and Sannikov (2015), Davis and Presno (2017), Chang et al. (2015), and Benigno et al. (2016).

One strand of this literature motivates capital controls based on aggregate demand externalities in the presence of nominal frictions on the use of monetary policy. Schmitt-Grohé and Uribe (2012) discussed the optimal use of capital controls in an economy that is a member of a monetary union when there is downward rigidity in prices. They showed that capital controls can be used as an instrument to overcome the involuntary unemployment caused by wage rigidity. Similarly, Farhi and Werning (2012) argued that a countercyclical capital controls policy can play a role in macroeconomic stabilization in a small open economy with a fixed exchange rate. They also argued that capital controls can mitigate the effects of excess international capital movements caused by risk premium shocks. Using a two-country model, De Paoli and Lipińska (2013) showed that restricting international capital flows through capital controls can be beneficial for individual countries, although it would limit international risk sharing. Devereux and Yetman (2014) considered the desirability of capital controls for an economy when its trading partner is in a liquidity trap. They found that capital controls can enhance the scope for monetary policy independence and improve welfare in the face of external shocks.

Another strand of this literature motivates capital controls based on the existence of pecuniary externalities. Benigno et al. (2016) developed models of foreign borrowing subject to collateral constraints and pecuniary externalities in the exchange rate that make the case for taxes on borrowing. They showed that a credible commitment to a price support policy in the event of a financial crisis always welfare-dominates
prudential capital controls, because it can achieve the unconstrained allocation. Bengui and Bianchi (2014) considered the implication of an environment in which the ability to enforce capital controls is limited. They showed that while leakages create distortions that make capital controls undesirable, the social planner may find optimal to tighten regulation on the regulated households in order to achieve higher stabilization effects. They also argued that there are important gains from capital controls despite the presence of leakages. Brunnermeier and Sannikov (2015) also studied the implications of pecuniary externalities in a two-country growth model with incomplete markets. Short-term capital flows can be excessive because each firm does not internalize that an increase in production capacity undermines their output price, worsening their terms of trade. In such conditions, capital controls or domestic macro-prudential measures that limit short-term borrowing can improve welfare.

Yet another strand characterizes capital controls as a tool to manage the international terms of trade. De Paoli and Lipińska (2013) described a model in which import and export taxes and subsidies are not available, and capital controls are instead tightened and loosened as competing concerns about output fluctuations gain and lose importance over the business cycle. Costinot et al. (2014) developed a theory of capital controls as dynamic terms-of-trade manipulation. They studied an infinite-horizon endowment economy with two countries in which one country chooses optimal taxes on capital flows while the other country is passive. They showed that it is optimal for the strategic country to tax capital inflows if it grows faster than the rest of the world and to tax capital outflows if it grows more slowly. Finally, Heathcote and Perri (2014) considered a two-country, two-good world in which international financial markets are incomplete, in the sense that the only asset traded internationally is a non-contingent bond. This creates \textit{prima facie} a potential role for policy intervention. The intervention that they consider is an extreme form of capital controls, in which asset trade is ruled out altogether. Thus,
they compare welfare when countries only trade a non-contingent, non-defaultable one period bond to welfare under financial autarky. By and large, therefore, the recent literature on capital controls has provided a number of channels through which such controls can improve welfare.¹

Our analysis differs from existing studies in several important ways. First, as in Escudé (2014), Kitano and Takaku (2014), Chang et al. (2015) and Davis and Presno (2017), we use an open-economy stochastic general equilibrium model to study the benefits of time-varying capital controls; however, unlike these contributions, we do so in a model with financial frictions, a feature that is important to understand some of the negative externalities associated with capital flows from the perspective of financial volatility, such as excessive credit growth or asset price pressures. Second, in contrast to all existing contributions, which tend to focus on controls on households or the nonfinancial sector, we focus on capital controls on bank-related short-term capital flows. Such flows have been an important component of cross-border capital flows in recent years. According to data by the Institute of International Finance for instance, since 2010 net inflows of private capital associated with commercial bank lending have consistently accounted for a larger fraction of total flows than portfolio equity flows to Latin America. In 2014 alone, bank-related capital inflows represented 11.4 percent of nonresident capital inflows, compared to 7.4 percent for portfolio investment flows; in proportion of non-FDI flows, these shares are 18.7 percent and 12.1 percent, respectively.² In countries like Brazil, Indonesia, and Turkey, domestic banks’ foreign credit exposures increased substantially in the past decade, despite the international deleveraging process that followed the global financial cri-

¹At the same time, it is worth noting that the empirical evidence on the benefits of capital controls remains largely ambiguous. For recent contributions and reviews of the evidence on the impact of capital controls, see Binici et al. (2010), Cordero and Montecino (2010), International Monetary Fund (2010, Chapter 4), Magud et al. (2011), Agénor (2012), Klein (2012), Edwards (2012), Agénor and Pereira da Silva (2013), Fernández et al. (2013), Forbes et al. (2015, 2016), Molnar et al. (2013), Eichengreen and Rose (2014), You et al. (2014), and Li and Rajan (2015). It is important to note, however, that few, if any, of these contributions have explicitly analyzed the impact of capital controls on financial stability—measured, in particular, in terms of second-order moments.

sis (see Cerutti (2015)). And because in our base experiment capital controls are related to changes in (aggregate) bank foreign borrowing, they are tantamount to a macroprudential instrument. Third, we solve for the optimal, welfare-maximizing capital controls simple rule, using a second-order approximation of the utility function and the model itself. Our analysis shows that temporary capital controls can indeed lead to a significant welfare improvement in response to external financial shocks. In addition, the optimal simple rule performs well relative to the Ramsey policy, both in terms of impulse responses and volatility. Fourth, we study the joint optimal determination of simple, implementable countercyclical rules in terms of both reserve requirements and capital controls. We show that a more aggressive reserve requirement rule (which responds to credit growth) requires less reliance on capital controls. Thus, the two instruments are substitutes at the margin, at least in response to external financial shocks. This is an important result because a common criticism of capital controls (especially when they begin to take a more permanent form) is that private agents find ways to evade them. At the same time, it may be more difficult to do so for reserve requirements.

The remainder of the paper is organized as follows. Section 2 describes the model, which is a simplified version of the model in Agénor et al. (2015). In addition to accounting for capital controls on bank borrowing abroad, the model features imperfect capital mobility and a two-level financial intermediation system, exchange rate smoothing, self insurance, sterilized foreign exchange market intervention, and imperfect substitutability between deposits and central bank borrowing. The equilibrium and some key features of the steady state are discussed in Section 3, and an illustrative calibration (designed to reproduce the main stylized facts associated with

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3See Hoggarth et al. (2010), Committee on International Economic Policy and Reform (2012), Herrmann and Mihaljek (2013), Reinhardt and Riddough (2014), and Bruno and Shin (2015) for a discussion of the importance of cross-border bank flows in international capital movements (especially changes in the external liabilities of resident banks) during the run up to, and the immediate aftermath of, the global financial crisis.

4Given the issue at stake, the model is simplified by excluding the cost channel and assuming full sterilization. It also provides a different rationale for imperfect substitutability between deposits and central bank borrowing.
episodes of large capital inflows induced by external financial shocks in the benchmark experiment) is presented in Section 4. The results of a temporary drop in the world safe interest rate, are described in Section 5. As documented in a number of studies, shocks to world interest rates have been a key impulse factor in explaining capital flows (a “sudden flood,” in the terminology of Agénor et al. (2014, 2015)) to some of the larger middle-income countries in Asia and Latin America. At the same time, these shocks have imposed significant constraints on policymakers in these countries. Following a drop in the world (risk-free) interest rate for instance, the scope for responding to the risk of macroeconomic and financial instability through monetary policy—above and beyond a “normal” response through a standard Taylor rule—is limited, because higher domestic interest rates would exacerbate capital inflows and magnify currency appreciation. In such conditions, a natural question is to consider which alternatives (capital controls and other macroprudential policies) can be implemented. Welfare-maximizing countercyclical capital controls are discussed in Section 6, whereas the joint determination of countercyclical reserve requirements and capital controls rules are examined in Section 7. The last section provides some concluding remarks and discusses some potentially fruitful directions for future research.

1.2 The Model

Consider a small open economy populated by six categories of agents: a representative household, a continuum of monopolistic (IG) firms producing intermediate goods, a final good (FG) producer, a capital good (CG) producer, a commercial bank, the government, and the central bank, which operates a managed float regime and conducts monetary policy through a standing facility. The country produces a continuum of intermediate goods, which are imperfect substitutes to a continuum of imported intermediate goods. Both categories of goods are combined to pro-
duce a homogeneous final good, which is either used for domestic consumption and investment, or exported.

### 1.2.1 Households

The objective of the representative household is to maximize

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_t^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - N_t^{1+\varsigma}) + \ln x_t^{\eta^x_t} H_t^{\eta_H} \right\},$$  \hspace{1cm} (1.1)

where $C_t$ is final good consumption, $N_t = \int_0^1 N_t^j d^j$, the share of total time endowment (normalized to unity) spent working, with $N_t^j$ denoting the number of hours of labor provided to IG producer $j$, $x_t$ a composite index of real monetary assets, $H_t$ the stock of housing, $\beta \in (0, 1)$ a discount factor, $\varsigma > 0$ the intertemporal elasticity of substitution in consumption, $\mathbb{E}_t$ the expectation operator conditional on the information available at the beginning of period $t$, and $\eta_N, \eta^x_t, \eta_H > 0$.

The composite monetary asset consists of real cash balances, $m_t^P$, and real bank deposits, $d_t$, both measured in terms of the price of final output, $P_t$:  \hspace{1cm} (1.2)

$$x_t = (m_t^P)^\nu d_t^{1-\nu}, \hspace{0.5cm} \nu \in (0, 1)$$

The household’s flow budget constraint is

$$m_t^P + d_t + b_t^P + z_t B_t^{F,P} + z_t^H \Delta H_t$$

$$= w_t N_t - T_t - C_t + \frac{m_{t-1}^P}{1 + \pi_t} + (1 + i_{t-1}^D) d_{t-1} + (1 + i_{t-1}^B) b_{t-1}^P$$

---

5There are two widely used methods of motivating money in New Keynesian DSGE models: "money-in-utility" function (MIU) and "cash-in-advance" constraint (CIA). We have adopted MIU specification over CIA as a matter of convenience. Using MIU function yields exactly the same Euler equation, labor supply equation, etc. as we could obtain in a real model without money balances; whereas in a CIA specification, the Euler equation would change and we will have to trace the Lagrangian multiplier on the CIA constraint.

6Both deposits and cash are accounted for because in this model with imperfect capital mobility the domestic bond rate is solved (as noted later) from the equilibrium condition of the currency market.
\(+ (1 + \delta_t^{E,P}) z_t B_t^{E,P} + J_t^D + J_t^K + J_t^B,\)

where \(z_t = E_t / P_t\) is the real exchange rate (with \(E_t\) the nominal exchange rate), 
\(z_t^H = P_t^H / P_t\) the real price of housing (with \(P_t^H\) the nominal price), 
\(1 + \pi_t = P_t / P_{t-1}\), 
\(b_t^P (B_t^{E,P})\) real (foreign-currency) holdings of one-period, noncontingent 
domestic (foreign) government bonds, \(i_t^D\) the interest rate on bank deposits, \(i_t^B\) and 
\(\delta_t^{E,P}\) interest rates on domestic and foreign government bonds, respectively, 
\(w_t\) the economy-wide real wage, \(T_t\) real lump-sum taxes, 
\(J_t^D = \int_0^1 (P_{j}^D J_{j}^D / P_t) dj\), \(J_t^K\), and 
\(J_t^B\), end-of-period profits of the IG producer, the CG producer, and the commercial 
bank. Housing does not depreciate and domestic government bonds are held only 
at home.

The gross rate of return on foreign bonds is defined as

\[1 + \delta_t^{E,P} = (1 + \delta_t^W)(1 - \theta_t^{E,P}),\]

(1.4)

where \(\delta_t^W\) is the risk-free world interest rate and \(\theta_t^{E,P}\) an endogenous spread, defined as

\[\theta_t^{E,P} = \frac{\theta_0^{E,P}}{2} B_t^{E,P},\]

(1.5)

with \(\theta_0^{E,P} > 0\). The household maximizes (1.1) with respect to \(C_t\), \(N_t\), \(m_{t+1}\), \(d_{t+1}\), 
\(b_{t+1}^P, B_{t+1}^{E,P}\), and \(H_{t+1}\), subject to (1.3), (1.4), and (1.5) taking as given period-\(t - 1\) 
variables as well as \(w_t\), \(T_t\), and real profits. The first-order conditions are

\[\mathbb{E}_t[(C_{t+1}^{1/\kappa})] = \beta \mathbb{E}_t\left( \frac{1 + \gamma_t^B}{1 + \pi_{t+1}} \right),\]

(1.6)

\[N_t = 1 - \frac{\eta NC_1^{1/\kappa}}{w_t},\]

(1.7)

\[m_t^P = \frac{\eta x \nu C_1^{1/\kappa} (1 + \gamma_t^B)}{\gamma_t^B},\]

(1.8)

\[d_t = \frac{\eta x (1 - \nu) C_1^{1/\kappa} (1 + \gamma_t^B)}{\gamma_t^B - \gamma_t^D},\]

(1.9)
\[ z^H_t H^d_t = \left\{ 1 - \mathbb{E}_t \left( \frac{1 + \pi^H_{t+1}}{1 + i^B_t} \right) \right\}^{-1} \eta H C^1_t, \]  
(1.10)

\[ B_t^{F,P} = \frac{(1 + i^W_t) \mathbb{E}_t (E_{t+1}/E_t) - (1 + i^B_t)}{\theta_0^{F,P} (1 + i^W_t) \mathbb{E}_t (E_{t+1}/E_t)}, \]  
(1.11)

where \( 1 + \pi^H_{t+1} = P^H_{t+1}/P^H_t \). Equation (1.11) yields uncovered interest parity when \( \theta_0^{F,P} \rightarrow 0. \)

### 1.2.2 Domestic Final Good

To produce the final good, \( Y_t \), a basket of domestically-produced differentiated intermediate goods, \( Y^D_t \), is combined with a basket of imported intermediate goods, \( Y^F_t \):

\[ Y_t = \left[ \Lambda_D(Y^D_t)^{(\eta-1)/\eta} + (1 - \Lambda_D)(Y^F_t)^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)}, \]  
(1.12)

where \( \Lambda_D \in (0, 1) \) and \( \eta > 0 \) is the elasticity of substitution between the two baskets, each of which defined as

\[ Y^i_t = \left\{ \int_0^1 [Y^i_{jt}]^{(\theta_i-1)/\theta_i} dj \right\}^{\theta_i/(\theta_i-1)}. \quad i = D, F \]  
(1.13)

In this expression, \( \theta_i > 1 \) is the elasticity of substitution between intermediate domestic goods among themselves \((i = D)\), and imported goods among themselves \((i = F)\), and \( Y^i_{jt} \) is the quantity of type-\( j \) intermediate good of category \( i \), with \( j \in (0, 1) \).

Cost minimization yields the demand functions for each variety of intermediate goods:

\[ Y^i_{jt} = \left( \frac{P^i_{jt}}{P^i_t} \right)^{-\theta_i} Y^i_t, \quad i = D, F \]  
(1.14)

where \( P^D_{jt} (P^F_{jt}) \) is the price of domestic (imported) intermediate good \( j \), and \( P^D_t \) and \( P^F_t \) are price indices, which are given from the zero-profit condition as

\[ P^i_t = \left\{ \int_0^1 (P^i_{jt})^{1-\theta_i} dj \right\}^{1/(1-\theta_i)}, \quad i = D, F \]  
(1.15)
so that $P_t^i Y_t^i = \int_0^1 P_t^j Y_t^j \, dj$. Demand for baskets of domestic and foreign goods is

$$Y_t^D = \Lambda_D^\eta (\frac{P_t^D}{P_t})^{-\eta} Y_t, \quad Y_t^F = (1 - \Lambda_D)^\eta (\frac{P_t^F}{P_t})^{-\eta} Y_t,$$  

(1.16)

where $P_t$ is the price of final output, given by

$$P_t = [\Lambda_D^\eta (P_t^D)^{1-\eta} + (1 - \Lambda_D)^\eta (P_t^F)^{1-\eta}]^{1/(1-\eta)}. $$  

(1.17)

We assume producer currency pricing and no transportation costs. The domestic-currency price of imported good $j$ is given by

$$P_{jt}^F = E_t F_{t-1}^F,$$  

(1.18)

where the foreign-currency price is normalized to unity and $\mu^F \in (0, 1)$ measures the degree of exchange rate pass-through. Thus, the law of one price holds only in the steady state.

Exports, $Y_t^X$, depend on the domestic-currency price of exports (which equals the exchange rate if the foreign-currency price is normalized to unity), relative to the price of goods sold domestically, $P_t^S$:

$$Y_t^X = (\frac{E_t}{P_t^S})^\kappa. \quad \kappa > 0$$  

(1.19)

Total output is thus also given by

$$Y_t = Y_t^S + Y_t^X,$$  

(1.20)

where $Y_t^S$ denotes the volume of final goods sold on the domestic market.
1.2.3 Domestic Intermediate Goods

Output of intermediate good \( j \), \( Y^D_{jt} \), is sold on a monopolistically competitive market and is produced by combining labor, \( N_{jt} \), and beginning-of-period capital, \( K_{jt} \):

\[
Y^D_{jt} = N_{jt}^{1-\alpha} K_{jt}^\alpha, \quad \alpha \in (0, 1)
\]  

(1.21)

Capital is rented from the CG producer (at the rate \( r^K_t \)) and paid for after the sale of output. Cost minimization yields the capital-labor ratio and the unit real marginal cost, \( mc_t \), as

\[
\frac{K_{jt}}{N_{jt}} = \left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{w_t}{r^K_t} \right), \quad \forall i
\]

(1.22)

\[
mc_t = \left( \frac{r^K_t}{\alpha} \right) \left( \frac{w_t}{1 - \alpha} \right)^{1-\alpha}.
\]

(1.23)

Each firm \( j \) chooses a sequence of prices so as to maximize the discounted present value of its profits:

\[
\{P^D_{jt+s}\}_{s=0}^\infty = \text{arg max } \sum_{s=0}^\infty \beta^s \lambda_{t+s} J^D_{jt+s},
\]

(1.24)

where \( \beta^s \lambda_{t+s} \) measures the marginal utility value to the representative household of an additional unit of real profits, \( J^D_{jt+s} \), received in the form of dividends at \( t + s \). In Rotemberg fashion, prices are costly to adjust; profits are thus defined as

\[
J^D_{jt} = \left( \frac{P^D_{jt}}{P^D_t} \right) Y^D_{jt} - mc_t Y^D_{jt} - \frac{\phi_D}{2} \left( \frac{P^D_{jt}}{P^D_{jt-1}} - 1 \right)^2 Y^D_{jt},
\]

(1.25)

where \( \phi_D \geq 0 \).

Using (1.14), the first-order condition for this problem takes the standard form

\[
(1 - \theta_D) \left( \frac{P^D_{jt}}{P^D_t} \right)^{- \theta_D} \frac{1}{P^D_t} + \theta_D \left( \frac{P^D_{jt}}{P^D_t} \right)^{- \theta_D - 1} \frac{mc_t}{P^D_t}
\]

(1.26)
\(-\phi_D \left\{ \frac{P^D_{jt}}{P^D_{jt-1}} - 1 \right\} \frac{1}{P^D_{jt-1}} \right\} + \beta \phi_D \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left( \frac{P^D_{jt+1}}{P^D_{jt}} - 1 \right) \frac{P^D_{jt+1}}{(P^D_{jt})^2} Y^D_{jt+1} \right\} = 0.\)

1.2.4 Capital Good

The aggregate capital stock, \( K_t = \int_0^1 K_j d\bar{j} \), is obtained by combining gross investment, \( I_t \), with the existing capital stock, adjusted for depreciation and adjustment costs:

\[
K_{t+1} = I_t + \left\{ 1 - \delta - \frac{\Theta_K}{2} \left( \frac{K_{t+1} - K_t}{K_t} \right)^2 \right\} K_t,
\]

(1.27)

where \( \delta \in (0, 1) \) is the depreciation rate and \( \Theta_K > 0 \).

Investment goods must be paid for in advance. The CG producer must therefore borrow from the bank \( l_t^I = I_t \). The household makes its exogenous housing stock, \( \bar{H} \), available without any direct charge to the CG producer, who uses it as collateral against which it borrows from the bank. Repayment is uncertain and occurs with probability \( q_t \in (0, 1) \). Expected repayment is thus \( q_t(1 + i_t^L)I_t + (1 - q_t)\kappa z_t^H \bar{H} \), where \( \kappa \in (0, 1) \) is the share of the housing stock that can be effectively pledged as collateral.

Subject to (1.27) and \( l_t^I = I_t \) the CG producer chooses the level of capital \( K_{t+1} \) so as to maximize the value of the discounted stream of dividend payments to the household. As shown by Agénor et al. (2014, 2015), the solution to this problem yields

\[
\mathbb{E}_t r^K_{t+1} = q_t (1 + i_t^L) \mathbb{E}_t \left\{ 1 + \Theta_K \left( \frac{K_{t+1}}{K_t} - 1 \right) \right\} \left( \frac{1 + i_t^B}{1 + \pi_{t+1}} \right) \]

(1.28)

\[-\mathbb{E}_t \left\{ q_{t+1}(1 + i_{t+1}^L) \left\{ 1 - \delta + \frac{\Theta_K}{2} \left( \frac{K_{t+2}}{K_{t+1}} \right)^2 - 1 \right\} \right\},\]

which boils down to the standard arbitrage condition \( \mathbb{E}_t r^K_{t+1} \simeq i_t^B - \mathbb{E}_t \pi_{t+1} + \delta \) in the absence of borrowing and adjustment costs.
1.2.5 Commercial Bank

The bank’s balance sheet is

\[ l_t^I + RR_t = d_t + z_t L_t^{F,B} + i_t^{C,B}, \]  

(1.29)

where \( L_t^{F,B} \) is foreign borrowing (in foreign-currency terms), \( i_t^{C,B} \) borrowing from the central bank, and \( RR_t \) required reserves, which are set as a fraction \( \mu_t^R \in (0, 1) \) of deposits:

\[ RR_t = \mu_t^R d_t. \]  

(1.30)

The bank’s cost of borrowing on world capital markets, \( i_t^{F,B} \), is defined as

\[ 1 + i_t^{F,B} = (1 + \tau_t^B)(1 + i_t^W)(1 + \theta_t^{F,B}), \]  

(1.31)

where \( \tau_t^B \in (0, 1) \) is a (Pigovian) tax imposed by the central bank and \( \theta_t^{F,B} \) is a risk premium that increases with the amount borrowed:

\[ \theta_t^{F,B} = \frac{\theta_0^{F,B}}{2} L_t^{F,B}, \]  

(1.32)

where \( \theta_0^{F,B} > 0 \).

The bank lasts one period and its expected real profits at the end of period \( t \) (or beginning of \( t + 1 \)) are defined as

\[ \mathbb{E}_t[(1 + \pi_{t+1}) J_{t+1}^R] = q_t (1 + i_t^C) l_t^I + (1 - q_t) \kappa z_t^H \bar{H} + \mu_t^R d_t - (1 + i_t^D) d_t \]  

(1.33)

\[ -(1 + i_t^C) l_t^{C,B} - (1 + i_t^{F,B}) \mathbb{E}_t \left( \frac{E_{t+1}}{E_t} \right) z_t L_t^{F,B}, \]

where \( i_t^C \) is the marginal cost of borrowing from the central bank, and \( \mu_t^R d_t \) the reserve requirements held at the central bank and returned to the bank at the end of the period. The other terms in (1.33) are self explanatory.
The bank sets the deposit and lending rates (offering therefore perfectly elastic demand for deposits and supply of loan) and determines foreign borrowing so as to maximize expected profits:

\[ i^D_t, i^L_t, L^{FB}_t = \arg \max \mathbb{E}_t[(1 + \pi_{t+1}) J^B_{t+1}]. \]  

(1.34)

Solving (1.34) subject to (1.29)-(1.33) yields

\[ i^D_t = (1 + \frac{1}{\eta_D})^{-1}(1 - \mu^R_t)i^C_t, \]  

(1.35)

\[ i^L_t = \frac{1 + i^C_t}{(1 + \eta_I^{-1})q_t} - 1, \]  

(1.36)

\[ L^{FB}_t = \frac{(1 + i^C_t) - (1 + \tau^B_t)(1 + i^W_t)\mathbb{E}_t(E_{t+1}/E_t)}{\theta_0^{FB}(1 + \tau^B_t)(1 + i^W_t)\mathbb{E}_t(E_{t+1}/E_t)}, \]  

(1.37)

where \( \eta_D, \eta_I > 0 \) are interest elasticities of the supply of deposits and the demand for loans, respectively.

The repayment probability depends positively on the expected value of collateral relative to the volume of loans, and the cyclical position of the economy:

\[ q_t = \left( \frac{\kappa\mathbb{E}_t z_{t+1}^H \bar{H}}{I_t^C} \right)^{\varphi_1} \left( \frac{Y_t}{\tilde{Y}} \right)^{\varphi_2}, \quad \varphi_1, \varphi_2 > 0 \]  

(1.38)

where \( \tilde{Y} \) is the steady-state level of final output.

1.2.6 Central Bank

The balance sheet of the central bank is given by

\[ z_t R^F_t + b^C_t + i^{C,B}_t - nw_t = m_t + RR_t, \]  

(1.39)

where \( z_t R^F_t \) denotes international reserves, \( b^C_t \) holdings of government bonds, \( m_t \) the real supply of cash, and \( nw_t \) the central bank’s real net worth.
The central bank’s reserve accumulation rule is defined as

\[ R_t^F = \left( \frac{E_tE_{t+1}}{E_t} \right)^{-\varphi^R} (R_{t-1}^F)^{\varphi^R} \left\{ (Y_t^F)^{\varphi^R} (L_{t}^{F,B} - B_{t}^{F,P})^{1-\varphi^R} \right\}^{1-\varphi^R}, \]  

(1.40)

where \( L_{t}^{F,B} - B_{t}^{F,P} \) denotes net private foreign-currency liabilities, \( Y_t^F \) imports, \( \varphi^R \geq 0 \) the degree of exchange rate smoothing, \( \varphi^R \in (0,1) \) the degree of persistence, and \( \varphi^R \in (0,1) \) the relative importance of the “trade” motive versus the “financial” motive in targeting reserves. The presence of the exchange rate in rule (1.40) is consistent with the evidence that middle-income countries tend to intervene frequently and systematically in the foreign exchange market to resist currency appreciation pressures.\(^7\)

Foreign exchange intervention is fully sterilized through open-market operations:

\[ z_t \Delta R_t^F + b_t^C - \frac{b_{t-1}^C}{1 + \pi_t} = 0. \]  

(1.41)

All income received by the central bank is transferred to the government; thus, changes in the nominal value of the central bank’s net worth are given by capital gains associated with exchange rate depreciation (\( \Delta NW_t = R_t^F \Delta S_t \)). Combining this result with (1.39) and (1.41) yields

\[ m_t = \frac{m_{t-1}}{1 + \pi_t} + (l_t^{C,B} - \frac{l_{t-1}^{C,B}}{1 + \pi_t}) - (RR_t - \frac{RR_{t-1}}{1 + \pi_t}). \]  

(1.42)

The central bank supplies liquidity elastically to the commercial bank, at a price that reflects both a base policy rate, \( i_t^R \), and a penalty charge. The base policy rate is set through a Taylor rule:

\[ \frac{1 + i_t^R}{1 + i_t^R} = \left( \frac{1 + i_t^R}{1 + i_t^R} \right)^{\chi} \left\{ \left( 1 + \frac{\pi_t^S}{1 + \pi_t^S} \right)^{\chi_1} \left( \frac{Y_t}{Y} \right)^{\chi_2} \right\}^{1-\chi}, \]  

(1.43)

\(^7\)See Daude et al. (2016) and Ghosh et al. (2017). In line with the empirical results of these contributions, we also experimented with the expected real exchange rate in the reserve accumulation equation. However, this did not make a significant difference to the results.
$R$ is the steady-state value of the policy rate, $\pi^{ST} \geq 0$ the central bank’s headline inflation target in terms of the price of goods sold domestically, $\chi \in (0, 1)$ and $\varepsilon_1, \varepsilon_2 > 0$.

The actual cost of borrowing for the bank is given by

$$1 + i_t^C = (1 + i_t^R)(1 + \theta_t^{C,B}),$$

(1.44)

where $\theta_t^{C,B}$ represents a penalty rate, which is positively related to the ratio of central bank borrowing to required reserves:

$$\theta_t^{C,B} = \theta_0^{C,B} \left( \frac{i_t^{C,B}}{RR_t} \right),$$

(1.45)

with $\theta_0^{C,B} > 0$. Thus, the penalty rate increases with the amount borrowed and falls with the amount of reserves held at the central bank, which act as (implicit) collateral, as for instance in Barnea et al. (2015). However, here collateral determines not the amount that can be borrowed from the central bank but rather the cost at which such borrowing occurs. This specification captures in a simple manner imperfect substitutability between (domestic) funding sources for the bank—a necessary condition for reserve requirements to be effective as a countercyclical instrument.

If the demand for deposits is sufficiently elastic, an increase in the required reserve ratio lowers the deposit rate as well as deposits and total required reserves, and therefore raises the premium at the initial level of central bank borrowing. The presence of imperfect substitution makes it therefore more expensive for financial intermediaries to replace deposits with central bank borrowing, and this increase in cost tends to feed into the market loan rate.
1.2.7 Government

The government budget constraint is given by

\[ b_t - \frac{b_{t-1}}{1 + \pi_t} = G_t - T_t + \frac{i_t^{B} b_{t-1}^{P}}{1 + \pi_t} \]

\[ + \tau_{t-1}^{W} L_{t-1}^{F,B} \frac{i_{t-1}^{W}}{1 + \pi_t} - (\frac{\tau_{t}^{C,B} i_{t-1}^{W}}{1 + \pi_t} + z_{t} i_{t-1}^{W} R_{t-1}^{F}), \]

where \( b_t = b_t^C + b_t^P \) is the real stock of riskless one-period bonds, and \( G_t \) real expenditure, which represents a fraction \( \psi \in (0,1) \) of domestic sales of the final good:

\[ G_t = \psi Y_t^S. \]

In what follows the government is assumed to keep its real stock of debt constant \( (b_t = b, \text{ for all } t) \) and to balance its budget by adjusting lump-sum taxes.

1.3 Equilibrium and Steady State

In a symmetric equilibrium, \( K_{jt} = K_t, N_{jt} = N_t, Y_{jt} = Y_t, P_{jt}^i = P_t^i, \) for all \( j \in (0,1) \) and \( i = D, F \). All IG firms produce the same output and prices are the same across firms.

Equilibrium in the goods market requires that sales on the domestic market be equal to domestic absorption inclusive of price adjustment costs, which are paid in real units:

\[ Y_t^S = C_t + G_t + I_t + \frac{\phi_D}{2} (\frac{P_{t}^{D}}{P_{t-1}^{D}} - 1)^2 (\frac{P_{t}^{D}}{P_{t}^{S}}) Y_t^D, \]

with the price of sales on the domestic market determined through the identity

\[ P_t Y_t = P_t^{S} Y_t^{S} + P_t^{X} Y_t^{X}. \]
currency market is thus

\[ m_t = m_t^p + l_t^l, \]  

(1.50)

from which the equilibrium bond rate can be determined.

The balance of payments is given by

\[ Y_t^X - Y_t^F + i_{t-1} W F_t - B_{t-1} L_{t-1} - L_{t-1} - F_t = 0, \]  

(1.51)

where \( F_t = R_t^F + B_t^F - L_t^F B \) is the economy’s net foreign asset position.

Finally, the risk-free world interest rate follows a first-order autoregressive process:

\[ \frac{1 + i_t^W}{1 + i_t^W} = (\frac{1 + i_{t-1}^W}{1 + i_t^W})^{\rho_W} \exp(\xi_t^W), \]

where \( \rho_W \in (0, 1) \) and the serially uncorrelated innovation \( \xi_t^W \) is normally distributed with mean zero and standard deviation \( \sigma_{\xi^W} \).

The steady-state solution of the model is derived in Appendix A. Its key features are similar to those described in Agénor et al. (2015), so we refer to those papers for a more detailed discussion.

### 1.4 Parameterization

The model is parameterized so that it reproduces in the benchmark experiment the main stylized facts associated with episodes of large capital inflows induces by financial “push” factors (real appreciation, current account deficit, lower interest rates, a credit boom, output expansion, and asset price pressures), as documented in Agénor and Montiel (2015) and Caballero (2016) for instance. Parameter values, which dwell in part on Agénor et al. (2015), are summarized in Table 1.1.

The discount factor \( \beta \) is set at 0.985, which gives an annual real interest rate of 6.2 percent. The intertemporal elasticity of substitution, \( \varsigma \), is 0.5, in line with estimates for middle-income countries (see Agénor and Montiel (2015)). The preference
parameter for leisure, $\eta_N$, is set at 10, to ensure that in the steady state households devote one third of their time endowment to market activity, as in Gertler et al. (2007) for instance. The preference parameters for composite monetary assets, $\eta_x$, is set at a low value, 0.02, to capture the common assumption in the literature that their weight in household preferences is negligible (see for instance Coenen et al. (2009)). The same value is used for the housing preference parameter, $\eta_H$. The share parameter in the index of money holdings, $\nu$, which corresponds to the relative share of cash in narrow money, is set at 0.35. This value is consistent with available data for middle-income countries. The sensitivity of the spread to household foreign bond holdings is set at 0.5.

The distribution parameter between domestic and imported intermediated goods in the production of the final good, $\Lambda_D$, is set at 0.7, to capture the case of a middle-income economy where imports are about a third of GDP, as in Medina and Roldós (2014) for instance. The elasticity of substitution between baskets of domestic and imported composite intermediate goods, $\eta$, is set at 1.5, a fairly standard value in the literature. The elasticities of substitution between intermediate domestic goods among themselves, $\theta_D$, and imported goods among themselves, $\theta_F$, are set equal at 10. The pass-through coefficient is set at $\mu^F = 0.3$, which is in line with the evidence on the strength of the pass-through effect in Latin America (see Inter-American Development Bank (2015, Appendix C)). The price elasticity of exports, $\kappa$, is set equal to 0.9, which is close to the value of unity used by Gertler et al. (2007) for Korea.

The share of capital in domestic output of intermediate goods, $\alpha$, is set at 0.35. With $\theta_D = 10$, the steady-state value of the markup rate, $\theta_D/(\theta_D - 1)$, is equal to 11.1 percent. The adjustment cost parameter for prices of domestic intermediate goods, $\phi_D$, is set at 74.5. This value implies a Calvo-type probability of not adjusting prices of approximately 0.71 percent per period or equivalently an average period of price fixity of about 3.5 quarters. These figures are consistent with the
estimates of Carvalho et al. (2014, Table 2) for Brazil. The rate of depreciation of private capital, $\delta$, is set equal to 0.02. The adjustment cost incurred by the CG producer for transforming the final good into investment, $\Theta_K$, is set at 14, to generate an investment path in response to shocks that is 2 to 3 times more volatile than domestic output, as documented in studies of macroeconomic fluctuations in developing countries (see Neumeyer and Perri (2005) for instance); this is the case in all the experiments that we report later on.

Regarding the commercial bank, the effective collateral-loan ratio, $\kappa$, is set at 0.2, to reflect inefficiencies in debt enforcement procedures in developing countries (see Djankov et al. (2008)). The elasticity of the repayment probability is set at $\varphi_1 = 0.1$ with respect to the effective collateral-loan ratio and $\varphi_2 = 0.3$ with respect to deviations in output from its steady state. Parameter $\theta_0^{F, R}$, which determines how the bank’s foreign borrowing responds to the differential in the cost of domestic and foreign borrowing, is set at 0.16; this value implies that bank foreign liabilities represent initially about 10 percent of their total liabilities, a reasonable benchmark in view of the evidence.

Regarding the central bank, the reserve requirement rate $\mu^R$ is set at 0.1, consistent with the data reported by Montoro and Moreno (2011) for some countries in Latin America. The degree of persistence in the central bank’s policy response, $\chi$, is set at 0.8 whereas, consistent with estimates of Taylor-type rules for middle-income countries, responses of the base policy rate to inflation and output deviations, $\varepsilon_1$ and $\varepsilon_2$, are set at 2.0 and 0.5, respectively (see for instance Moura and Carvalho (2010)). The sensitivity of the penalty rate to the bank borrowing-required reserve ratio, $\theta_0^{C, B}$, to a low value initially, 0.1, which is sufficient to illustrate the main points of our analysis. The parameter characterizing the degree of exchange rate smoothing in the foreign reserves targeting rule, $\varphi_1^R$, is set at 0.5 initially, to reflect a relatively low degree of intervention. The relative weight in the trade motive for self insurance is assumed to be predominant (compared to the capital account motive)
and accordingly the parameter $\varphi^R$ is set at 0.8, whereas the degree of persistence in the rule, $\varphi^R_2$, is set also at 0.8. Given our focus on temporary capital controls, we set the initial value of $\tau^B$ equal to 0. As in Gertler et al. (2007) and Agénor et al. (2014), the share of government spending in output, $\psi$, is set at 0.2. Finally, the degree of persistence of the shock to the world risk-free rate, $\rho_W$, is set at 0.8, which implies a fairly high degree of inertia.

1.5 Drop in World Risk-Free Interest Rate

To illustrate the impact of external financial shocks in the absence of capital controls, we consider a temporary drop in the world risk-free interest rate by 35 basis points at a quarterly rate, or about 141 basis points at an annual rate. The results of this experiment are displayed in Figure 1.1.$^8$

On impact, the shock lowers the return on foreign assets and the cost of borrowing abroad for the domestic bank. Thus, households’ holdings of foreign bonds decline, whereas the bank’s foreign liabilities increase initially; both combine to generate an inflow of capital, which leads to an appreciation of the domestic currency. Given that $\tau^B_t$ is constant in this experiment, the fall in the expected depreciation rate further lowers the (premium exclusive) cost of foreign borrowing measured in domestic currency terms, that is, the term $(1 + \tau^B_t)(1 + i^W_t)\mathbb{E}(E_{t+1}/E_t)$ in (1.37). As a result, the increase in bank foreign borrowing is magnified.

At the same time, the nominal appreciation lowers the domestic price of imported intermediate goods, which stimulates demand for this category of inputs and the production of final goods. It also tends to lower inflation (measured in terms of the price of domestic sales) but the increase in cyclical output, combined with higher real wages, tend to raise prices. The base policy rate therefore increases and so do

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$^8$The description of the transmission mechanism of a world interest rate shock differs here in several ways from Agénor et al. (2015); a key reason for that is that in the present case inflation increases on impact, despite the appreciation of the exchange rate, as a result of the increase in cyclical output and real wages.
the deposit and bond rates. However, because expected inflation increases by more, the real bond rate falls, thereby inducing households to increase consumption (as well as leisure) today. Moreover, the bond rate increases by more than the deposit rate, implying a reduction in bank deposits, as shown in the figure. Thus, despite the inflow of foreign borrowing, which tends to reduce bank borrowing from the monetary authority, the central bank borrowing-required reserves ratio increases, and so does the penalty rate. This, in turn, magnifies the increase in the refinancing rate induced by a higher base policy rate. The higher cost of borrowing from the central bank tends to raise the loan rate. At the same time, however, the boom in economic activity, combined with a strong collateral effect (related to the increase in real house prices), tend to increase the probability of repayment. This effect dominates the increase in the refinancing rate, implying therefore a fall in the loan rate.

In addition to an intertemporal effect on consumption, the fall in the real bond rate leads to an increase in the demand for housing services, which tends to raise real estate prices. In turn, this raises the value of the collateral that firms can pledge. But because the real loan rate falls initially, borrowing for investment outlays increases—so much so that the collateral-loan ratio falls, which tends to reduce the repayment probability. But because of the expansion of output, the net effect on the probability of repayment is positive. The nominal loan rate therefore falls. Thus, aggregate demand (spending on goods sold domestically) unambiguously increases on impact. In addition to the level effect on final output, there is also a composition effect: the appreciation of the nominal and real exchange rates translates into a drop in the share of final output allocated to exports, and an increase in the share sold domestically. Overall, the results of this experiment show that, consistent with the evidence, external shocks that lead to large inflows of capital generate a domestic boom characterized by increases in asset prices and aggregate demand, an expansion in output, inflationary pressures, real exchange rate appreciation, and a
current account deficit.

### 1.6 Optimal Simple Capital Controls Rule

In the foregoing discussion it was assumed that the tax rate on bank capital flows, \( \tau^B_t \), is kept constant. We consider now the case where the central bank implements countercyclical changes in the tax rate \( \tau^B_t \) by relating it to changes in foreign bank borrowing:

\[
1 + \tau^B_t = \left( 1 + \tau^B_{t-1} \right)^{1+\frac{L^F_B(t)}{L^F_B(t-1)}} \left\{ \frac{L^F_B(t)}{L^F_B(t-1)} \right\}^{1-\chi^B_1},
\]

where \( \chi^B_1 \in (0, 1) \) and \( \chi^B_2 > 0 \). To the extent that it raises the effective cost of foreign borrowing, this tax can be viewed as an unremunerated reserve requirement on banks’ (net) foreign exchange liabilities, of the type used by Chile during the period 1991-98 (see Gallego et al. (2002)) and more recently by Brazil and Thailand (see Abhakorn and Tantisantiwong (2012) and Chamon and Garcia (2016)). It is also consistent with the “macroprudential levy” implemented in August 2011 by the Bank of Korea, in an attempt to dampen the growth in banks’ foreign-currency liabilities, albeit without the maturity dimension (see Bruno and Shin (2014)). In practice, capital controls tend to take a permanent form or to be imposed during crisis (or pre-crisis) periods, rather than a time-varying rule of the type described in (1.52).\(^9\) Nevertheless, it provides a natural benchmark for a normative analysis of the benefits associated with market-based restrictions on cross-border bank-related capital flows, using simple, implementable rules.\(^10\)

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\(^9\)Fernández et al. (2013) examined the behavior of capital controls in 91 countries over the period 1995-2011. They found that these controls were acyclical, in the sense that policymakers did not seem to tighten capital controls on inflows or soften capital controls on outflows to curb expansions in aggregate activity, or overvaluations of the real exchange rate, or large current account deficits.

\(^10\)Note also that in the model, given that there is only one bank, in principle this form of capital controls could be seen as either microprudential or macroprudential—in the former case because it aims to mitigate financial risks at the level of the institution, and in the latter because its goal is to mitigate the volatility of (bank-related) capital flows, and thus systemic financial risks (see Ostry et al. (2012)). However, given our focus on social welfare, which depends on volatility of the financial system as a whole, we will consider (1.52) as fundamentally macroprudential in nature.
The results of the same interest rate experiment as described earlier are reported in Figure 1.2, together with the benchmark case, for $\chi_1^B = 0.2$ (implying therefore low persistence) and $\chi_2^B = 0.03$. They indicate that although interest rates and net private capital inflows (defined as steady-state log deviations in $L_t^{F,B} - B_t^{F,P}$) appear to be more volatile, movements in cross-border bank borrowing, exchange rates, and the real economy appear to be dampened. Intuitively, the increase in the tax rate $\tau_t^B$ induced by the initial acceleration in bank foreign borrowing helps to mitigate the fall in the (premium exclusive) cost of foreign borrowing measured in domestic-currency terms, that is, the term $(1 + \tau_t^B)(1 + i_t^W)E_t(E_{t+1}/E_t)$ in (1.37). As a result, the increase in bank foreign borrowing is partially reversed. In turn, this mitigates the impact of capital inflows on the nominal exchange rate, the domestic-currency price of imported intermediate goods, and therefore the expansionary effect of the shock on domestic output. At the same time, however, less foreign borrowing means (all else equal) more borrowing from the central bank, which in turn raises the cost at which the commercial bank borrows domestically. On impact this increase is not large; it is however more persistent during a number of periods. Because investment depends on future movements in the loan rate, it tends to fall immediately. Concomitantly, a weaker appreciation mitigates on impact the downward effect of the pass-through on inflation, which also contributes to a higher policy rate. A more volatile refinance rate translates into larger fluctuations in market interest rates, and thus increased volatility in private holdings of foreign bonds. Movements in these flows tend to dominate those in cross-border bank borrowing, thereby explaining why fluctuations in total private capital flows are magnified.\footnote{It is also worth keeping in mind that we are focusing here only on capital controls on foreign bank borrowing; adding endogenous controls on household holdings of foreign bonds would naturally help to mitigate volatility of total private capital flows.} In fact, these conflicting effects on volatility are the fundamental reason why, as discussed later, a welfare-maximizing solution for $\tau_t^B$ (or, more precisely, an optimal value of the reaction parameter $\chi_2^B$) exists.
To assess the robustness of the previous results, two sensitivity tests are conducted; one with respect to $\chi_1^B$, and another with respect to a different determinant of capital controls. The first test involves a value of $\chi_1^B$ equal to 0.8, to capture a high degree of inertia, while keeping $\chi_2^B$ at 0.03. The results are shown in Figure 1.3. They show indeed that, with greater inertia, countercyclical capital controls mitigate volatility across the board—including, this time, in the bond rate and foreign exchange reserves. Intuitively, with a higher degree of inertia, capital controls respond relatively less to contemporaneous changes in bank foreign borrowing; all else equal, to maximize social welfare a more aggressive response is therefore needed.

The second test involves capital controls responding to a broad measure of activity, cyclical output. The rule is thus similar to (1.52), with $L_t^{FB}/L_{t-1}^{FB}$ replaced now by $Y_t/\bar{Y}$. The results are reported in Figure 1.4, with a value of $\chi_1^B = 1$ for illustrative purposes. They indicate that the rule performs even better than a rule that responds to bank foreign borrowing; all variables display less volatility now, including total private capital inflows. The key reason is that market interest rates are now less volatile, implying also less volatility in household holdings of foreign bonds. At the same time, however, it is important to note that a rule based on cyclical output may be more difficult to implement in real time, due to uncertainty associated with initial output estimates and subsequent (and sometimes large) revisions.

We then solve for the welfare-maximizing value of the reaction parameter $\chi_2^B$, based on a second-order approximation of the model and of expected lifetime utility (1.1), conditional on the initial steady state ($t = 0$) being the deterministic steady state (see Kim and Kim (2003) and Schmitt-Grohé and Uribe (2004)). As shown in Appendix B, our measure of welfare, expressed in units of consumption, is

$$W_t \approx \frac{\tilde{C}_t^{1-\varsigma} \text{var}(\tilde{C}_t) \cdot \frac{\eta_N \tilde{N}_t^2}{2(\bar{N} - 1)^2 \text{var}(\tilde{N}_t)}}{1 - \beta},$$

where $\text{var}(\tilde{C}_t)$ and $\text{var}(\tilde{N}_t)$ denote the unconditional variances of (the log deviations
of) consumption and employment, and \( \dot{V} = \dot{C}^{1-\gamma^{-1}}/(1-\gamma^{-1}) + \eta_N \ln(1-\dot{N}) \). Thus, because at time \( t = 0 \) deviations of the model’s variables from their steady-state values are zero, the second-order approximate solution relates social welfare solely to second-order moments, namely, the volatility of private consumption and employment.\(^{12}\) Given the general equilibrium nature of the model, these measures also capture indirectly the effect of financial volatility.\(^{13}\)

The results are displayed by the continuous line in Figure 1.5 for the rule based on bank foreign borrowing, a constant reserve requirement rate, and for \( \chi_1^B = 0.2 \), again, to emphasize the fact that the proposed rule focuses on temporary controls. We use a grid step of 0.02, which is sufficient for our purpose. The figure shows clearly that one can indeed define a welfare-maximizing capital controls rule; the optimal value of \( \chi_2^B \) is 0.12. This value can also be read directly from the first line of Table 1.2. In addition, the table shows that a higher degree of persistence in the rule \( \chi_1^B = 0.8 \) implies a higher optimal degree of aggressiveness in the rule, that is, \( \chi_2^B = 0.2 \). Compared to the benchmark case of no policy intervention, the welfare gain is of the order of 0.5 percentage points with low persistence and 0.9 percentage points with high persistence.

Intuitively, the reason why a welfare-maximizing solution exists is because a more aggressive capital controls rule reduces volatility in the economy, but only up to a certain point. As noted earlier, such a policy reduces incentives for the bank to borrow abroad, thereby mitigating the impact of the world interest rate shock on capital inflows, the nominal exchange rate, the domestic-currency price of imported intermediate goods, and thus on domestic output. At the same time,

\(^{12}\)Given that the housing market is always equilibrium, and that the supply of housing is constant, the volatility of real house prices does not enter our measure of welfare.

\(^{13}\)In calculating welfare, we have followed the common practice of ignoring real money balances (see, for instance, Bergin et al. (2007) and De Fiore and Tristani (2013)). One way of justifying this choice is to note that there is a functional equivalence between using money as an argument of the utility function, and either entering it into liquidity costs (see Feenstra (1986)) or in a shopping time technology (see Croushore (1993)). Given this equivalence, accounting for money in the utility function is mainly a matter of convenience, rather than a reflection of a firm belief that it provides the proper micro-foundations of monetary theory. Ignoring it is therefore a sensible approach when evaluating welfare.
however, it increases the volatility of market interest rates. Initially, the former effect dominates and volatility of consumption and employment tends to fall, which implies that welfare increases. Beyond a certain point, however, the second effect begins to dominate; the increase in the volatility of market interest rates—namely, the loan rate, which affects private investment, and the bond rate, which affects the intertemporal allocation of consumption and the demand for bank deposits—is such that the net effect of a more aggressive capital controls policy is to increase the volatility of consumption and employment. The welfare-maximizing solution is the point at which the marginal benefits of a more aggressive policy are offset by the marginal costs. Put differently, it is never optimal to increase the tax on foreign borrowing to the point where it exactly offsets the drop in the world risk-free interest rate, thereby leaving the cost of foreign borrowing (given the expected depreciation rate) unchanged.

It is also important to understand the model mechanism and the margins where externalities and financial frictions can justify a role for government intervention. In our model, financial frictions arise from a default risk (or repayment probability) which depends on the value of collateral (i.e. housing assets). When a world interest rate shock hits the economy, asset price increases, default risk reduces, leading to a lower cost of borrowing and thus a higher amount of loans. The increase in the investment level also contributes to a higher output, which further increases the repayment probability, through a "financial accelerator" effect. The rational for capital controls is similar to Bianchi (2011) and Benigno et al. (2016) as mentioned in the introduction: The effects of an exogenous shock are magnified by financial frictions through a "financial accelerator", as a result, private agents tend to "overborrow" and the economy is "overheated". These pecuniary externalities

\[ \text{footnote}{Note that housing plays a crucial role in our model for three reasons: First, housing serves as a collateral where borrowers can pledge. Having housing as a collateral is well-documented and is commonly used in the macroeconomic literature (see, for example, Iacoviello (2005)). Second, our modelling strategy of housing markets provides a simple and intuitive way to introduce asset prices. Third, in our framework, house prices can affect the default risk and the degree of credit market imperfections, and thus the scope for government intervention.} \]
are not internalized by agents. However, if the financial regulator can intervene and use capital controls to limit the "overborrowing", the negative externalities would be corrected to some extent, thereby the economy is less vulnerable and welfare is enhanced.

In addition, in this setting, the interest rate volatility channel operates mainly because of the assumption of imperfect substitutability between deposits and central bank borrowing. With perfect substitutability (so that $\theta_0^{C,B} = 0$ in (1.45)), changes in bank foreign borrowing would have no direct effect on the central bank borrowing-required reserves ratio, and thus no direct impact on the refinance rate and market interest rates. Conversely, the higher $\theta_0^{C,B}$ is, the stronger would be the interest rate volatility channel associated with a more aggressive capital controls rule and the smaller should be the optimal value of $\chi_2^B$. This is indeed what is illustrated by the dotted line in Figure 1.5, which corresponds to $\theta_0^{C,B} = 0.12$ instead of $\theta_0^{C,B} = 0.1$ as in the benchmark case. The optimal value of the reaction parameter is now $\chi_2^B = 0.08$, instead of 0.12.

It is worth noting also that a qualitatively similar result can be obtained under perfect substitutability between deposits and central bank borrowing if we assume that banking activity involves a nonseparable cost between producing loans and funding sources. In such conditions, it can be easily be established that the loan rate would depend directly on the depreciation adjusted, premium-exclusive cost of foreign borrowing, $(1 + \tau_l^B)(1 + i_t^{E,B})E_t(E_{t+1}/E_t)$. However, we will continue to use specification (1.45) because imperfect substitutability between deposits and central bank borrowing is necessary in general to generate a countercyclical role for reserve requirements and because, as discussed next, we now turn to the welfare-maximizing combination of capital controls and reserve requirements.

To assess the performance of our optimal simple capital controls rule, we solve a Ramsey problem under which the central planner maximizes the social welfare subject to the private sector’s optimizing conditions. The Ramsey planner chooses
state-contingent allocations and prices to maximize welfare taking all the equilibrium conditions (except the capital controls rule) as given. To conduct welfare under the Ramsey optimal policy, we take a second-order approximation of all model equations, including the first-order conditions of the welfare maximization problem of the Ramsey planner. Following Woodford (2003), we focus on optimal commitment policy from a timeless perspective.\(^{15}\) Maximized welfare (relative to the benchmark case) is shown in the last line of Table 1.4. The results show that the optimal simple rule performs fairly well relative to the Ramsey policy; the gain associated with the latter is less than half of a basis point. In addition, as in Cúrdia and Woodford (2010) for instance, we assessed the closeness of the approximation by comparing the impulse responses under the optimal simple rule to those obtained under the Ramsey policy. The results (which are not reported here to save space) show again that the simple rule performs very well for all the main variables, compared to the Ramsey policy.

1.7 Capital Controls and Reserve Requirements

In the foregoing discussion it was assumed that the reserve requirement rate, \(\mu_t^R\), is kept constant. As discussed at length in Agénor et al. (2015), in recent years policymakers in middle-income countries have often used reserve requirements as part of a countercyclical toolkit to mitigate macroeconomic fluctuations caused by the capital inflows. Accordingly, we consider now the case where the central bank implements both the countercyclical capital controls simple rule specified in (1.52) and an equally simple, implementable countercyclical reserve requirement rule that relates (as in Agénor et al. (2015)) changes in \(\mu_t^R\) to deviations in the ratio of bank

\(^{15}\)Note that our model features distortions due to monopolistic competition on the goods market and financial frictions in the banking sector. We assume that subsidies are not available, so the decentralized equilibrium is not efficient—even in the nonstochastic equilibrium. Instead, as in most of the literature, we evaluate welfare around a distorted steady state and the constrained Ramsey planner can only achieve the second-best allocation.
loans to total output:

\[
\frac{1 + \mu_R^R}{1 + \bar{\mu}_R} = \left(1 + \mu_{t-1}^R\right)\chi_t^R \left\{\left(\frac{\mu_t^R}{\bar{\mu}_t^R}\right)\right\}^{1-\chi_t^R},
\]

where \(\chi_1^R \in (0, 1)\) and \(\chi_2^R > 0\).

The results are shown in Tables 1.2 and 1.3, for a capital controls rule involving either the change in bank foreign borrowing or cyclical output. There are two results that emerge from these tables. First, there is indeed an optimal combination of the reaction parameters in the countercyclical capital controls and reserve requirements rules that maximizes welfare. This combination is given by \((\chi_2^R = 0.04, \chi_2^R = 4)\) for a low degree of persistence in the capital controls rule \((\chi_1^R = 0.2)\) and by \((\chi_2^R = 0.12, \chi_2^R = 16)\) for a high degree of persistence in the capital controls rule \((\chi_1^R = 0.8)\), when the rule is specified in terms of changes in foreign bank borrowing (see in Table 1.2). Similar results are obtained when the rule is specified in terms of cyclical output, as shown in Table 1.3, where the grid step is now 2. This provides some rationale for the evidence suggesting that a number of middle-income countries have in recent years used both instruments to respond to swings in capital flows. The results also suggest that these instruments are complements, in the sense that in general both are needed to maximize welfare. Compared to the benchmark case of no policy intervention, the welfare gain associated with the welfare-maximizing policy is now of the order of 0.8 percentage points regardless of the degree of persistence in the capital controls rule.

Intuitively, the two policies are complements because, even though they operate through different channels, they both help to mitigate real and financial volatility. Capital controls operate through their direct impact on bank foreign borrowing and ultimately, as noted earlier, through their dampening effect on the initial downward movement in the loan rate. Reserve requirements, by contrast, operate through household portfolio allocation. A higher reserve requirement rate lowers the deposit...
rate and thus bank deposits. In the model, the drop in deposits is large enough to dominate the initial increase in foreign borrowing induced by lower world interest rates; as a result, commercial bank borrowing from the central bank increases, thereby raising the penalty rate, the refinance rate, and mitigating the initial drop in the loan rate.\textsuperscript{16} Thus, the two policies reinforce each other to the extent that they both contribute to maintaining market borrowing costs for capital producers at a higher level than they would otherwise be.

Second, the tables also show that when the response of both instruments is determined jointly, a more aggressive reserve requirement rule reduces reliance on capital controls—regardless of what they respond to. For instance, with a high degree of persistence in the capital controls rule ($\chi_1^B = 0.8$), the optimal response of capital controls to a change in bank foreign borrowing is $0.12$ instead of $0.2$, whereas the degree of aggressiveness in the reserve requirements rule increases from 0 to 16 (see Table 1.2). In that sense, countercyclical reserve requirements and capital controls can be viewed as \textit{partial substitutes} (at the margin) in maximizing welfare. Intuitively, the capital controls rule generates faster decreasing marginal returns (in terms of welfare) than the reserve requirements rule; thus, combining the two instruments makes the relationship between the degree of policy aggressiveness and welfare less concave, thereby generating a superior outcome with less reliance on restrictions on bank foreign borrowing. For the same reason the reverse does not hold; adding capital controls as a secondary instrument to countercyclical reserve requirements implies a more aggressive use of \textit{both} instruments. Thus, there is \textit{asymmetric} substitution between the two policy instruments.

Finally, although the focus of this paper has been on welfare, it is worth considering the behavior of individual volatility measures under alternative policy regimes.

\textsuperscript{16}As can be inferred from (1.45), even when central bank borrowing rises, the penalty rate could fall if the level of required reserves increases significantly. This could occur because, as can be inferred from (1.30), movements in $\mu^R$ and $d_t$ operate in opposite directions. Given our calibration, the net effect on required reserves is positive but relatively small, implying indeed that the penalty rate increases. See Agénor et al. (2015) for a more detailed discussion of countercyclical reserve requirement rules in an open economy.
Table 1.4 compares the asymptotic standard deviations of key variables under five cases, following the same world risk-free interest rate shock discussed earlier: no countercyclical policies \((\chi^B_2 = \chi^R_2 = 0)\), optimal capital controls \((\chi^B_2 = 0.12)\), the Ramsey optimal policy, optimal reserve requirements \((\chi^R_2 = 2)\), and optimal combination of the two simple rules \((\chi^B_2 = 0.04, \chi^R_2 = 4)\). The table confirms that capital controls and reserve requirements are highly effective in terms of mitigating the volatility of key macroeconomic and financial variables, and that the optimal capital controls rule performs well compared to the Ramsey optimal policy.\(^{17}\) The results also suggest that these tools are in general complements, meaning that their combination leads to the lowest levels of volatility for all the key real and financial variables. Indeed, if macroeconomic stability is defined in terms of the volatility of output and inflation, and financial stability (as in several recent contributions) in terms of the volatility of the credit-to-output ratio and the volatility of real house prices—two variables that have often been associated with financial crises—the results show that capital controls, especially when they are combined with countercyclical reserve requirements, are highly effective at promoting economic stability. Put differently, our welfare-based results are consistent with those that one would obtain by using an arbitrary policy loss function specified in terms of commonly-used measures of macroeconomic and financial stability.

### 1.8 Concluding Remarks

Dramatic shifts in capital flows into and out of many middle-income countries over the past few years have led some researcher and policymakers to question whether an open capital market is always welfare maximizing. Specifically, it has been shown that surges in capital flows can lead to excessive asset price volatility in these countries. If the terms at which agents borrow in these economies depend on collateral

\(^{17}\)Note that, in line with the foregoing discussion, the welfare-maximizing policies always imply a more volatile nominal bond rate. However, consumption, which depends on the real bond rate, is always less volatile.
values, these fluctuations in asset prices act to magnify fluctuations in economic activity. In such conditions, there may be a role for policy to control these excessive capital inflows and outflows and reduce volatility in collateral values.

This paper studied the performance of time-varying capital controls on cross-border bank borrowing in an open-economy model with credit market imperfections and imperfect capital mobility. The model was parameterized for a middle-income country and was shown to replicate the main stylized facts associated with a shock to the world risk-free interest rate (capital inflows, real appreciation, credit boom, asset price pressures, and an expansion in economic activity). A simple, implementable capital controls rule, based on changes in bank borrowing abroad, was then specified. Because its goal is to mitigate the volatility of (bank-related) capital flows, and thus indirectly financial volatility, the rule is fundamentally macroprudential in nature. A welfare-maximizing policy, defined in terms of the degree of aggressiveness of the rule, was established numerically. In addition, it was shown that the optimal simple capital controls rule performs well relative to the Ramsey policy.

The analysis was next extended to solve jointly for optimal countercyclical reserve requirements and capital controls simple rules, implying that the two instruments are in general complements. Put differently, if reserve requirements are viewed as an implicit tax on financial intermediation, it is optimal to tax banks on both components of their market funding sources at a business cycle frequency. However, it was also shown that a more aggressive reserve requirement rule (which responds to the credit-output ratio) induces less reliance on capital controls; thus, at the margin, the two instruments are partial substitutes from the perspective of welfare maximization. These results remain qualitatively unchanged when the countercyclical capital controls rule displays persistence or responds to cyclical output. Beyond the specific tools considered here, our results have broader implications for the ongoing debate regarding the extent to which countercyclical macroprudential instruments are complements or substitutes in promoting financial stability.
A useful extension would be to study the potential implementation costs of capital controls. By and large, the evidence suggests that incentives to evade restrictions on capital flows become stronger over time when they take a permanent form. The capital controls rule studied in this paper operates at a business cycle frequency; it is therefore less likely to induce this type of distortions. Nevertheless, it is possible that even in the short term tighter restrictions on bank foreign borrowing (as discussed here) may lead to a shift in the behavior of the nonfinancial private sector which is such that it weakens the performance of these controls. If the implementation costs of capital control regulations were included in our analysis, the welfare benefits of using macroprudential capital controls may become smaller or even negative.

A related issue is the possibility, as documented by Beirne and Friedrich (2014) and Bruno et al. (2015), that controls on some types of inflows may lead over time to substitution or spillover effects. A key question then is whether there are important gains from capital controls despite the existence of of implementation costs. Considering an environment where pecuniary externalities call for prudential capital controls, Bengui and Bianchi (2014) examine the effectiveness of capital controls, taking into account the leakages arising from limited regulation enforcement. In their modelling framework, the financial regulator can only enforce capital controls on a subset of the population. They show that regulated agents reduce their risk-taking decisions in response to capital controls whereas unregulated agents tend to perceive that crises are less likely and hence respond by taking on more debt, thereby undermining the effectiveness of the controls. They find that leakages do not necessarily make macroprudential policy less desirable, and that stabilization gains remain large despite leakages.

Another useful extension would be to study the impact of capital controls in a multi-country world. There has been a growing number of contributions that account for the spillover effects of capital controls. Forbes et al. (2016) for instance found portfolio effects (indirect effects) and externalities from capital controls in Brazil,
and they suggested that the assessment of capital controls should consider their effects on portfolio effects to other countries. Similarly, Fratzscher (2014), Ghosh et al. (2014), and Giordani et al. (2017) found evidence of cross-border spillovers whereby capital controls imposed by countries are associated with larger flows to other countries. They also argued that capital account restrictions can significantly influence the volume of cross-border flows. Finally, focusing on a sample of Latin-American countries, Lambert et al. (2011) investigated the potential spillover effects that capital account restrictions imposed on one country may have on neighboring countries. They also found that a rise in the Brazilian tax on capital inflows had negative cross-border externalities. A multi-country analysis of capital controls that internalizes this type of spillover effects could help to define optimal rules for the global economy.
1.9 Appendix

Appendix A

Steady-State Solution

Steady-state values of all endogenous variables (denoted by tildes) are calculated by dropping all time subscripts from the relevant equations.

From (1.43), with $Y_t = \tilde{Y}$,

$$\tilde{\pi}^S = \tilde{\pi}^{S,T},$$

(1.54)

which implies that in the steady state, inflation is equal to its target value. The focus in what follows is on the case where $\pi^{S,T} = \tilde{\pi}^S = 0$.

From (1.6), one obtains $\beta/(1 + \pi^T) = 1/(1 + \tilde{i}^B)$, which implies that with $\pi^T = 0$ the steady-state value of the bond rate is

$$\tilde{i}^B = \beta^{-1} - 1.$$

(1.55)

In the steady state, it must be also that

$$\tilde{i}^B = \tilde{i}^R,$$

(1.56)

which implies that the bank has no incentive to borrow from the central bank to buy government bonds.

From (1.7), (1.8), (1.9), (1.10), and (1.11), the household’s demand for cash, bank deposits, housing services, and foreign bonds are

$$\tilde{N} = 1 - \frac{\eta_N \tilde{C}^{1/\kappa}}{\tilde{w}},$$

(1.57)

$$\tilde{m}^p = \frac{\eta_p \nu \tilde{C}^{1/\kappa}(1 + \tilde{i}^B)}{\tilde{i}^B},$$

(1.58)

$$\tilde{d} = \frac{\eta_d (1 - \nu) \tilde{C}^{1/\kappa}(1 + \tilde{i}^B)}{\tilde{i}^B - \tilde{i}^D},$$

(1.59)
\[ \hat{z}^H \hat{H}^d = \left\{ 1 - \left( \frac{1 + \hat{z}^H}{1 + \bar{i} B} \right)^{\gamma_H} \right\}^{-1} \left[ \frac{\gamma_H}{(c')^{-1/\gamma_H}} \right], \quad (1.60) \]

\[ \hat{P}_{FP} = \frac{\bar{i}^W - \bar{i} B}{\theta_{0}^{P,F} (1 + \bar{i} W)}. \quad (1.61) \]

From (1.16), steady-state demand for domestic and foreign intermediate goods is given by

\[ \hat{Y}^D = \Lambda_D^\eta \left( \frac{\hat{P}^D}{\bar{P}} \right)^{-\eta} \hat{Y}, \quad \hat{Y}^F = (1 - \Lambda_D)^\eta \left( \frac{\hat{P}^F}{\bar{P}} \right)^{-\eta} \hat{Y}. \quad (1.62a) \]

From (1.17) the steady-state value of the price of final output is

\[ \hat{P} = \left[ \Lambda_D^\eta (\hat{P}^D)^{1-\eta} + (1 - \Lambda_D)^\eta (\hat{P}^F)^{1-\eta} \right]^{1/(1-\eta)}. \quad (1.63) \]

From (1.18), the steady-state value of the price of foreign imported intermediate goods is obtained as:

\[ \hat{P}^F = \bar{E}. \quad (1.64) \]

From (1.19), the steady-state value of exports is

\[ \hat{Y}^X = Y_0^X \left( \frac{\bar{E}}{\bar{P}^S} \right)^{\kappa}, \quad (1.65) \]

From (1.20), the steady-state value of the domestic final good is given by

\[ \hat{Y} = \hat{Y}^S + \hat{Y}^X. \quad (1.66) \]

From (1.21), steady-state output of domestic intermediate goods is given by

\[ \hat{Y}^D = \hat{N}^{1-\alpha} \hat{K}^\alpha. \quad (1.67) \]

From (1.22), the steady-state condition describing the optimal utilization of production factors is

\[ \frac{\hat{K}}{\hat{N}} = \left( \frac{\alpha}{1-\alpha} \right) \left( \frac{\hat{w}}{\bar{i} \hat{K}} \right), \quad (1.68) \]
which can be solved for the steady-state real wage.

Price adjustment costs are zero in the steady state. Under symmetry, the price adjustment equation (1.26) becomes

\[ m_c t = \frac{\theta_D - 1}{\theta_D} + \frac{\phi_D}{\theta_D} \left[ \pi_t^D (1 + \pi_t^D) \right] - \frac{\phi_D}{\theta_D} E_t \left\{ \rho_{t,t+1} \pi_{t+1}^D (1 + \pi_{t+1}^D) \left( \frac{Y_{t+1}^D}{Y_t^D} \right) \right\}, \]

where \( \rho_{t,t+1} = \beta \lambda_t / \lambda_{t+1} \). Thus, the steady-state value of the marginal cost is

\[ \tilde{m}_c = \frac{\theta_D - 1}{\theta_D}. \] (1.69)

In the steady state, with \( K_{t+1} = K_t, 0.5 \Theta (\tilde{K} / \tilde{K} - 1)^2 \tilde{K} = 0 \); thus, capital adjustment costs are zero. Substituting this result in (1.27) yields

\[ \tilde{I} = \delta \tilde{K}. \] (1.70)

Using (1.55) and (1.28) gives the steady-state value of the rental rate of capital:

\[ \tilde{r}_K = \tilde{q}(1 + \tilde{i}^L)(\beta^{-1} - 1 + \delta). \] (1.71)

From (1.35), (1.36), and (1.37), the steady-state values of the deposit rate, the loan rate, and bank foreign borrowing are

\[ \tilde{i}^D = (1 + \frac{1}{\eta_D})^{-1} (1 - \tilde{\mu}^R) \tilde{i}^C, \] (1.72)

\[ 1 + \tilde{i}^L = \frac{1 + \tilde{i}^C}{(1 + \eta_I^{-1}) \tilde{q}}; \] (1.73)

\[ \tilde{L}^{FB} = \frac{\tilde{i}^C - \tilde{i}^W}{\theta_0^{FB} (1 + \tilde{i}^W)}. \] (1.74)

Note that, to ensure that \( \tilde{i}^L > 0 \), we must have \( |\eta_I| > 1 \), together with \( \eta_I < 0 \).
Setting $Y_t = \tilde{Y}$ in (1.38), the steady-state value of the repayment probability is

$$\tilde{q} = \left(\frac{\kappa \tilde{z} H}{\tilde{I}}\right)^{\tilde{p}_1}. \quad (1.75)$$

The amount of loans demanded by the CG producer is $\tilde{l} = \tilde{I}$. From (1.29), the steady-state level of the bank’s borrowing from the central bank is determined residually as

$$\tilde{l}^{C,B} = \tilde{I} - \tilde{z}^{B,F,B} - (1 - \tilde{\mu}^R)\tilde{d}. \quad (1.76)$$

From (1.40), the steady-state level of the central bank’s foreign reserves is

$$\tilde{R}^F = (\phi_1^R \tilde{Y}^F)^{\tilde{p}_R} \left[\phi_2^R (\tilde{L}^{F,B} - \tilde{B}^{F,P})\right]^{1-\tilde{p}_R}. \quad (1.77)$$

From (1.44) and (1.45), the steady-state value of the cost of borrowing from the central bank is

$$1 + \tilde{r}^C = (1 + \tilde{r}^R)[1 + \theta_0^{C,B}(\frac{\tilde{l}^{C,B}}{\tilde{\mu}^R \tilde{d}})]. \quad (1.78)$$

With again $\tilde{\pi}^S = \pi^{S,T} = 0$, from (1.46) and (1.47), the steady-state value of lump-sum taxes is

$$\tilde{T} = \psi \tilde{Y}^S + \tilde{r}^B \tilde{b}^P - \tilde{r}^R \tilde{l}^{C,B} - \tilde{r}^W \tilde{z}^{R,F}. \quad (1.79)$$

The equilibrium condition of the goods market, equation (1.48), yields the steady-state condition $\tilde{Y}^S = \tilde{C} + \tilde{G} + \tilde{I}$, which can be rearranged, using (1.47) and (1.70), to give

$$\tilde{Y}^S = \frac{\tilde{C} + \delta \tilde{K}}{1 - \psi}. \quad (1.79)$$

The steady-state price of sales on the domestic market is, from (1.49):

$$\tilde{P}^S = (\tilde{P}^Y - \tilde{P}^X \tilde{Y}^X) / \tilde{Y}^S. \quad (1.80)$$
From (1.50), the equilibrium condition of the market for cash yields

\[ \tilde{m} = \tilde{m}^P + \tilde{l}^r. \]

From (1.41), with \( \Delta R_t^F = 0 \), the stock of bonds held by the central bank is constant in the steady state; Given that the overall stock of bonds is also constant, household holdings of government bonds are given by

\[ \tilde{b}^P = b - \tilde{b}^C. \]  

(1.81)

The steady-state equilibrium condition of the market for foreign exchange, equation (1.51), yields

\[ \tilde{Y}^X - \tilde{Y}^F + \tilde{W} \tilde{F} + \tilde{\theta}^F \tilde{B}^F - \tilde{\theta}^F \tilde{L}^F = 0, \]  

(1.82)

whereas the economy’s net foreign asset position is

\[ \tilde{F} = \tilde{R}^F + \tilde{B}^F - \tilde{L}^F. \]
Appendix B

Welfare Analysis

Our welfare calculations are based on a second-order approximation to the household’s period utility function around the deterministic steady state. As documented in the literature (see Kim and Kim (2003) and Schmitt-Grohé and Uribe (2004)), a first-order approximation is inaccurate to perform welfare comparisons across alternative stochastic environments. Moreover, a correct second-order approximation of the equilibrium welfare function requires a second-order approximation to the model characterizing the economy. Thus, in this study, as for instance in Chang et al. (2015), second-order approximation techniques are used for both the utility function and the economy.

Given that the housing market is always equilibrium, and that the supply of housing is constant, the utility benefit from housing services is also constant and can be ignored. Further, as noted in the text, and following standard methodology, we abstract from the utility derived from money balances. From (1.1), the present discounted value of the household’s expected utility function, conditional on the initial state’s \((t = 0)\) being the deterministic steady state, becomes

\[
U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s V_{t+s} = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_{t+s}^{1-\gamma}}{1 - \beta^s} + \eta N \ln(1 - N_{t+s}) \right\},
\]

(1.83)

where \(V_t = V(C_t, N_t)\) is the period utility function. Taking a second-order approximation to \(V_t\) around the deterministic steady state yields

\[
V(C_t, N_t) \approx V(\bar{C}, \bar{N}) + V_C(\bar{C}, \bar{N})(C_t - \bar{C}) + V_N(\bar{C}, \bar{N})(N_t - \bar{N}) + \frac{1}{2} V_{CC}(\bar{C}, \bar{N})(C_t - \bar{C})^2 \\
+ \frac{1}{2} V_{NN}(\bar{C}, \bar{N})(N_t - \bar{N})^2 + V_{CN}(\bar{C}, \bar{N})(C_t - \bar{C})(N_t - \bar{N}) + O(||\xi||^3),
\]

where \(O(||\xi||^3)\) is a third-order residual term. Ignoring that term, this approximation
can be rewritten as

\[
V(C_t, N_t) \simeq \frac{\tilde{C}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - \tilde{N}) + \tilde{C}^{-\varsigma^{-1}}(C_t - \tilde{C}) + \frac{\eta_N}{N - 1}(N_t - \tilde{N}) - \frac{1}{2\varsigma} \tilde{C}^{-\varsigma^{-1}-1}(C_t - \tilde{C})^2 - \frac{\eta_N}{2(N - 1)^2}(N_t - \tilde{N})^2,
\]

or equivalently

\[
V(C_t, N_t) \simeq \frac{\tilde{C}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - \tilde{N}) + \tilde{C}^{1-\varsigma^{-1}} \tilde{C}_t + \frac{\eta_N \tilde{N}}{N - 1} \tilde{N}_t - \frac{1}{2\varsigma} \tilde{C}^{1-\varsigma^{-1}} \tilde{C}^2_t - \frac{\eta_N \tilde{N}^2}{2(N - 1)^2} \tilde{N}_t^2,
\]

where \( \tilde{C}_t \) and \( \tilde{N}_t \) denote log-deviations of \( C_t \) and \( N_t \) from their steady-state values.

The unconditional expectation of the value function, which is the expected infinite discounted sum of the period utilities, is given by

\[
U_t = E_t \sum_{s=0}^{\infty} \beta^s V_{t+s} \simeq \frac{1}{1 - \beta} \left\{ \frac{\tilde{C}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - \tilde{N}) \right\} - \frac{1}{2\varsigma} \tilde{C}^{1-\varsigma^{-1}} \text{var}(\tilde{C}_t) - \frac{\eta_N \tilde{N}^2}{2(N - 1)^2} \text{var}(\tilde{N}_t),
\]

where \( \text{var}(x_t) \) denotes the unconditional variance of \( x_t \), calculated from period \( t \) to infinity. In deriving (1.84) The fact that the unconditional expectation of log-deviations from steady state is zero, that is, \( E(\tilde{X}_t) = 0 \), was used.

To express welfare in units of consumption, we divide the value function by the marginal utility of consumption evaluated at the steady state, \( \tilde{C}^{-\varsigma^{-1}} \), and denote this welfare measure by \( W_t \). We therefore have

\[
W_t \simeq \frac{\tilde{C}^{\varsigma^{-1}}}{1 - \beta} \left\{ \tilde{V} - \frac{1}{2\varsigma} \tilde{C}^{1-\varsigma^{-1}} \text{var}(\tilde{C}_t) - \frac{\eta_N \tilde{N}^2}{2(N - 1)^2} \text{var}(\tilde{N}_t) \right\},
\]

where

\[
\tilde{V} = \frac{\tilde{C}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - \tilde{N}).
\]
Thus, to compute welfare under alternative policy rules, it is sufficient to compute the unconditional variances of consumption and employment in the model and plug them into equation (1.85).
Table 1.1: Benchmark Parameterization: Key Parameter Values

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<td>Preference parameter for money holdings</td>
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Table 1.2: Optimal Degree of Aggressiveness of the Capital Controls Rule and Reserve Requirements Rule I

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Low degree of persistence in capital controls rule, χ₁ = 0.2

High degree of persistence in capital controls rule, χ₁ = 0.8

Note: Entries in this table represent welfare, measured in terms of consumption units, relative to the benchmark case where there are no rules under operation, that is, the case of χ₁ = χ₂ = 0.

Source: Authors’ calculations.
### Table 1.3: Optimal Degree of Aggressiveness of the Capital Controls Rule and Reserve Requirements Rule II

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<td>1.00237</td>
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<td>1.00672</td>
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<td>1.00791</td>
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<td>1.00570</td>
<td>1.00659</td>
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<td>1.00771</td>
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<td>1.00399</td>
<td>1.00449</td>
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<tr>
<td>20</td>
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<td>0.99923</td>
<td>1.00174</td>
<td>1.00310</td>
<td>1.00398</td>
<td>1.00459</td>
<td>1.00504</td>
<td>1.00537</td>
<td>1.00561</td>
<td>1.00579</td>
<td>1.00592</td>
<td>1.00592</td>
</tr>
</tbody>
</table>

| High degree of persistence in capital controls rule, $\delta_1 = 0.8$ | | | | | | | | | | | | |
| 0          | 1.0000     | 1.00309 | 1.00353 | 1.00365 | 1.00369 | 1.00371 | 1.00372 | 1.00373 | 1.00373 | 1.00373 | 1.00373 | 1.00373 |
| 2          | 1.00024    | 1.00658 | 1.00663 | 1.00638 | 1.00612 | 1.00591 | 1.00573 | 1.00559 | 1.00547 | 1.00536 | 1.00527 | 1.00527 |
| 4          | 1.00200    | 1.00702 | 1.00772 | 1.00767 | 1.00747 | 1.00725 | 1.00704 | 1.00686 | 1.00670 | 1.00656 | 1.00643 | 1.00643 |
| 6          | 1.00035    | 1.00640 | 1.00764 | 1.00816 | 1.00814 | 1.00802 | 1.00787 | 1.00771 | 1.00756 | 1.00743 | 1.00730 | 1.00730 |
| 8          | 0.99885    | 1.00540 | 1.00743 | 1.00812 | 1.00835 | 1.00838 | 1.00832 | 1.00823 | 1.00813 | 1.00802 | 1.00791 | 1.00791 |
| 10         | 0.99759    | 1.00427 | 1.00671 | 1.00774 | 1.00820 | 1.00839 | 1.00846 | 1.00846 | 1.00841 | 1.00836 | 1.00829 | 1.00829 |
| 12         | 0.99653    | 1.00312 | 1.00581 | 1.00709 | 1.00775 | 1.00811 | 1.00831 | 1.00840 | 1.00844 | 1.00844 | 1.00842 | 1.00842 |
| 14         | 0.99563    | 1.00201 | 1.00479 | 1.00623 | 1.00706 | 1.00756 | 1.00787 | 1.00806 | 1.00818 | 1.00825 | 1.00828 | 1.00828 |
| 16         | 0.99487    | 1.00095 | 1.00369 | 1.00519 | 1.00612 | 1.00672 | 1.00713 | 1.00741 | 1.00760 | 1.00773 | 1.00782 | 1.00782 |
| 18         | 0.99422    | 0.99995 | 1.00254 | 1.00400 | 1.00495 | 1.00560 | 1.00607 | 1.00641 | 1.00666 | 1.00684 | 1.00697 | 1.00697 |
| 20         | 0.99365    | 0.99900 | 1.00135 | 1.00267 | 1.00354 | 1.00417 | 1.00464 | 1.00499 | 1.00527 | 1.00547 | 1.00563 | 1.00563 |

Note: Entries in this table represent welfare, measured in terms of consumption units, relative to the benchmark case where there are no rules under operation, that is, the case of $\delta_1 = \delta_2 = 0$.

Source: Authors’ calculations.
Table 1.4: Asymptotic Standard Deviations of Key Variables under Alternative Policy Regimes

<table>
<thead>
<tr>
<th></th>
<th>No counter-cyclical policies</th>
<th>Optimal capital controls</th>
<th>Ramsey policy</th>
<th>Optimal res. requirements</th>
<th>Optimal combination</th>
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<tr>
<td><strong>Real variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic sales, final</td>
<td>0.0035</td>
<td>0.0022</td>
<td>0.0021</td>
<td>0.0018</td>
<td>0.0012</td>
</tr>
<tr>
<td>good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>0.0020</td>
<td>0.0019</td>
<td>0.0017</td>
<td>0.0013</td>
<td>0.0012</td>
</tr>
<tr>
<td>Investment</td>
<td>0.0078</td>
<td>0.0049</td>
<td>0.0044</td>
<td>0.0038</td>
<td>0.0025</td>
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<tr>
<td>Consumption</td>
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<td>0.0008</td>
<td>0.0007</td>
<td>0.0007</td>
<td>0.0006</td>
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<tr>
<td>Real exchange rate</td>
<td>0.0034</td>
<td>0.0028</td>
<td>0.0025</td>
<td>0.0040</td>
<td>0.0026</td>
</tr>
<tr>
<td>Exports</td>
<td>0.0031</td>
<td>0.0025</td>
<td>0.0025</td>
<td>0.0036</td>
<td>0.0023</td>
</tr>
<tr>
<td>Price inflation</td>
<td>0.0010</td>
<td>0.0011</td>
<td>0.0010</td>
<td>0.0009</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Financial variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base policy rate</td>
<td>0.0023</td>
<td>0.0024</td>
<td>0.0019</td>
<td>0.0018</td>
<td>0.0016</td>
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<tr>
<td>Refinance rate</td>
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<td>0.0020</td>
<td>0.0018</td>
<td>0.0017</td>
<td>0.0007</td>
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<tr>
<td>Loan rate</td>
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<td>0.0005</td>
<td>0.0003</td>
<td>0.0002</td>
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<tr>
<td>Loan-refinance rate</td>
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<td>0.0024</td>
<td>0.0026</td>
<td>0.0016</td>
<td>0.0013</td>
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<td>Government bond rate</td>
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<td>0.0006</td>
<td>0.0006</td>
<td>0.0005</td>
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<tr>
<td>Real house prices</td>
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<td>0.0016</td>
<td>0.0018</td>
<td>0.0015</td>
<td>0.0012</td>
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<tr>
<td>Repayment probability</td>
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<td>0.0006</td>
<td>0.0005</td>
<td>0.0004</td>
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<tr>
<td>Loan-to-output ratio</td>
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<td>0.0027</td>
<td>0.0021</td>
<td>0.0020</td>
<td>0.0014</td>
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<tr>
<td>Bank foreign lending</td>
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<td>0.3591</td>
<td>0.3176</td>
<td>0.3952</td>
<td>0.3539</td>
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<tr>
<td>Private capital inflows</td>
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<td>0.1933</td>
<td>0.1424</td>
<td>0.1364</td>
<td>0.1763</td>
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<tr>
<td>Official foreign reserves</td>
<td>0.0024</td>
<td>0.0035</td>
<td>0.0033</td>
<td>0.0026</td>
<td>0.0025</td>
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<tr>
<td><strong>Maximized welfare</strong></td>
<td>--</td>
<td>1.0011</td>
<td>1.0016</td>
<td>1.0032</td>
<td>1.0045</td>
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</table>

Note: Entries in the last line represent welfare, measured in terms of consumption units, relative to the benchmark case (no countercyclical policies). The results in columns 2, 3 and 4 are calculated for $\alpha_1^F = 0.2$. 
Figure 1.1: Experiment: Transitory Drop in the World Risk-Free interest Rate Benchmark Case

Note: Interest rates, inflation, and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. The real exchange rate is defined as the ratio of the nominal exchange rate divided by the price of final goods.
Figure 1.2: Experiment: Transitory Drop in the World Risk-Free interest Rate Benchmark Case and Endogenous Countercyclical Capital Controls Rule

Note: Interest rates, inflation, and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. The real exchange rate is defined as the ratio of the nominal exchange rate divided by the price of final goods.
Figure 1.3: Experiment: Transitory Drop in the World Risk-Free interest Rate Alternative Endogenous Countercyclical Capital Controls Rule

Note: Interest rates, inflation, and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. The real exchange rate is defined as the ratio of the nominal exchange rate divided by the price of final goods.
Figure 1.4: Experiment: Transitory Drop in the World Risk-Free interest Rate Benchmark Case and Endogenous Countercyclical Capital Controls Rule Responding to Cyclical Output

Note: Interest rates, inflation, and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. The real exchange rate is defined as the ratio of the nominal exchange rate divided by the price of final goods.
Note: The rule is based on bank foreign borrowing and $\chi_1^B = 0.2$. The value of $\chi_2^B$ in the capital controls rule is calculated on the basis of a second-order approximation of the utility function and the equations of the model. Values on the vertical axis of this graph represent welfare, measured in terms of consumption units, relative to the benchmark case where there are no rules under operation, that is, the case of $\chi_2^B = \chi_2^R = 0$. 

Figure 1.5: Social Welfare and the Degree of Aggressiveness of Capital Controls to Changes in Bank Foreign Borrowing
Chapter 2

Macroprudential Policy Coordination in a Currency Union

2.1 Introduction

Increased interconnectedness of financial institutions and markets, and more highly correlated financial shocks, have intensified cross-border spillovers—as well as so-called “spillbacks,” as documented by the Bank for International Settlements (2016) and the International Monetary Fund (2016)—and have led to renewed calls to strengthen prudential regulation and supervision of financial institutions, both within and between countries. These policies have been viewed by some observers to be essential to mitigate the substantial risks associated with international financial integration, and the potentially large economic costs that countries may face when crises occur and are propagated across borders.

At the same time, there has been increased recognition that differences in national regulatory regimes and policies across countries can themselves become a source, and conduit for, international spillovers. In particular, by triggering cross-border regulatory arbitrage, differences in macroprudential rules may lead to sharp swings in capital flows and magnify the international propagation of real and financial shocks, through changes in asset prices and collateral values.\footnote{See Aiyar et al. (2014) and Beirne and Friedrich (2014) for empirical evidence on the channels} When financial
cycles are not well synchronized across countries, or systemic intermediaries can evade at little cost policy actions taken by national authorities, the overall combination of macroprudential policies may be suboptimal—even when each country’s policy is optimal at the national level. As a result, financial instability risks may worsen at the level of the global economy. The question arises therefore as to whether formal coordination of these policies between countries—beyond the reciprocity agreements promoted by the Basel III Accord in the context of capital requirements, for instance—would not improve global financial stability and welfare.

Recent analytical contributions have indeed identified several channels through which cross-country coordination of macroprudential policies could mitigate the adverse effects of cross-border spillovers and raise welfare. Some of these contributions, including those of Bengui (2014), Jeanne (2014), Korinek (2014, 2017), and Kara (2016), are based on small analytical models. A growing number of others are based on two-country dynamic stochastic general equilibrium (DSGE) models with financial market imperfections and include Kollmann et al. (2011), Kollmann (2013), Rubio (2014), Cuadra and Nuguer (2014), Quint and Rabanal (2014), Mendicino and Punzi (2014), Brzoza-Brzezina et al. (2015), Palek and Schwanebeck (2015), Poutineau and Vermandel (2015), and Rubio and Carrasco-Gallego (2016).

Of particular interest to us in this study are those contributions focusing on a currency union with national policymakers and a common central bank, both of which possibly taking on a macroprudential regulatory role as an additional mandate. A key question in that context has been the level (national or supranational) through which national macroprudential policies can generate cross-border spillovers.

Another strand of literature has focused on the scope for, and the benefits from, international coordination of monetary policies. See Pappa (2004), Benigno and Benigno (2008), Liu and Pappa (2008), Coenen et al. (2009), Kolasa and Lombardo (2014), Banerjee et al. (2016), and Fujiwara and Teranishi (2017) for specific contributions, as well as Taylor (2013), Eichengreen (2014) and Engel (2016) for a broader perspective. Even though many of the models used in that literature do not account explicitly for financial frictions and regulatory regimes, some of their results (as discussed later) are relevant for the ongoing debate on macroprudential policy coordination across countries.

Some of these contributions have also looked at the combination of monetary and macroprudential policies (see Mendicino and Punzi (2014) and Quint and Rabanal (2014)), but this is beyond the scope of this paper.
at which macroprudential regulation should be conducted. This issue is particularly important in a currency union with a \textit{one-size-fits-all} monetary policy and business cycles are not fully synchronized—prompting some observers to argue that proactive domestic macroprudential policies are needed not only from the perspective of financial stability but also output stability, given the impact of macroprudential instruments on credit, and the demand- and supply-side links between credit and economic activity.

Rubio (2014) for instance explored how loan-to-value (LTV) ratios, endogenously related to output and house prices, should be set in such an environment. Her results emphasized the importance of asymmetries for the conduct of macroprudential policies in a monetary union, especially when heterogeneity results in differences in aggregate volatility. In the same vein, Rubio and Carrasco-Gallego (2016) found that, compared to the case where an LTV macroprudential policy is implemented at the level of a single member country, the welfare gain is larger if all members of the union (or a common supranational entity) implement it in coordinated fashion. At the same time, the additional welfare gain from introducing country-specific macroprudential is small. Brzoza-Brzezina et al. (2015) also examined the effectiveness of LTV ratios as a macroprudential policy instrument, linked to changes in credit, house prices, and output, under the assumption that core and periphery union members are impacted by asymmetric shocks. Their results showed that centralized macroprudential policy can substantially lower the magnitude of credit and output fluctuations in the periphery. They also found that decentralized macroprudential policy is more successful than a common policy from a welfare perspective.

Quint and Rabanal (2014) focused instead on the case where a “generic” macroprudential instrument influences credit market conditions by affecting directly the fraction of liabilities that banks can lend. They found that, under a variety of scenar-

\footnote{In practice, however, it is hard to think of sectoral macroprudential instruments (such as LTV ratios or debt-to-income ratios) as being set by a centralized institution in a currency union, because of significant institutional differences between national housing markets.}
ios, the introduction of a macroprudential rule would help to reduce macroeconomic volatility and improve union-wide welfare, thereby partially substituting for the lack of national monetary policies. Palek and Schwanebeck (2015) also considered the case where the regulatory policy instrument affects the borrowing costs faced by entrepreneurs. Their results showed that macroprudential policy is effective at mitigating fluctuations of the economies at the union level under a variety of scenarios, thereby improving welfare.

The purpose of this paper is twofold. First, it aims to contribute to a better understanding of the cross-border spillover effects of macroprudential policy in a currency union where credit and capital markets are imperfect and housing plays a key role as collateral. Second, it aims to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in a currency union, relative to the case where countries pursue independently their own policies, and to assess how these gains depend on how financial stability is measured, the degree of asymmetry in preferences between national regulators and the common regulator, the degree of financial integration, and the degree of heterogeneity in credit market imperfections across countries.

In contrast to the existing literature, we focus on reserve requirements as the instrument of macroprudential regulation. In recent years policymakers in a number of countries have indeed used reserve requirements to mitigate credit fluctuations and promote macroeconomic and financial stability—not only in middle-income countries, where time and again they have been used aggressively, but in some advanced economies as well (see Agénor et al. (2015) and Cerutti et al. (2017)). They have also been advocated as a way of taxing the negative systemic externality associated with credit booms in these economies (see Kashyap and Stein (2012)). Our analysis is thus both positive and normative, in the sense that it aims to assess whether such

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5 More generally, the idea that macroprudential regulation can be modeled as a tax (on deposits, like reserve requirements, or on loans or bank net worth) has appeared in other contributions as well. See Agénor et al. (2017) for a discussion.
a policy could also prove to be an effective countercyclical instrument in a monetary union.

Also in contrast with most existing contributions, we address this issue in an explicit game-theoretic framework. This allows us to account for strategic interactions between countries when they choose their policies in the absence of cooperation. Specifically, we compare the properties of two alternative, explicit mandates to achieve financial stability: macroprudential policy, in the form of a simple, implementable rule, delegated to a common regulator (the cooperative equilibrium or centralized regime), and macroprudential policy delegated to the individual member countries (the noncooperative Nash equilibrium or decentralized regime), with the common central bank retaining control of monetary policy. This separation of mandates is consistent with the fact that, in practice, distinct institutions are often made responsible for achieving narrower goals on the grounds of accountability (see Committee on the Global Financial System (2016)). Our focus is on understanding whether delegating the setting of the macroprudential instrument to the common central bank helps to reduce the magnitude of cross-border spillovers and stabilize better than when individual countries pursue their own policies. We begin with the case where the two countries are perfectly symmetric and shocks, real and financial, originate in the home country only. We also initially measure financial stability in terms of the volatility of the credit-to-output ratio.

A numerical comparison of the decentralized regime (in which regulators in each country set the required reserve ratio to minimize own financial volatility) and the centralized regime (where the common regulator sets either a uniform ratio or separate ratios to minimize union-wide financial volatility) shows that the gains from coordination from the perspective of the home country (where the shocks occur) or the union as a whole are significant in response to financial shocks. Intuitively, the ability of the common regulator to internalize spillovers to the foreign country, and spillbacks to the home country, when setting the common required reserve ratio
generates a stabilization benefit that translates into a lower policy loss. Moreover, when member countries are faced with asymmetric shocks, a one-size-fits-all policy of setting a uniform required reserve ratio is suboptimal compared to separate instrument setting. However, when shocks are real in nature the country of origin may be worse off under cooperation—even if at the same time the union as a whole benefits from it. If transfers from winners to losers cannot be enforced, cooperation in such conditions can be sustained only with a collective binding political commitment.

We also find that the gains from coordination are stronger when the national and common regulators are both concerned with output stability as well, but the common regulator attaches a higher weight to financial stability than the national regulators. The gains from coordination, at both the union and each country’s levels, tend to increase also with the degree of financial market integration, because the common regulator is able to internalize the effects of greater integration on cross-border spillovers through financial markets. Finally, we find that the relative gain from coordination, from the perspective of the home country, tends to increase with the degree of asymmetry in credit markets between the member where the shocks originate and the other member of the union.

The remainder of the paper proceeds as follows. Section 2 describes the model, which features imperfect capital mobility and imperfect substitutability between deposits and central bank borrowing—a critical assumption for generating a role for reserve requirements. The equilibrium and some key features of the steady state are discussed in Section 3, and a core parameterization is presented in Section 4. Our goal here is not to match any particular set of data, but rather to characterize (using as much as possible standard parameter values) some qualitative properties of the dynamic path of the model. Nevertheless, our choice of parameters reflects to a significant extent recent estimates for the euro area. The results of asymmetric productivity and financial shocks are described in Section 5. The optimal, loss-minimizing policy under the two alternative mandates described earlier are ex-
examined in Section 6. The macroprudential policy instrument that we consider, as
noted earlier, is reserve requirements. A simple implementable rule, linking changes
in the required reserve ratio to deviations in the credit-to-output ratio, is defined,
both at the national and union-wide levels. Sensitivity analysis is reported in Sec-
tion 7, in order to examine how the model’s structural features affect the gains from
coordination. We consider, in particular, the degree of financial integration, asym-
metry in country size, and the degree of credit market imperfections. Even though
(as noted earlier) the model is not built and parameterized to match exactly the
key features of the euro area, the broad policy implications of our analysis for that
entity are discussed in Section 8. The last section discusses some potentially fruitful
directions in which our analysis can be extended.

2.1.1 Households

Households in both countries have identical preferences. The objective of the rep-
resentative household in the home country is to maximize

\[ U_t^H = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left( \frac{(C_{t+s}^H)^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1 - N_{t+s}^H) + \ln((x_{t+s}^H)^{\eta_x}(A_{t+s}^H)^{\eta_A}) \right), \]

(2.1)

where \( C_t^H \) is consumption of the home final good, \( N_t^H = \int_0^1 N_t^{H,j} \, dj \), the share of
total time endowment (normalized to unity) spent working, with \( N_t^{H,j} \) denoting
the number of hours of labor provided to home IG producer \( j \), \( x_t^H \) a composite
index of real monetary assets, \( A_t^H \) the stock of housing, \( \beta \in (0, 1) \) a discount factor,
\( \varsigma > 0 \) the intertemporal elasticity of substitution in consumption, \( \mathbb{E}_t \) the expectation
operator conditional on the information available at the beginning of period \( t \), and
\( \eta_N, \eta_x, \eta_A > 0 \).

The composite monetary asset consists of real cash balances, \( m_t^{HP} \), and real bank
deposits, \( d^H_t \), both measured in terms of the price of home final output, \( P^H_t \):

\[
x^H_t = (m_{t}^{HP})^{\nu} (d^H_t)^{1-\nu}. \quad \nu \in (0, 1)
\]  

(2.2)

The household’s flow budget constraint is

\[
m_{t}^{HP} + d^H_t + b_t^{HH} + b_t^{HF} + z^H_{A} \Delta A^H_t
\]

\[
= w^H_t N^H_t - T^H_t - C^H_t + \frac{m_{t-1}^{HP}}{1 + \pi^H_{t-1}} + \left(\frac{1 + i_{t-1}^{HD}}{1 + \pi^H_{t-1}}\right) d_{t-1}^H + \left(\frac{1 + i_{t-1}^{HB}}{1 + \pi^H_{t-1}}\right) b_{t-1}^{HH} + (1 + i_{t-1}^{F}) b_{t-1}^{HF} + J^H_{t-I} + J^H_{t-K} + J^H_{t-B},
\]

where \( z^H_{A} = P^{HA}_t / P^H_t \) is the real price of housing (with \( P^{HA}_t \) the nominal price), \( 1 + \pi^H_{t} = P^H_t / P^H_{t-1} \), \( b_t^{HH} (b_t^{HF}) \) real holdings of one-period, noncontingent home (home-currency value of foreign) government bonds by domestic households, \( i_t^{HD} \) the interest rate on bank deposits, \( i_t^{HB} \) the interest rate on home government bonds, \( i_t^{F} \) the premium-adjusted (or effective) interest rate on foreign government bonds, \( w^H_t \) the economy-wide real wage, \( T^H_t \) real lump-sum taxes, \( J^H_{t-I} \) \( J^H_{t-K} \), and \( J^H_{t-B} \), end-of-period profits of the IG producer, the CG producer, and the commercial bank, respectively. For simplicity, housing does not depreciate.

Home households face intermediation costs when taking a position on the foreign bond market. The effective rate of return on foreign bonds is given by

\[
1 + i_t^{F} = (1 + i_t^{FB})(1 + \theta_t^{HF}),
\]

(2.4)

where \( i_t^{FB} \) is the unadjusted foreign bond rate and \( \theta_t^{HF} \) a premium, which falls with the household’s own stock of foreign bonds:

\[
\theta_t^{HF} = -\frac{\theta_0^{B}}{2 b_t^{HF}},
\]

(2.5)

with \( \theta_0^{B} > 0 \) a symmetric cost parameter.
The home household maximizes (2.1) with respect to $C^H_t$, $N^H_t$, $m^{HP}_t$, $d^H_t$, $b^{HH}_{t+1}$, $b^{HF}_{t+1}$, and $A^H_t$, subject to (2.3), (2.4), and (2.5), taking period-$t-1$ variables as well as $w^H_t$, $T^H_t$, and real profits as given. The first-order conditions are

$$
\mathbb{E}_t\left[\left(\frac{C^H_{t+1}}{C^H_t}\right)^{1/\kappa}\right] = \beta\mathbb{E}_t\left(\frac{1 + i^HB_t}{1 + \pi^H_{t+1}}\right),
$$  
(2.6)

$$
N^H_t = 1 - \frac{\eta_N(C^H_t)^{1/\kappa}}{w^H_t},
$$  
(2.7)

$$
m^{HP}_t = \frac{\eta_x(C^H_t)^{1/\kappa}(1 + i^HB_t)}{i^HB_t - i^HD_t},
$$  
(2.8)

$$
d^H_t = \frac{\eta_x(1 - \nu)(C^H_t)^{1/\kappa}(1 + i^HB_t)}{1 + \pi^H_{t+1}},
$$  
(2.9)

$$
z^{HA}_{A_t} = \left\{1 - \mathbb{E}_t\left(\frac{1 + \pi^HA_{t+1}}{1 + i^HB_t}\right)\right\}^{-1} \eta_A(C^H_t)^{1/\kappa},
$$  
(2.10)

$$
b^{HF}_t = \frac{i^FB_t - i^HB_t}{\theta^B_0 (1 + i^FB_t)},
$$  
(2.11)

where $1 + \pi^HA_{t+1} = P^HA_{t+1}/P^HA_t$.

Foreign households face a resource allocation problem similar to the one faced by home households. In particular, their demand for home bonds is given by

$$
b^{FH}_t = \frac{i^HB_t - i^FB_t}{\theta^B_0 (1 + i^FB_t)},
$$  
(2.12)

Equations (2.11) and (2.12) imply that interest parity ($i^HB_t = i^FB_t$), or perfect capital mobility, obtains when $\theta^B_0 \to 0$. Thus, as discussed later, the impact of financial integration on the gains from coordination can be assessed by varying $\theta^B_0$.

2.1.2 Final Good Production

To produce the home final good, $Y^H_t$, a basket of domestically-produced differentiated intermediate goods sold at home, $Y^{HH}_t$, is combined with a basket of imported
intermediate goods produced abroad (that is, foreign exports), $Y_{t}^{FH}$:

$$Y_{t}^{H} = \Lambda I(Y_{t}^{HH}(\eta^{-1}/\eta) + (1 - \Lambda I)(Y_{t}^{FH}(\eta^{-1}/\eta)^{\eta/\eta}),$$  \hspace{1cm} (2.13)

where $0.5 < \Lambda I < 1$, to capture home bias in final good production, and $\eta > 0$ is the elasticity of substitution between the two baskets, each of which defined as

$$Y_{t}^{i} = \left\{ \int_{0}^{1} [Y_{jt}^{i}](\theta_{i}/\theta_{i})^{\theta_{i}/(\theta_{i} - 1)} \right\}^{1/(\theta_{i} - 1)} \quad i = HH, FH$$  \hspace{1cm} (2.14)

In this expression, $\theta_{i} > 1$ is the elasticity of substitution between intermediate home goods among themselves ($i = HH$), and imported goods among themselves ($i = FH$), and $Y_{jt}^{i}$ is the quantity of type-$j$ intermediate good of category $i$, with $j \in (0, 1)$.

Cost minimization yields the demand functions for each variety $j$ of intermediate goods:

$$Y_{jt}^{i} = \left( \frac{P_{jt}^{i}}{P_{t}^{i}} \right)^{-\theta_{i}}Y_{t}^{i}, \quad i = HH, FH$$  \hspace{1cm} (2.15)

where $P_{jt}^{HH}$ ($P_{jt}^{FH}$) is the home price of home (imported) intermediate good $j$, and $P_{t}^{HH}$ and $P_{t}^{FH}$ are price indices, which are given by

$$P_{t}^{i} = \left\{ \int_{0}^{1} (P_{jt}^{i})^{1 - \theta_{i}} dj \right\}^{1/(1 - \theta_{i})} \quad i = HH, FH$$  \hspace{1cm} (2.16)

Demand functions for baskets of home and foreign goods are

$$Y_{t}^{HH} = \Lambda^{\eta}(P_{t}^{HH}P_{t}^{H})^{-\eta}Y_{t}^{H}, \quad Y_{t}^{FH} = (1 - \Lambda I)^{\eta}(P_{t}^{FH}P_{t}^{H})^{-\eta}Y_{t}^{H},$$  \hspace{1cm} (2.17)

where $P_{t}^{H}$ is the price of home final output, given by

$$P_{t}^{H} = \left[ \Lambda^{\eta}(P_{t}^{HH})^{1 - \eta} + (1 - \Lambda I)^{\eta}(P_{t}^{FH})^{1 - \eta} \right]^{1/(1 - \eta)},$$  \hspace{1cm} (2.18)
with an analogous expression for the price of final output abroad, $P^F_t$.

Assuming no transportation costs between countries, and no rigidities, the law of one price implies that the home price of imported good $j$ is given by

$$P^{FH}_{jt} = P^{FF}_{jt},$$

where $P^{FF}_{jt}$ is the price of foreign intermediates, set in the foreign country. However, because of home bias in production, $P^H_t$ and $P^F_t$ in general differ from each other; their ratio defines the real exchange rate.

### 2.1.3 Production of Intermediate Goods

Home output of intermediate home good $j$, $Y^{HI}_{jt}$, is sold on a monopolistically competitive market and is produced by combining home labor, $N^H_{jt}$, and beginning-of-period home capital, $K^H_{jt}$:

$$Y^{HI}_{jt} = Y^Y_t (N^H_{jt})^{1-\alpha} (K^H_{jt})^\alpha,$$

where $\alpha \in (0, 1)$ and $\epsilon^Y_t$ is a common technology shock, which follows an AR(1) process of the form $\epsilon^Y_t = \epsilon^Y_{t-1} \exp(\xi^Y_t)$, where $\rho^Y \in (0, 1)$, $\xi^Y_t \sim N(0, \sigma^\epsilon^Y)$, and a $\tilde{\cdot}$ is used to denote a steady-state value.

Capital is rented from the CG producer at the rate $r^HK_t$ and paid for after the sale of output. Cost minimization yields the capital-labor ratio and the unit real marginal cost, $mc^H_t$, as

$$\frac{K^H_{jt}}{N^H_{jt}} = (\frac{\alpha}{1-\alpha}) (\frac{w^H_t}{r^HK_t}) \quad \forall i,$$

$$mc^H_t = \left(\frac{w^H_t}{r^HK_t}\right)^{1-\alpha} (\frac{\epsilon^H_t}{\epsilon^Y_t})^\alpha.$$

Each firm $j$ chooses a sequence of prices so as to maximize the discounted present
value of its profits:

\[ \{P_{jt+s}^{HH}\}_{s=0}^{\infty} = \arg \max_{\beta^s \lambda_t + s} \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} J_{jt+s}^{HI}, \]  

(2.23)

where \( \beta^s \lambda_{t+s} \) measures the marginal utility value to the representative home household of an additional unit of real profits, \( J_{jt+s}^{HI} \), received in the form of dividends at \( t + s \). In Rotemberg fashion, prices are costly to adjust; profits are thus defined as

\[ J_{jt}^{HI} = \left( \frac{P_{jt}^{HH}}{P_{jt}^{HI}} \right) Y_{jt}^{HI} - m_{t}^{H} Y_{jt}^{HI} - \frac{\phi_{t}}{2} \left( \frac{P_{jt}^{HH}}{P_{jt-1}^{HH}} - 1 \right)^2 Y_{jt}^{HI}, \]  

(2.24)

where \( \phi_{t} \geq 0 \).

Using (2.15), the first-order condition for this problem takes the standard form

\[ (1 - \theta_{HH}) \left( \frac{P_{jt}^{HH}}{P_{jt}^{HI}} \right)^{-\theta_{HH}} \frac{1}{P_{jt}^{HH}} + \theta_{HH} \left( \frac{P_{jt}^{HH}}{P_{jt}^{HI}} \right)^{-\theta_{HH}-1} m_{t}^{H} \]  

(2.25)

\[ -\phi_{t} \left\{ \left( \frac{P_{jt}^{HH}}{P_{jt-1}^{HH}} - 1 \right) \frac{1}{P_{jt-1}^{HH}} \right\} + \beta_{t} \mathbb{E}_{t} \left\{ \frac{\lambda_{t+1}}{\lambda_{t}} \left( \frac{P_{jt+1}^{HH}}{P_{jt}^{HI}} - 1 \right) \right\} = 0. \]

The law of one price implies again that the price of home intermediate goods sold on the foreign market (that is, the price of home exports), \( P_{t}^{HF} \), is equal to the home price:

\[ P_{t}^{HF} = P_{t}^{HH}. \]  

(2.26)

As noted earlier, trade between the two countries occurs only at the level of intermediate goods. The market-clearing condition equates therefore total output of home intermediate good \( j \) with world demand for that good, that is, the sum of the home and foreign demands for home good \( j \):

\[ Y_{jt}^{HI} = Y_{jt}^{HH} + Y_{jt}^{HF}, \]  

(2.27)

---

\[ ^{6} \text{From (2.19) and (2.26), the terms of trade are thus given by } P_{t}^{HF}/P_{t}^{FH} = P_{t}^{HH}/P_{t}^{FF}. \text{ By log-linearizing (2.18) and the equivalent definition of } P_{t}^{F}, \text{ it can be shown that deviations in the real exchange rate are proportional to deviations in the terms of trade between the two countries.} \]
with, similar to (2.15), \( Y_{jt}^{HF} = (P_{jt}^{HF}/P_{jt}^{HF})^{-\theta_t}Y_{jt}^{HF} \) denoting home exports. A similar condition holds for foreign production of each intermediate good \( j \):

\[
Y_{jt}^{FI} = Y_{jt}^{FF} + Y_{jt}^{FH},
\]

(2.28)

with \( Y_{jt}^{FH} \) (home imports) given by (1.14).  

### 2.1.4 Capital Good Production

The aggregate capital stock, \( K_t^H = \int_0^1 K_{jt}^H \, dj \), is obtained by combining gross investment, \( I_t^H \), with the existing capital stock, adjusted for depreciation and adjustment costs:

\[
K_{t+1}^H = I_t^H + \left\{ 1 - \delta - \frac{\Theta_K}{2} \left( \frac{K_{t+1}^H - K_t^H}{K_t^H} \right)^2 \right\} K_t^H,
\]

(2.29)

where \( \delta \in (0,1) \) is the depreciation rate and \( \Theta_K > 0 \).

Investment goods must be paid for in advance. The CG producer must therefore borrow from the bank \( l_t^H = I_t^H \). The household makes its exogenous housing stock, \( \bar{A}^H \), available without any direct charge to the CG producer, who uses it as collateral against which it borrows from the bank. Repayment is uncertain and occurs with probability \( q_t^H \in (0,1) \). Expected repayment is thus \( q_t^H(1 + i_t^{HL})I_t^H + (1 - q_t^H)\kappa z_t^{HA}\bar{A}^H \), where \( \kappa \in (0,1) \) is the share of the housing stock that can be effectively pledged as collateral.

Subject to (2.29) and \( I_t^H = I_t^H \) the CG producer chooses the level of capital \( K_{t+1}^H \) so as to maximize the value of the discounted stream of dividend payments to the household. As shown by Agénor et al. (2014, 2015), the solution to this problem

\(^7\text{Note that we also have in value terms } P_t^H Y_t^{HI} = P_t^{HH} Y_t^{HH} + P_t^{HF} Y_t^{HF}, \text{ where } P_t^{HI} \text{ is the output price of intermediate goods. But given that from (2.26) } P_t^{HF} = P_t^{HH}, \text{ and given (2.27), this condition boils down to } P_t^{HI} = P_t^{HH}, \text{ which justifies specifying the optimization problem of the IG producer in (2.23) directly in terms of } P_t^{HH}.\)
yields\textsuperscript{8}

\[ E_t r^{HK}_{t+1} = q^H_t (1 + i^{HL}_t) E_t \left\{ [1 + \Theta_K \left( \frac{K^{H}_{t+1}}{K^{H}_t} - 1 \right)] \left( \frac{1 + i^{HB}_t}{1 + \pi^{H}_{t+1}} \right) \right\} \quad (2.30) \]

\[ -E_t \left\{ q^H_{t+1} (1 + i^{HL}_{t+1}) \left\{ 1 - \frac{\Theta_K}{2} \left( \frac{K^{H}_{t+1} + 1}{K^{H}_t} \right)^2 - 1 \right\} \right\}. \]

\textbf{2.1.5 Commercial Bank}

The home bank’s balance sheet is

\[ i^H_t + RR^H_t = d^H_t + l^{HB}_t, \quad (2.31) \]

where \( l^{HB}_t \) is borrowing from the common central bank, and \( RR^H_t \) required reserves, which are set as a fraction \( \mu^H_t \in (0, 1) \) of deposits:

\[ RR^H_t = \mu^H_t d^H_t. \quad (2.32) \]

The bank’s expected real profits at the end of period \( t \) (or beginning of \( t + 1 \)) are defined as

\[ E_t \left[ (1 + \pi^H_{t+1}) z^{HB}_{t+1} \right] = q^H_t (1 + i^{HL}_t) i^H_t + (1 - q^H_t) \kappa z^A_{t+1} \quad (2.33) \]

\[ + \mu^H_t d^H_t - (1 + i^{HD}_t) d^H_t - (1 + i^C_t) l^{HB}_t, \]

where \( i^C_t \) is the marginal cost of borrowing from the common central bank, and \( \mu^H_t d^H_t \) the reserve requirements held at the central bank and returned to the bank at the end of the period. The other terms in (2.33) are self explanatory.

The bank sets the deposit and lending rates so as to maximize expected profits:

\[ i^{HD}_t, i^{HL}_t = \arg \max \ E_t \left[ (1 + \pi^H_{t+1}) z^{HB}_{t+1} \right]. \quad (2.34) \]

\textsuperscript{8}Equation (2.30) boils down to the standard arbitrage condition \( E_t r^{HK}_{t+1} \approx i^H_t - \pi^H_{t+1} + \delta \) in the absence of borrowing and adjustment costs.
Solving (2.34) subject to (2.31)-(2.33) yields

\[ i_t^{HD} = (1 + \frac{1}{\eta_D})^{-1}(1 - \mu^H_t)\eta_t^C, \tag{2.35} \]

\[ i_t^{HL} = \frac{1 + i_t^C}{(1 + \eta^{-1}_L)q_t^H} - 1, \tag{2.36} \]

where \( \eta_D, \eta_L > 0 \) are interest elasticities of the supply of deposits and the demand for loans, respectively. Borrowing from the common central bank is determined residually from (2.31).

The repayment probability depends positively on the expected value of collateral relative to the volume of loans (as a result of a moral hazard effect), and the cyclical position of the economy (which affects incentives to repay):

\[ q_t^H = (\frac{k\tilde{E}_t^{A_t}A_t}{Y_t^{A_t}})^{\varphi_1} (\frac{Y_t^H}{\tilde{Y}^H})^{\varphi_2} \epsilon_t^Q, \quad \varphi_1, \varphi_2 > 0 \tag{2.37} \]

where \( \tilde{Y}^H \) is the steady-state level of home final output and \( \epsilon_t^Q \) a disturbance term which follows an AR(1) process of the form \( \epsilon_t^Q = \rho^Q \epsilon_{t-1} + \zeta_t^Q \), where \( \rho^Q \in (0, 1) \) and \( \zeta_t^Q \sim N(0, \sigma_{\zeta^Q}) \).

### 2.1.6 Government

All income received by the union’s central bank on each country’s bank borrowing, \( i_t^{HB} \) and \( i_t^{FB} \), is transferred back to each national government. The government budget constraint is thus given by

\[ b_t^H = G_t^H - T_t^H + (1 + i_t^{HB}) \frac{b_{t-1}^H}{1 + \pi_t^H} - i_t^{C} \frac{i_t^{HB}}{1 + \pi_t^H} \tag{2.38} \]

where \( b_t^H = b_t^{HH} + b_t^{FH} \) is the real stock of riskless one-period bonds held by home and foreign households, and \( G_t^H \) real expenditure on home final goods, which represents
a fraction \( \psi \in (0, 1) \) of home output:

\[
G_t^H = \psi Y_t^H.
\]  
(2.39)

In what follows the government in each country is assumed to keep its real stock of debt constant and to balance its budget by adjusting lump-sum taxes.

### 2.1.7 Common Central Bank

The common central bank operates a standing facility, which involves a perfectly elastic supply of (uncollateralized) loans to home and foreign banks, \( l_t^{HB} \) and \( l_t^{FB} \) respectively, at the prevailing cost of borrowing. It also supplies cash to households and firms in both countries. The balance sheet of the common central bank (measured in home prices) is thus given by

\[
l_t^{HB} + \left( \frac{P_t^F}{P_t^H} \right) l_t^{FB} = m_t^H + \left( \frac{P_t^F}{P_t^H} \right) m_t^F + RR_t^H + \left( \frac{P_t^F}{P_t^H} \right) RR_t^F,
\]

(2.40)

where \( m_t^H (m_t^F) \) is the supply of cash to the home (foreign) country, and \( RR_t^H (RR_t^F) \) required reserves held by the home (foreign) country.

Changes in the supply of currency to the home country are set by the central bank to reflect only changes in home monetary conditions:

\[
m_t^H = \frac{m_{t-1}^H}{1 + \pi_t^H} + \left( l_t^{HB} - \frac{l_{t-1}^{HB}}{1 + \pi_t^H} \right) - (RR_t^H - \frac{RR_{t-1}^H}{1 + \pi_t^H}),
\]

(2.41)

with an analogous equation for the foreign country.

The central bank supplies liquidity elastically to the commercial bank in each country, at a price \( i_t^C \), the refinance rate, which reflects both a base policy rate, \( i_t^R \), and a penalty charge. In turn, the base policy rate is set on the basis of a weighted
average of inflation and output in the two countries:

\[
\frac{1 + \frac{\bar{i}_R}{\bar{r}}} {1 + \bar{r}} = \left(1 + \frac{\bar{i}_R}{\bar{r}}\right) \chi \left\{ \left[\frac{(1 + \pi_{lH})^{v/2}(1 + \pi_{lF}^{1-v/2})}{1 + \pi_T^{1-v/2}}\right] \varepsilon_1 \left[\frac{Y_{lH}}{Y_{lF}}\right]^{1-v/2} \varepsilon_2 \right\}^{1-\chi},
\]

(2.42)

where \(\bar{i}_R\) is the steady-state value of the policy rate, \(\pi_{lF} = P_{lF}^F / P_{lF}^{F-1} - 1, \pi_T \geq 0\) the union-wide inflation target, \(\chi \in (0, 1), \varepsilon_1, \varepsilon_2 > 0\) and \(0 < v \leq 2\) measures the weight attached to home country; when \(v = 1\), countries have equal weights.

The refinance rate for the home and foreign commercial banks is given by

\[
1 + i_C^t = (1 + \bar{i}_R^t)(1 + \theta_i^{CB}),
\]

(2.43)

where \(\theta_i^{CB}\) represents a penalty rate, which is positively related to the ratio of central bank borrowing to required reserves:

\[
\theta_i^{CB} = \theta_0^{CB} \left[\frac{\bar{l}_{iHB}^{HB}/RR_i^H}{\bar{l}_{iFB}^{FB}/RR_i^F}\right]^{v/2} \left[\frac{\bar{l}_{iFB}^{FB}/RR_i^F}{\bar{l}_{iFB}^{FB}/RR_i^F}\right]^{1-v/2} \chi^{CB},
\]

(2.44)

with \(\theta_0^{CB}, \chi^{CB} > 0\). Thus, the penalty rate increases with the amount borrowed and falls with the amount of reserves held at the central bank, which act as (implicit) collateral. By implication, the penalty rate is constant at \(\theta_0^{CB}\) in the steady state.

This specification provides a simple and intuitive way to introduce imperfect substitutability between deposits and central bank borrowing—a necessary condition for reserve requirements to operate in a countercyclical fashion.\(^9\)

The production structure and the main real and financial flows between agents are summarized in Figure 2.1.

\(^9\)See Agénor et al. (2015) for a detailed discussion. In a model with multiple banks and an interbank market, the penalty rate could be defined as a premium that banks charge for borrowing from each other and could be related to the ratio of the amount borrowed over each bank’s core funding or equity capital.
2.2 Equilibrium and Steady State

In a symmetric equilibrium, all intermediate-good firms, at home and abroad, produce the same output and prices are the same across firms. Thus, the market-clearing conditions (2.27) and (2.28) for good \( j \) also imply that total output of home and foreign intermediate goods be equal to world demand for those goods:

\[
Y_t^{HI} = Y_t^{HH} + Y_t^{HF}, \quad Y_t^{FI} = Y_t^{FF} + Y_t^{FH}. \tag{2.45}
\]

Equilibrium in the market for final goods in each country requires that output be equal to domestic absorption, inclusive of price adjustment costs:

\[
Y_t^H = C_t^H + C_t^H + I_t^H + \frac{\phi_t}{2} \left( \frac{P_{HH}}{P_{HI}} - 1 \right)^2 \left( \frac{P_{HH}}{P_t} \right) Y_t^{HI}, \tag{2.46}
\]

\[
Y_t^F = C_t^F + C_t^F + I_t^F + \frac{\phi_t}{2} \left( \frac{P_{FF}}{P_{IF}} - 1 \right)^2 \left( \frac{P_{FF}}{P_t} \right) Y_t^{FI}. \tag{2.47}
\]

Bank loans are made in the form of cash. The equilibrium condition of the home currency market is thus

\[
m_t^{FH} = m_t^{HP} + l_t^H, \tag{2.48}
\]

and analogously for the foreign country.

In equilibrium, net trade in government bonds (or, equivalently, the world net supply of bonds) must be zero, so that

\[
b_t^{HH} + b_t^{FH} = 0, \quad b_t^{FF} + b_t^{HF} = 0. \tag{2.49}
\]

Analogously, in a two-country world current account excesses and deficits must be zero:

\[
CA_t^H + CA_t^F = 0, \tag{2.50}
\]

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with the home country’s current account defined as

\[
CA^H_t = P^H_t Y^H_F - P^F_t Y^F_H + \theta^H_t P^H_{t-1} b^H_{t-1} - \theta^F_t P^F_{t-1} b^F_{t-1},
\]

(2.51)

where \(Y^H_F\), exports of intermediate goods by the home country, correspond to the
foreign country’s imports, \(Y^F_H\), home imports, correspond to the foreign country’s
exports of intermediates, and \(i^H_t\) (symmetrically to (2.4) and (2.5)) is the premium-
adjusted home bond rate, defined as

\[
1 + i^H_t = (1 + i^B_t)(1 + \theta^F_t),
\]

(2.52)

where \(\theta^F_t\) is the spread faced by foreign households, defined as

\[
\theta^F_t = -\frac{\theta_0^F}{2} b^{FH}_t,
\]

(2.53)

with \(\theta_0^F > 0\).

The steady-state solution of the model is described in Appendix A. Its key features are similar to those described in Agénor et al. (2014, 2015) for an individual
country, so we refer to those papers for a detailed discussion. In brief, the home
repayment probability is \(\bar{q}^H = (\kappa \bar{z}^H A^H/\bar{q}^H)\), whereas home interest rates are
given by \(\bar{q}^B = \beta^{-1} - 1\), \(\bar{q}^C\) (which implies that the bank has no incentives
to borrow from the central bank to purchase bonds), \(\bar{q}^{HD} = (1 + \eta^-_D)^{-1}(1 - \bar{q}^H)\gamma^C\),
and \(\bar{q}^{HL} = \beta^{-1}/(1 + \eta^-_L)\gamma^H - 1\). The cost of borrowing from the common central
bank is thus \(1 + \gamma^C = (1 + i^R)(1 + \bar{\gamma}_0^C) > 1 + i^R\). From these equations it can
be shown that \(\bar{q}^{HD} > \gamma^C\) and, because \(\eta^-_L < 0, \bar{q}^H(1 + \bar{q}^{HL}) > 1 + \gamma^C\), which ensures that \(\bar{q}^{HL} > \gamma^C\) and that the bank always has an incentive to borrow from the

\[\text{Consolidating all the budget constraints also yields (recalling that the nominal exchange rate}
\text{is normalized to unity) } CA^H_t = (P^H_t b^H_F - P^H_{t-1} b^H_{t-1}) - (P^F_t b^F_F - P^F_{t-1} b^F_{t-1}), \text{ where changes in}
\text{holdings of the home country’s foreign bonds correspond to a capital outflow for the home country}
\text{(or an inflow for the foreign country), whereas changes in holdings of the foreign country’s home}
\text{bonds, correspond to a capital inflow for the home country.} \]
central bank. They also yield $\tilde{q}^H(1 + \tilde{i}^{HL}) > 1 + \tilde{i}^{HB}$, which implies that in equilibrium the bank has no incentive to hold government bonds. Finally, the steady-state value of the stock of foreign bonds held by the representative home household is $\tilde{b}^{HF} = (\tilde{i}^{FB} - \tilde{i}^{HB})/\eta_0^B(1 + \tilde{i}^{FB})$, which is positive as long as the foreign (risk-free) bond rate exceeds the home bond rate.

2.3 Parameterization

To study the properties of the model we parameterize it using standard values used in the literature on small open-economy and two-country models—especially those focusing on the euro area, for which a number of recent papers provide parameter values estimated with Bayesian techniques. In addition, for some of the parameters that are deemed critical from the perspective of this study, sensitivity analysis is reported later on. In the benchmark parameterization, we assume that the two countries are perfectly symmetric.

The discount factor $\beta$ is set at 0.99, which gives a steady-state annualized real interest rate of about 4.1 percent. The intertemporal elasticity of substitution is 0.5, in line with the empirical evidence discussed by Braun and Nakajima (2012) for instance and the calibrated value used by Brzoza-Brzezina et al. (2015) for their core-periphery model of the euro area (see also Thimme (2017)). The preference parameter for leisure, $\eta_N$, is set at 10, to ensure that in the steady state households devote one third of their time endowment to market activity, a fairly common benchmark in the literature (see Corsetti et al. (2014), Christoffel and Schabert (2015), and Poutineau and Vermandel (2015) for instance). The parameter for composite monetary assets, $\eta_x$, is set at a low value, 0.02, to capture the common assumption in the literature that their weight in household preferences is negligible (see for instance Coenen et al. (2009) and Christoffel and Schabert (2015)). The same value is used for the housing preference parameter, $\eta_A$. The share parameter in the index of
money holdings, $\nu$, which corresponds to the relative share of cash in narrow money, is set at 0.2 to capture a significantly higher use of deposits in transactions. The cost parameter related to foreign (home) bond holdings by home (foreign) households, $\theta^B_0$, is set at 0.1. This value is consistent with a relatively high, albeit imperfect, degree of capital mobility.

The distribution parameter between home and imported intermediate goods in the production of the final good, $\Lambda_I$, is set at 0.7, to capture the case of a country where imports are initially about a third of GDP, as in Tomura (2010) for instance. The same value is used for the foreign country. The elasticity of substitution between baskets of domestic and imported composite intermediate goods, $\eta$, is set at 1.5, a fairly standard value, which implies that these goods are substitutes in the production of the final good. The elasticities of substitution between home intermediate goods among themselves, $\theta_{HH}$, and imported goods among themselves, $\theta_{FF}$, are both set equal to 10. This is the same value used by Quint and Rabanal (2014) for instance.

The share of capital in domestic output of intermediate goods, $\alpha$, is set at 0.35, a fairly standard value. The adjustment cost parameter for prices of domestic intermediate goods, $\phi_D$, is set at 74.5 to capture a relatively high degree of nominal price stickiness. This value is very close to the average value initially estimated by Ireland (2001, Table 3) and implies a Calvo-type probability of not adjusting prices of approximately 0.71 percent per period, or equivalently an average period of price fixity of about 3.5 quarters. These figures are consistent with the point estimates of Quint and Rabanal (2014, Table 2) and Christoffel and Schabert (2015, Table 2) for the euro area. They are also in the range of values estimated by Gerali et al. (2010) and Darraçq Pariès et al. (2011). The capital depreciation rate, $\delta$, is set at a quarterly rate of 0.025, which is in the span of values typically used in the literature (see for instance Gerali et al. (2010), Kolasa and Lombardo (2014) and Mendicino and Punzi (2014)). The adjustment cost incurred by the CG producer
for transforming investment into capital, $\Theta_K$, is set at 14, in order to match the fact that the standard deviation of the cyclical component of investment is 3 to 4 times more volatile as GDP in the euro area. This value is also close to the upper bound estimated by Gerali et al. (2010, Table 2A) for the euro zone.

Regarding the commercial bank, the effective collateral-loan ratio, $\kappa$, is set at 0.2, to capture the relatively high costs associated with debt enforcement procedures, as documented by Djankov et al. (2008). The elasticity of the repayment probability is set at $\varphi_1 = 0.05$ initially with respect to the effective collateral-loan ratio and at $\varphi_2 = 0.2$ with respect to deviations in output from its steady state. As discussed later, we perform sensitivity analysis with respect to $\varphi_2$, to assess the role of credit market imperfections.

Regarding the common central bank, the required reserve ratio $\mu^R$ is set at 0.08; this value is higher than those reported for the euro area (see Christoffel and Schabert (2015)) but they are consistent with data for other high-income countries (see Cerutti et al. (2017)). The degree of persistence in the central bank’s policy response, $\chi$, is set at 0.8, whereas the responses of the base policy rate to inflation and output deviations, $\varepsilon_1$ and $\varepsilon_2$, are set at 1.6 and 0.15, respectively. These values represent averages of the estimates reported by Brzoza-Brzezina et al. (2015, Table 1), Quint and Rabanal (2014, Table 2), and Christoffel and Schabert (2015, Table 2) for the euro area.

The elasticity of the penalty rate to the bank borrowing-required reserves ratio, $\chi^{CB}$, is set to 1.1, to capture a convex cost and imperfect substitutability between central bank liquidity and deposits. The scale parameter $\theta_0^{CB}$ is set to a low value of 0.0007, to ensure that the refinance rate is (almost) identical to the policy rate in the steady state. The share of noninterest government spending in final output, $\psi$, is set at 0.18, as in Christoffel and Schabert (2015). This value is also close to the value of 0.2 used by Corsetti et al. (2014) for instance and several other contributions. The autocorrelation coefficients of the productivity and repayment probability shocks,
\( \rho^Y \) and \( \rho^Q \), are set at 0.8 and 0.57, respectively. The latter value is the same as the value estimated by Alpanda and Aysun (2014) for their spread shock.

Parameter values are exactly identical for the two countries initially and are summarized in Table 2.1.

2.4 Experiments

To illustrate the properties of the model, we briefly examine the international transmission of two types of real and financial shocks occurring in the home country: a positive productivity shock and an adverse financial shock, captured by a negative shock to the repayment probability. The latter is similar to a negative shock to the demand for housing services in (2.1), or equivalently (given constant supply) a shock to real house prices, which affects collateral values and thus the risk of default. In both cases we assume initially that countries are of the same size (so that \( \nu = 1 \)) and consider later the case of unequal proportions.

2.4.1 Productivity Shock

The results of a positive home productivity shock are illustrated in Figure 2.2. The higher level of home output raises the repayment probability and reduces the domestic loan rate, which stimulates investment and aggregate demand. The fall in marginal cost lowers inflation, which in turn induces the common central bank to set a lower policy rate—despite the fact that higher cyclical output at home operates in the opposite direction. The deposit rate therefore falls, and so does the bond rate. The drop in nominal market interest rates exceeds the fall in the (one-period ahead) inflation rate, thereby reducing the real bond rate and inducing households to spend more and save less today. The increase in consumption is associated with higher demand for housing services, thereby raising house prices. In turn, higher house prices increase collateral values and further contributes to the initial increase in the
repayment probability and the drop in the loan rate, magnifying in the process the initial increase in home investment and output.

The shock is transmitted to the foreign country through trade, financial, and monetary policy channels. The increase in home output leads to higher demand for both home and imported intermediate inputs, which stimulates output abroad and generates first-round effects that are qualitatively similar to (although smaller in magnitude than) those described earlier for the home economy. The fall in domestic interest rates leads to higher demand for foreign assets and a capital inflow in the foreign economy, which tends to lower the bond rate there as well. Finally, the initial drop in home inflation leads (as noted earlier) to a drop in the base policy interest rate set by the common central bank, which further contributes to a fall in the loan rate in the foreign economy. This monetary policy channel is a key feature of currency unions.\footnote{Because inflation falls more in the home country, and because the central bank reduces the common policy rate on the basis of the behavior of average inflation, the real interest rate falls by more in the home country than in the foreign country. In the absence of a currency union, the home central bank would have cut its policy rate by more than the common central bank (whose decisions are based on country averages) does. The policy channel helps therefore to mitigate domestic macroeconomic fluctuations.}

2.4.2 Financial Shock

The results of a negative shock to the repayment probability in the home country are illustrated in Figure 2.3. The direct effect of this shock is to raise the loan rate and to reduce investment at home. This leads to a contraction in aggregate demand and to lower inflation. Because the initial impact is also a reduction in average inflation, the central bank lowers the policy rate, which tends to reduce market interest rates at home and abroad.\footnote{In the foreign country, the drop in output tends to lower the repayment probability, which should normally lead to a higher lending rate; however, this effect is dominated by the drop in the refinance rate. Note also that investment abroad also falls, despite the reduction in the current nominal loan rate, as a result of a larger drop in the one-period ahead expected inflation rate, which raises the real cost of borrowing.} In the home country the (expected) real bond rate falls initially, thereby raising consumption and house prices; in the foreign country, by
contrast, the opposite occurs—capital inflows are associated with a higher real bond rate, thereby reducing current consumption and house prices there. However, the increase in consumption at home is relatively small compared to the drop in investment, so the net effect on aggregate demand is negative. In addition to the monetary policy channel, the cross-border propagation of the home country shock occurs again through trade in intermediate goods, which is driven by changes in the relative price of home and foreign final goods.

The positive co-movements among countries in output, inflation and investment associated with both shocks are consistent with the predictions of a large number of econometric and simulation studies that have studied the cross-border effects of these shocks in open economies. We have assumed, however, that countercyclical policy is implemented only through the setting of policy rates by the common central bank; we now turn to the case where macroprudential policy also responds endogenously under alternative institutional mandates.

2.5 Optimal Simple Macroprudential Rules

As discussed in the introduction, the key issue that we want to address in this paper is whether, in a currency union, financial stability is better achieved by conducting macroprudential policy (in the form of countercyclical reserve requirements) at the level of the union, instead of its individual members. To do so we compare outcomes under two alternative mandates, under the assumption that monetary policy continues to be conducted by the common central bank. The first is the decentralized (or autonomous) regime, where countries pursue independent policies and set reserve requirements unilaterally. In a situation akin to a Nash bargaining game, each regulator sets its own optimal macroprudential rule, taking as given the behavior of the other regulator. A Nash equilibrium in this setting is a combination of

13The effect on foreign consumption is however significantly smaller, which explains why the drop in foreign output is much weaker.
home and foreign required reserve ratios—or, more accurately, response parameters in required reserve rules, as shown later—for which neither country can unilaterally deviate from and generate some gain by doing so.

Specifically, in the decentralized equilibrium, we first assume that each financial regulator is able to set reserve requirements and we define the strategy space of the non-cooperative equilibrium in terms of reserve requirement ratios. As discussed by Lombardo and Sutherland (2006) and Coenen et al. (2009), among others, the Nash equilibrium that emerges from the strategic game played by the two countries depends crucially on the instrument chosen by the two players. Second, each player minimizes its own loss function by choosing a sequence of reserve requirements, taking as given the equilibrium sequence of policy variables of the other player. Third, we establish best response functions for each individual country. Finally, in our analysis, the best response functions of the two countries jointly define the best response. We look for an equilibrium where neither player has incentives to deviate from, i.e. the decentralized Nash equilibrium. Similar analysis of the non-cooperative Nash game is also carried out by Benigno and Benigno (2006), Lombardo and Sutherland (2006), Coenen et al. (2009) and Banerjee et al. (2016), albeit in a context of monetary policy coordination.

The second is the centralized (or cooperative) regime where either a single or separate required reserve ratios are set for both countries by the common central bank. In both cases, we consider a simple policy rule whereby changes in the required reserve ratio are related to an operational target for financial (in)stability, deviations in the ratio of bank loans to final output.\footnote{See Agénor et al. (2015) for a more detailed discussion of the rationale for this type of rule.} The focus on that variable is consistent with the large body of evidence suggesting that fluctuations in credit have often been associated with financial crises (see for instance Aikman et al. (2015) and Taylor (2015)).

Specifically, in the first regime, changes in the required reserve ratio in each
country \(i = H, F\) are driven by:\(^{15}\)

\[
\frac{1 + \mu^i_t}{1 + \bar{\mu}^i} = (1 + \mu^i_{t-1})^{\chi_1} \left\{ \left( \frac{\bar{l}^i_t/Y^i_t}{\bar{l}^i_t/Y^{H,F}_t} \right)^{\chi_2^{D,i}} \right\}^{1-\chi_1},
\]

(2.54)

where \(\chi_1 \in (0, 1)\) is a persistence parameter and \(\chi_2^{D,i} > 0\) is the response parameter to deviations in the credit-to-output ratio.\(^{16}\) In this case, the financial regulator in each country determines the optimal value of \(\chi_2^{D,i}\) so as to minimize its loss function \(\mathcal{L}_t^{D,i}\) or its own measure of financial risks, defined in terms of the volatility of the credit-to-GDP ratio:

\[
\min_{\chi_2^{D,i}} \mathcal{L}_t^{D,i} = \text{var} \left( \frac{\bar{l}^i_t}{Y^i_t} \right).
\]

(2.55)

In the second regime, and assuming separate instrument setting for each member, the common policy responds to a geometric average of country-specific credit-to-output ratios:

\[
\frac{1 + \mu^i_t}{1 + \bar{\mu}^i} = (1 + \mu^i_{t-1})^{\chi_1} \left\{ \left( \frac{\bar{l}^H_t/Y^H_t}{\bar{l}^H_t/Y^{H,F}_t} \right)^{\chi_2^{C,H}} \cdot \left( \frac{\bar{l}^F_t/Y^F_t}{\bar{l}^F_t/Y^{H,F}_t} \right)^{\chi_2^{C,F}} \right\}^{1-\chi_1}.
\]

(2.56)

The common central bank sets now \(\chi_2^{C,H}\) and \(\chi_2^{C,F}\), but this time to minimize the union-wide loss function or a common measure of financial risks, defined in terms of a weighted average of individual country loss functions:

\[
\min_{\chi_2^{C,H}, \chi_2^{C,F}} \mathcal{L}_t^C = \frac{U}{2} \mathcal{L}_t^{C,H} + (1 - \frac{U}{2}) \mathcal{L}_t^{C,F},
\]

(2.57)

where \(\mathcal{L}_t^{C,i}\) is defined in a way similar to (2.55).

Alternatively, we also consider the case where the common regulator follows a

\(^{15}\)As can be inferred from (2.54), as well as (2.56) and (2.58), the values of the optimal response parameters do not affect the steady-state level of the required reserve ratio, only its cyclical properties.

\(^{16}\)Throughout this discussion, the persistence parameter \(\chi_1\) is kept constant.
one-size-fits-all policy and sets a uniform, union-wide required reserve ratio:

$$\frac{1 + \mu_t}{1 + \hat{\mu}} = \left(1 + \mu_{t-1}\right)^{\chi_1} \left\{\left[\frac{l_H^{H}}{l_H^{H-Y}}\right]^{v/2} \left[\frac{l_F^{F}}{l_F^{F-Y}}\right]^{1-v/2}\right\}^{1-\chi_1}, \quad (2.58)$$

and therefore chooses $\chi_2^C$ so that

$$\min_{\chi_2^C} \mathcal{L}_t^C = \frac{v}{2} \mathcal{L}_t^{C, H} + \left(1 - \frac{v}{2}\right) \mathcal{L}_t^{C, F}, \quad (2.59)$$

To measure the gains—or lack thereof—from coordination, two issues must be addressed: a) whether, from the perspective of each individual member, own-country policy loss in the centralized regime (based on the common optimal rule) is lower than in the decentralized regime (based on each country’s own optimal rule); and b) whether, from the perspective of the union as a whole, union-wide policy loss in the centralized regime is smaller than the aggregate policy loss in the decentralized regime, calculated as a weighted average $(v/2, 1 - v/2)$ of each country’s policy loss under autonomy. A smaller policy loss for each country under a) is a sufficient, but not necessary, condition for a smaller policy loss under b). The outcome in that second case also depends on the magnitude of the individual country gains (or losses) in the decentralized regime and the relative weight of each member country, as measured by $v$, in the common loss function.

To calculate the policy gain under a), we take the relative difference between the value of each country’s loss function, evaluated at either the separate optimal values $\chi_2^{C, H}$ and $\chi_2^{C, F}$ or the common optimal response parameter $\hat{\chi}_2^C$ (solved for in both cases by the common regulator minimizing the union-wide loss function (2.57) or (2.59)), that is, $\hat{\mathcal{L}}_t^{C, i}$, and the minimized value of each country’s loss function at the optimal own response parameter $\hat{\chi}_2^{D, i}$ (solved for independently by each national regulator based on (2.55)), $\hat{\mathcal{L}}_t^{D, i}$. The sign of the two measures $\hat{\mathcal{L}}_t^{C, i} - \hat{\mathcal{L}}_t^{D, i}$ allows us therefore to assess the gain or loss associated with macroprudential policy coordination, from the perspective of each member separately.
To calculate the gains under \( b \), we take the relative difference between the minimized value of the union-wide loss function at the separate optimal values \( \hat{\chi}_2^{C,H} \) and \( \hat{\chi}_2^{C,F} \) or the common optimal response parameter \( \hat{\chi}_2^{C} \), \( \hat{\bar{L}}_t^C \), and the weighted average of the minimized values of each country’s loss function at the optimal own response parameter \( \hat{\chi}_2^{D,i} \), solved for independently by each country in the decentralized regime, defined as \( \hat{\bar{L}}_t^D = v/2\hat{L}_t^{D,H} + (1 - v/2)\hat{L}_t^{D,F} \). The sign of \( \hat{\bar{L}}_t^C - \hat{\bar{L}}_t^D \) determines again the gains (or losses) from coordination, but this time from the perspective of the union as a whole, rather than a particular member.

Figures 2.4 and 2.5, and the first two columns of Table 2.2, show the results for the productivity and financial shocks discussed earlier. In all cases, we set again \( v = 1 \) and the degree of persistence in the individual country and common rules, \( \chi_1 \), to a fairly low value, 0.1.\(^{17}\) We use a grid step of 1.5 (0.5) for the response parameter to the credit-to-output ratio for the productivity (financial) shock. Figure 2.4 corresponds to the uniform instrument case under cooperation; the curve in each panel shows a relative measure of the value of the policy loss function for both members, calculated by dividing the loss when \( \chi_2 > 0 \), with the policy loss when \( \chi_2 = 0 \), that is, when there is no countercyclical rule in operation. Based on the methodology explained earlier, the optimal values of \( \chi_2 \), 15 and 5.5, are those that minimize the common loss function (2.59). Figure 2.5 corresponds to the case where the common regulator sets the response parameters separately for the two countries; for each shock, there is therefore a pair of values for \( \chi_2 \)—18, 3 for the productivity shock and 6, 1 for the financial shock, which minimize (2.57). For comparative purposes, Table 2.2 also reports the individual country and union-wide loss functions when \( \chi_2 = 0 \), that is, in the absence of countercyclical regulatory response. For convenience, we also report the gains from coordination in relative terms, that is, in proportion of outcomes under decentralization.

The results show first that the (relative) policy loss function has a U-shape

\(^{17}\)Results with an alternative value of 0.8 do not affect qualitatively the results.
form, in both the centralized and decentralized regimes. The intuition is as follows. Initially, as the policy is implemented, volatility begins to fall, because it stabilizes credit, investment and aggregate demand. However, as the policy becomes more aggressive, the more volatile market interest rates become; in turn, the volatility in interest rates induces more volatility in investment and output, and therefore financial volatility—so much so that it eventually dominates the initial gains. Thus, there exists an optimal value for the response parameter to the credit-to-output ratio for the home country regulator (decentralized regime) and for the common financial regulator (centralized regime). However, in the decentralized regime, the optimal response involves a corner solution for the foreign country—with asymmetric shocks originating in the home country only, it is optimal for the foreign regulator not to respond through countercyclical adjustment in its required reserve ratio.

Second, the results in Table 2.2 show that although the gains from coordination are positive at the union level and for the foreign country for both types of shocks, this is the case for the home country only when the financial shock occurs. For the union as a whole, the gain is of the order of 3 (1.1) percentage points for the productivity (financial) shock when setting a uniform instrument, and 4.4 (1.9) percentage points for the productivity (financial) shock when setting separate instruments.\(^{18}\) Intuitively, the common regulator internalizes the effects of credit fluctuations (occurring through spillovers to the foreign country and spillbacks to the home country) in both members by pursuing a more aggressive policy and is therefore able to generate a superior outcome for the union as a whole—particularly so when separate macroprudential rules are set for the the two members. Indeed, a comparison of the optimal policies suggests that a common macroprudential policy in a union where members are structurally identical but facing asymmetric financial shocks implies

\(^{18}\)By implication, as can also be inferred from Table 2.2, optimal countercyclical macroprudential regulation always lead to a lower union-wide policy loss, that is, lower financial volatility compared to the case where required reserve ratios are kept constant across union members in response to shocks—regardless of whether policies are centralized or decentralized. This result also holds for subsequent experiments reported in Tables 2.3 to 2.6.
a more uniform response than under the decentralized regime: instead of response parameter pairs of 27, 0 and 7, 0 to the productivity and financial shocks (implying, as noted earlier, no response by the foreign country), the corresponding responses are 15 and 5.5 under the one-size-fits-all policy and 18, 3 and 6, 1 for separate instruments, respectively. Thus, under a centralized regime, the home country’s response is less aggressive, and the foreign country’s response more aggressive. The broader response at the union level translates into a coordination gain. In fact, under coordination the foreign country benefits a lot more from coordination than the home country—particularly so when the shock is real and when instruments are set separately by the common regulator.

However, the results also indicate that the home country benefits from coordination only when a financial shock occurs—regardless of whether the central regulator sets its policy instrument uniformly or separately for each member. When a productivity shock occurs, it is transmitted directly across borders through changes in imports and exports of intermediate goods; its effect on the foreign credit-to-output ratio is fairly muted. Consequently, the response by the common regulator, which involves a weaker response than the home regulator, implies that volatility of that ratio is actually higher under coordination.\footnote{By contrast, when a financial shock occurs, given its direct effect on the loan rate and the credit-to-output ratio, both countries benefit from a coordinated countercyclical response; cooperation is thus Pareto improving in that case.} Put differently, the home country would be better off acting alone; short of a politically-motivated decision to join a common macroprudential policy, its willingness to cooperate can be secured only if it involves a side payment or a transfer from the union member who benefits from it.

In summary, there are two major implications of these results. The first is that, when countries in a currency union are faced with asymmetric shocks, macroprudential policy coordination is beneficial to all members (and, by implication, the union) only when shocks are financial in nature; for real shocks, the country of ori-
gin may be worse off—even when the union as a whole benefits from a centralized policy regime. In a sense, this corroborates a key result obtained elsewhere in the literature, which suggests that macroprudential policy is effective mainly when it responds to financial shocks. However, in such conditions, enforcing a cooperative agreement requires either maintaining adequate transfer incentives between winners and losers, or imposing a binding political commitment on all union members. The second implication is that although a one-size-fits-all macroprudential policy can generate benefits from coordination, especially when shocks are financial in nature, setting instruments separately—assuming that this policy is feasible in real time—generates superior outcomes.

These results differ from those of the earlier empirical literature on monetary policy cooperation, in which under a high degree of capital mobility and flexible exchange rates the gains from international policy coordination are shown to be quantitatively small if policy is optimal in each country (see Taylor (2013) and Banerjee et al. (2016)). But they are consistent with the results in Fujiwara and Teranishi (2017), who provide support (in a two-country model with flexible prices and monopolistic banking) to the idea that monetary policy cooperation can be welfare improving in the presence of financial frictions taking the form of staggered loan contracts and sticky loan rates, and more directly related to the results in Agénor et al. (2017) regarding tax-like macroprudential regulation in a core-periphery setting with financial frictions.

2.6 Sensitivity Analysis

To assess the robustness of our results with respect to the gains from coordination, we perform sensitivity analysis with respect to the following features: the measurement of financial stability, the role of output stability and the degree of asymmetry in policy preferences between national regulators and the common regulator, the
degree of financial integration, heterogeneity in credit market imperfections across countries—a potentially important consideration when assessing the implications of asymmetric financial shocks in currency unions, as discussed by Agénor and Aizenman (2011)—correlated shocks across countries, and asymmetric country size.

### 2.6.1 House Prices and Financial Stability

In the foregoing analysis financial stability was measured in terms of the volatility of the credit-to-output ratio only, in line with the robust empirical evidence on its predictive capacity as an indicator for the build-up of financial vulnerabilities. In addition some contributions, such as Anundsen et al. (2014), have also identified booms in house prices as a cause of financial fragility and financial crises—especially in an environment when borrowers are able to concomitantly lever up the collateral value of their assets.

Accordingly, we extend our analysis by assuming that financial regulators evaluate financial stability by a weighted average of the volatility of both the credit-to-output ratio and real house prices; equation (2.55) takes now the form

\[
L_{i}^{D,j} = \varphi \text{var} \left( \frac{l_i}{Y_i} \right) + (1 - \varphi) \text{var} (z_{iA}). \quad i = H, F
\]  

(2.60)

where \( \varphi \in (0, 1) \). To account for the evidence that once the magnitude of credit expansion is taken into account, the occurrence or the magnitude of booms in asset prices do not contribute significantly to predicting financial crises, we set \( \varphi = 0.85 \).

The results are reported in the last two columns of Table 2.2. Although the magnitude of the gains are by and large smaller than in the base experiment (mainly because the foreign country gains less under coordination), they remain consistent with them. In particular, when a productivity shock occurs the home country achieves once again a policy loss under coordination, relative to noncooperation—regardless of the way the policy instrument is set by the common regulator.
2.6.2 Output Stability and Asymmetric Policy Preferences

As noted in the introduction, an ongoing debate focuses on whether in currency unions, where countries cannot conduct independent exchange rate and monetary policies (and with fiscal policy increasingly constrained by budget rules), macroprudential policies should not be used more actively to achieve output stability.\textsuperscript{20} To the extent indeed that these policies may alter the monetary transmission mechanism (through their impact on credit flows and market interest rates) they may also help to achieve price stability and dampen output fluctuations.

We address this issue by modifying the policy loss function of national regulators (2.55) to

\[
L^{D,i}_t = \kappa \text{var}(\frac{l^i_t}{Y^i_t}) + (1 - \kappa)\text{var}(\frac{Y^i_t}{Y^i_t}), \quad i = H, F
\]

which implies that the loss function of the common regulator becomes, setting \( \nu = 1 \),

\[
L^C_t = 0.5 \left\{ \kappa^C [\text{var}(\frac{l^H_t}{Y^H_t}) + \text{var}(\frac{l^F_t}{Y^F_t})] + (1 - \kappa^C)[\text{var}(\frac{Y^H_t}{Y^H_t}) + \text{var}(\frac{Y^F_t}{Y^F_t})] \right\},
\]

where \( \kappa, \kappa^C \in (0, 1) \). We consider two alternative cases. In the first case, which we refer to as symmetric policy preferences, both national regulators and the common regulator attach the same (low) weight to output stability; in the experiments, we use \( \kappa = \kappa^C = 0.9 \). In the second, referred to as asymmetric policy preferences, we assume that the common regulator attaches a higher weight to financial stability than national regulators; in a sense, the common regulator internalizes more than its national counterparts the fact that spillovers create financial risks. In that scenario, we use \( \kappa = 0.9 \) and \( \kappa^C = 0.95 \).\textsuperscript{21}

The results are reported in Table 2.3. They show first that, compared to the base

\textsuperscript{20}See for instance Gelain and Ilbas (2014) and Sergeyev (2016).
\textsuperscript{21}A conceptually similar approach to our second case is pursued in Bodenstein et al. (2014), although their focus is on welfare maximization. Breaking the first two terms and the third in their equation (65), and multiplying the third by \( 1 - \beta \) to keep the limit finite, yields the sum of the household utility function minus a coefficient \( \mu_{mpr} \) times the unconditional variance of the interest spread—which whose volatility is directly linked to credit volatility. Thus, in their setting the policymaker is concerned not only with maximizing utility but also with minimizing financial volatility.
results reported in the first two columns of Table 2.2, the gains from coordination remain significant, albeit smaller under symmetric policy preferences for output stability. The fact that the home country benefits less under a productivity shock also holds. By contrast, with asymmetric policy preferences, the gains from coordination at the union level are significantly larger than in the base case or the case of symmetric preferences, regardless of how the instrument is set by the common regulator and the type of shocks hitting the home country. In addition, the gain is larger for both the home country (under both shocks) and the foreign country (under the financial shock). Intuitively, by attaching a greater weight to financial stability than national regulators, common policies generate a larger gain from coordination.

2.6.3 Financial Integration

The impact of the degree of financial integration on the gains from coordination can be assessed by considering a reduction in the coefficient, $\theta^B_0$, which (as shown earlier) helps to parameterize the degree of capital mobility. To analyze the effects of increased integration, we set $\theta^B_0$ to a smaller value of 0.05, instead of 0.1.

The results of this experiment are reported in the first two columns of Table 2.4. Qualitatively, they are similar to those reported in the base case experiment—except that now, the home country also gains from the productivity shock when the required reserve ratio is set uniformly across countries. This essentially reflects the fact that the cross-border transmission of this shock through the financial channel, and its spillback effect on the domestic economy, are now stronger. More importantly, in quantitative terms the gains from coordination are significantly larger than those reported in Table 2.2—both at the level of the individual member countries and the union as a whole. With greater financial integration, changes in domestic and foreign interest rates become more closely correlated. This implies that shocks in the home country are transmitted to a greater extent to the foreign country, implying therefore larger spillovers and greater cross-border synchronization, which are internalized by
the common regulator. This magnifies the benefits of cross-border coordination of macroprudential policies in a currency union. These results are consistent with those of Sutherland (2004) with respect to the gains from monetary policy coordination associated with greater financially integration, although our focus is on credit market imperfections and financial stability rather than risk sharing.

2.6.4 Credit Market Imperfections

In the foregoing analysis it was assumed that members of the union are symmetric in all respects. An issue worth exploring is whether the gains from coordination tend to increase or fall when there is heterogeneity in credit market imperfections across countries. In the present model, the magnitude of these imperfections is captured through different parameters: the share of collateral that borrowers must pledge to secure loans, κ; and the response parameters of the repayment probability (or, equivalently, the inverse of the risk premium charged to borrowers) with respect to the collateral-loan ratio and cyclical output, \( \varphi_1 \) and \( \varphi_2 \), respectively. We focus in what follows on changes in \( \varphi_2 \) and consider two experiments.

First, we consider the case where, compared to the original experiment, the parameter \( \varphi_2 \) takes a higher value (0.25 instead of 0.2) for both countries. Results are reported in the last two columns of Table 2.4. They show first that, in contrast to the base experiment, both the home and foreign members benefit from coordination when instruments are set separately. Even though, in that case, the foreign country gains less, the union-wide gains are larger for both shocks. This is also the case when the instrument is uniformly set. These effects are also quantitatively large; for the financial shock for instance, and for the case of separate instruments, the

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22Gilchrist (2004) and Faia (2007) were among the first to draw attention to the role of differences in financial structures and financial frictions for the international propagation of shocks in open economies. Neither contribution, however, considers the benefits of cross-border policy coordination in mitigating the impact of these shocks.

23Because of the multiplicative specification adopted in (2.37) and the fact that the model is log-linearized, changes in \( \kappa \) have no effect on the transitional dynamics and the volatility of the credit-to-output ratio.
gain from coordination is more than twice as large. Intuitively, when credit market imperfections are more pervasive, in the decentralized regime the home country regulator reacts more strongly to changes in the credit-to-output ratio in order to promote financial stability. But given that the foreign country regulator does not find it optimal to react at all, the transmission of shocks is only partly mitigated. In the centralized regime, by contrast, the common regulator internalizes the fact that home country shocks have a larger impact on the foreign economy and sets macro-prudential policy instrument (either uniformly or separately) to mitigate financial volatility in both countries.

The second experiment involves heterogeneity in credit market imperfections in member countries. Specifically, we consider the case where $\varphi_2$ is kept constant at its benchmark value in the foreign country, but is taken to vary for the home country. As before we calculate the gains from coordination in relative terms, that is, in proportion of outcomes under decentralization.

The results for union-wide gains from coordination are shown in Figure 2.6, using a grid step of 0.025 for the home country value of $\varphi_2$. They indicate that the case for international macroprudential policy coordination becomes stronger as countries become more dissimilar in terms of the degree of imperfections in their credit markets and when shocks (real or financial) originate in the country where these imperfections are the strongest. In addition, the gain in response to the productivity shock (which affects directly cyclical output) is larger, compared to the financial shock, by an order of magnitude. The intuition is the same as before; the common regulator’s ability to internalize spillovers and spillbacks, which are both magnified with asymmetric credit markets among union members, increases the benefit of delegating macroprudential policy decisions to a supranational entity.

\footnote{This is sufficient for our purpose given that the calculations are fairly time consuming—for each value of $\varphi_1$, the optimal value of $\chi_2$ must solved for under both regimes and the optimal values of the loss functions is calculated.}
2.6.5 Correlated Shocks across Countries

The foregoing analysis has focused on the case of asymmetric shocks occurring in the home country only. With symmetric shocks, given that union members are identical in all respects in the core experiments (including policy preferences), coordination does not generate any gain; but if shocks occur in both countries at the same time while differing in size, one would expect policy responses in the foreign country to be more aggressive and the gain for the union to be positive—allbeit lower than those reported in Table 2.2 for instance.

To confirm these conjectures, the core experiment was repeated under the assumption that shocks in the domestic and foreign countries occur simultaneously but that the shock in the foreign is of the order of 0.8 standard deviation only. The results are not reported in full to save space; but they show that, as expected, a) under Nash, it is optimal for both national regulators to react to the changes in the credit-to-output ratio—with $\chi_2 = 21, 18$ and $6, 5$ for the productivity and financial shocks, respectively, compared to $27, 0$ and $7, 0$ in Table 2.2; b) the common regulator responds more aggressively—with $\chi_2 = 16.5$ and $5.5$ under the uniform instrument for the productivity and financial shocks, respectively, and $\chi_2 = 18, 15$ and $6, 5.5$ under separate instruments, which are either equal or higher than the corresponding values reported in Table 2.2; and c) the gain for the union from coordination is positive, of the order of $0.7$ and $0.1$ percentage points for the productivity and financial shocks, respectively, when setting separate instruments. However, these gains are also significantly lower compared to when the shock is purely asymmetric across countries—$4.4$ and $1.9$ percentage points respectively with separate instruments, as reported in Table 2.2.

2.6.6 Asymmetric Country Size

In the foregoing discussion it was assumed that the two union members are perfectly symmetric in size. We now consider a “core-periphery” setting where the home
country is large relatively to the foreign country. Specifically, we set \( v = 1.6 \), which means that the core (home) country is four times larger than the periphery (foreign) country. At the same time, all structural parameters are kept the same as in the baseline experiments.\(^{25}\)

To assess the implications of size for the gains from macroprudential policy coordination, we proceed in two steps. First, we set \( v = 1.6 \) in the common loss functions (2.57) and (2.59) only, while keeping symmetric weights \( (v = 1) \) in the common central bank’s Taylor rule (2.42). This allows us therefore to abstract from the impact of size on the monetary policy channel (discussed earlier) and to isolate the effect of size on the optimal cooperative policy only. Second, we \( v = 1.6 \) both in the common loss functions and the interest rate rule. In either case the union-wide loss function in the decentralized regime is of course aggregated with \( v = 1.6 \).

The results for each scenario are shown in Tables 2.5 and 2.6, where two cases are considered: shocks originating in the core country and shocks (of the same size) originating in the periphery country. In the first case, the results are qualitatively the same as those reported in Table 2.2—regardless of whether the weights in the monetary policy rule are adjusted or not. In particular, in response to a productivity shock in the home country, coordination entails a loss for that country, regardless of how the common regulator sets its policy instrument. In addition, now both the home country and the union are worse off under cooperation in response to the financial shock when the required reserve ratio is set uniformly. Thus, even at the union level, a one-size-fits-all policy is suboptimal. In terms of magnitude, coordination generates a larger gain for the foreign country, but the gains are generally much smaller for the union as a whole—of the order of 0.9 (Table 2.5) or 0.2 (Table 2.6) percentage points for the financial shock, compared to 1.9 in the baseline experiment reported in Table 2.2.

\(^{25}\)Brzoza-Brzezina et al. (2015) follow a similar approach and so do Quint and Rabanal (2014), except for the degree of price rigidities. Note also that the parameter characterizing home bias in the production of the final good in each country remains unchanged.
When the shocks originate in the foreign (periphery) country, some of the results are, naturally enough, reversed. In particular, in response to a productivity shock in the foreign country, coordination entails a loss for that country—again, regardless of whether size is accounted for in the monetary policy rule. The intuition behind this result is similar to what was discussed earlier, when shocks were assumed to originate in the home country. In addition, the gains for the union as a whole are of similar magnitude as before when size is factored into the setting of the refinance rate (Table 2.6) but substantially larger otherwise (Table 2.5): of the order of 8.1 percentage points for the productivity shock and 4 points for the financial shock, compared again to 4.4 and 1.9 points, respectively, in the baseline experiment, when instruments are set separately.\textsuperscript{26} The reason is that the core country benefits relatively more from the monetary policy channel when the common central bank puts equal weights on changes in output and inflation in the periphery (where shocks now originate) in setting the base policy rate, while at the same time the common regulator attaches a higher weight to the core country in solving for the optimal policy.

\section{2.7 Policy Implications}

As noted in the introduction, the global financial crisis revived interest in the international coordination of financial regulation—in both its structural and countercyclical dimensions. The growing recognition that the overall combination of macroprudential policies may be suboptimal from the perspective of global stability when financial cycles are not synchronized across countries—even when each country’s macroprudential policy is optimal at the national level—also contributed to greater emphasis on international coordination.

Our analysis helps to shed some light on the benefits of countercyclical coordination for financial stability in currency unions—including, in our view, the euro area.\textsuperscript{26} Similar results hold when the macroprudential instrument is set uniformly by the common regulator.
Although, as noted earlier, the model is not specifically formulated and calibrated for that particular entity, it captures several of its core structural features—including trade in intermediate goods and imperfect capital mobility. In particular, bilateral trade in intermediate inputs represents now a very large share of overall trade flows in goods and services between members of the euro area (see Miroudot et al. (2009)). There is also ample empirical evidence suggesting that, despite significant progress in financial integration in the euro area since 1999, the costs of adjusting cross-border financial positions remain substantial (see Coeurdacier and Rey (2013)) and that credit markets remain insufficiently integrated as a result of differences in practices—in credit risk assessment, for instance—laws and regulations, and market fragmentation (see Weill (2009) and European Central Bank (2015)). This evidence is consistent with our assumptions that capital mobility, although high, is not perfect, and that the cost at which banks borrow from the common central bank depends not only on a base policy rate but also on a country-specific premium.  

The evidence also suggests that business cycles remain imperfectly synchronized among member countries (see Giannone et al. (2009), Merler (2015) and Stremmel (2015)), suggesting that idiosyncratic shocks continue to be a major factor in macroeconomic fluctuations in individual countries.

Specifically, our analysis has two main implications for the euro area. The first is related to the institutional design of macroprudential regulation. Within the European Union, the European Banking Authority (EBA), established in January 2011, aims to ensure effective and consistent prudential regulation and supervision across the European banking sector, whereas the European Systemic Risk Board (ESRB), established in December 2010, is responsible for the macroprudential oversight of the financial system, primarily by issuing warnings and recommendations.  

\[\text{27}\] However, the model does not account for cross-border bank lending, an increasingly important feature of financial linkages in the euro zone (see Poutineau and Vermandel (2015)). This issue is discussed further in the conclusion.

\[\text{28}\] At the national level, there are four institutional models for the allocation of macroprudential powers: the government, the central bank, the financial authority, and a committee with representatives from all three of these bodies.

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ember 2014 the Single Supervisory Mechanism (SSM), under which the European
Central Bank (ECB) took on bank and prudential supervisory duties (alongside its
previous responsibility for price stability) for the countries that participate in the
banking union initiated in 2012—mostly those of the eurozone—became operative.
The objective was to ensure that the SSM and the ECB would interact, with the
SSM focusing on microprudential policy and the ECB on monetary policy, in ac-
cordance with the separation principle. However, the ECB as the Single Supervisor
has mandatory powers over the banking system, leaving no supranational European
agency with similar powers over nonbank financial institutions. Moreover, the ECB
has the power to set tighter regulatory requirements than national authorities, ac-
cording to SSM Regulation No. 468 of April 2014. In particular, the ECB may top
up specific macroprudential measures—capital instruments, including countercycli-
cal capital buffers and capital surcharges on systemically important institutions, risk
weights on real estate exposures, as well as liquidity instruments, such as liquidity
coverage ratios—if it considers actions by national authorities to be insufficient to
mitigate systemic risks.\footnote{Capital instruments are those falling within the scope of the Capital Requirement Regulation (CRR) and Capital Requirement Directive 4 (CRD4), which implement the Basel III Accord. The ECB is required to notify the national authorities, which can object to its measures; but at this moment these objections are not legally binding.} Furthermore, national authorities must notify the ECB
of their intention to implement macroprudential tools and the ECB can object to
them. The very coexistence of four layers of decision-making regarding macropru-
dential regulation in the European Union (the EBA, the ESRB, the ECB, and
national authorities) makes the institutional architecture fairly complex and raises
prima facie concerns about coordination, information sharing, and communication
in practice. On the issue of coordination specifically, our analysis has implications
for interactions between the ECB and national authorities: given the frequency of
asymmetric shocks in practice, a high degree of centralization in macroprudential
responses may indeed be optimal when countries share similar structural characteris-
tics. Moreover, in that context setting countercyclical policy instruments separately
for each country by the common regulator may be preferable to a one-size-fits-all policy.

The second implication is that in a currency union where macroprudential measures can be used, to some degree, as a substitute by national authorities for a national monetary policy, a common regulator who puts more weight on financial stability can achieve superior outcomes in terms of both macroeconomic stability and financial stability in response to financial shocks. Indeed, in a currency union like the euro area where monetary and exchange rate policy instruments are not available, and fiscal policy is constrained by balanced budget rules and debt limits (as a result of the Stability and Growth Pact), national policymakers have few tools to address cyclical conditions. Some observers have argued that to the extent that time-varying macroprudential policy instruments affect aggregate demand (through their impact on credit, asset prices, and interest rates), they may contribute to mitigating output fluctuations in individual member countries—allowing them in a sense to tailor the one-size-fits-all interest rate policy of the currency union. Our analysis shows that when national authorities and the common regulator both care to the same extent about output stability (while still predominantly focusing on financial stability), coordination still entails some gains, both in terms of lower financial volatility and output volatility, compared to independent policies. However, these gains are magnified—regardless of whether the shocks are real or financial—when the common regulator cares more about financial stability than output stability, compared to national regulators. Put differently, while there is some scope for the ECB to factor in output fluctuations in deciding how macroprudential policies should react to asymmetric shocks between countries of similar size and structure, it should attach a higher weight than national regulators to financial stability in setting its countercyclical responses.
2.8 Concluding Remarks

The purpose of this paper was to contribute, using a game-theoretic approach, to a better understanding of the spillover effects of macroprudential policy in a currency union and to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in that setting, relative to the case where member countries pursue their own policies. We also assessed how these gains depend on a number of structural characteristics—including the degree of financial integration and the degree of heterogeneity in credit markets across countries. In the model, countries are linked structurally through international trade in intermediate goods and capital flows through bond markets. Both domestic credit market and world capital market imperfections are accounted for. The analysis was initially conducted under the assumption that the countries are of similar size and structure, and that policymakers have distinct institutional mandates—that is, a clear separation in policy responsibilities: monetary policy focusing on the inflation-output trade-off and, conditional on the stance of monetary policy, macroprudential policy geared at mitigating financial risks. The common monetary policy involves setting the refinance rate as the sum of a policy rate and a penalty rate, which depends on the central bank borrowing-required reserves ratio to capture imperfect substitutability between bank deposits and central bank liquidity. We then considered the case where, as in Gelain and Ilbas (2014) for instance, the financial regulator is also concerned about output stability (with monetary policy retaining sole responsibility for price stability), and the case where countries are asymmetric, with respect to size and the degree of credit market imperfections. We also examined how the degree of financial integration affects the gains from coordination.

The main results of the paper were summarized in the introduction; to conclude, it is worth highlighting instead some directions in which our analysis can be extended. First, to enhance the analysis of cross-border transmission of financial shocks a union-wide (global) bank lending to home and foreign banks could be in-
troduced, as in Kollmann et al. (2011), Ueda (2012), Kollmann (2013), Alpanda and Aysun (2014) Banerjee et al. (2016), and Nuguer (2016), or alternatively an interbank market where national banks lend to each other, as in Poutineau and Vermandel (2015). In some of these models, banks pay their depositors a premium over the risk-free rate when raising loanable funds and, similar to the standard financial accelerator framework, this spread is made an increasing function of banks’ leverage. As a result, the lending rate faced by entrepreneurs in each country would depend not only on borrowers’ leverage (as in the standard financial accelerator model) but also on the banks’ leverage. Therefore, shocks that affect banks’ net worth would have a similar, symmetric effect on risk premia around the world. More generally, this literature suggests that models in which financial frictions only apply to domestic contracts—as is the case in this paper—may not be sufficient for generating a quantitatively large foreign response to domestic shocks. To do so financial frictions may need to be incorporated into international financial contracts as well. Accounting for this type of frictions could magnify the gains from international macroprudential coordination.

Second, the focus of our analysis has been on reserve requirements as the macroprudential policy instrument. A broader or more “generic” interpretation of these requirements, as either a tax on deposits or a tax on lending operating indirectly through the cost of bank borrowing (as for instance in Quint and Rabanal (2014) and Palek and Schwanebeck (2015)) is also legitimate, given that indeed in our framework changes in the required reserve ratio affect market interest rates through changes in the central bank’s refinance rate. In addition, as shown by Bianchi (2011) for a generic bank balance sheet, capital and reserve requirements have similar effects and may therefore be thought of \textit{ex ante} (although not \textit{ex post}) as substitutes from a macroprudential perspective. An extension of the present model to account for both instruments—taking into account the fact that reserve requirements can be more easily manipulated and at a lower cost—would help to explore further the
robustness of our results and their broader policy implications. It would also help to account for the possibility that systemic intermediaries may evade national decisions to adjust capital requirements through regulatory arbitrage—a possibility that, as noted in the introduction, could create another rationale for macroprudential coordination across countries.
2.9 Appendix

Appendix A

Steady-State Solution

This Appendix presents steady-state values (denoted by tildes) for the home country; results for the foreign country are symmetric, except where indicated.

From (2.42), with $Y_t^i = \bar{Y}_t^i$, $i = H, F$,

$$\tilde{\pi}^H = \tilde{\pi}^F = \pi^T,$$  

(2.62)

which implies that in the steady state, inflation in both countries is the same and equal to its common target value. The focus in what follows is on the case where $\pi^T = 0$.

From the first-order condition (2.6), $1 + \tilde{\pi}^H = \beta (1 + \tilde{i}^{HB})$, which implies that with $\pi^T = 0$ the steady-state value of the bond rate is

$$\tilde{i}^{HB} = \beta^{-1} - 1.$$  

(2.63)

In the steady state, it must be also that

$$\tilde{i}^{HB} = \tilde{i}^{R},$$  

(2.64)

which implies that the bank has no incentive to borrow from the common central bank to buy government bonds.

From (2.7), (2.8), (2.9), (2.10), and (2.11), the household’s demand for cash, bank deposits, housing services, and foreign bonds are

$$\tilde{N}^H = 1 - \frac{\eta \tilde{C}^{\tilde{C}^H}}{\tilde{\omega}^H},$$  

(2.65)
\[ \tilde{m}_{HP} = \frac{\eta_n \nu (C^H)^{1/\kappa} (1 + \tilde{i}^{HB})}{\tilde{i}^{HB}}, \quad (2.66) \]

\[ \tilde{d}^H = \frac{\eta_n (1 - \nu) (C^H)^{1/\kappa} (1 + \tilde{i}^{HB})}{\tilde{i}^{HB} - \tilde{i}^{HD}}, \quad (2.67) \]

\[ \tilde{z}^{HA} \tilde{A}^d = \left\{ 1 - \left( \frac{1 + \tilde{\pi}^H}{1 + \tilde{i}^{HB}} \right) \right\}^{-1} \left[ \frac{\eta_A}{(C^H)^{-1/\kappa}} \right], \quad (2.68) \]

\[ \tilde{y}^{HF} = \frac{\tilde{\gamma}^{FB} - \tilde{i}^{HB}}{\theta_0^B (1 + \tilde{i}^{FB})}. \quad (2.69) \]

From (2.17), steady-state demand for domestic and foreign intermediate goods is given by

\[ \tilde{Y}^{HH} = \Lambda^H_t (\frac{\tilde{P}^{HH}}{P^H})^{-\eta} \tilde{Y}^H, \quad \tilde{Y}^{FH} = (1 - \Lambda^I_t)\eta (\frac{\tilde{P}^{FH}}{P^H})^{-\eta} \tilde{Y}^H. \quad (2.70) \]

From (2.18) the steady-state value of the price of final output is

\[ \tilde{P}^H = [\Lambda^H_t (\tilde{P}^{HH})^{1-\eta} + (1 - \Lambda^I_t)\eta (\tilde{P}^{FH})^{1-\eta}]^{1/(1-\eta)}. \quad (2.71) \]

From (2.19), the steady-state value of the price of imported intermediate goods is obtained as:

\[ \tilde{P}^{FH} = \tilde{\rho}^{FF}. \quad (2.72) \]

From (2.27), the steady-state value of exports is

\[ \tilde{Y}^{HF} = \tilde{Y}^{HI} - \tilde{Y}^{HH}. \quad (2.73) \]

From (2.20), steady-state output of domestic intermediate goods is given by

\[ \tilde{Y}^{HI} = (\tilde{N}^H)^{1-\alpha} (\tilde{K}^H)^\alpha. \quad (2.74) \]

From (2.21), the steady-state condition describing the optimal utilization of pro-
duction factors is

$$\frac{\tilde{K}^H}{\tilde{N}^H} = \left( \frac{\alpha}{1 - \alpha} \right) \frac{\tilde{\delta}_{HR}}{\tilde{r}_{HR}},$$  

(2.75)

Price adjustment costs are zero in the steady state. Under symmetry, the price adjustment equation (2.25) becomes

$$mc_t^H = \frac{\theta_{HH} - 1}{\theta_{HH}} + \frac{\phi_l}{\theta_{HH}} \left[ \pi_t^{HH} (1 + \pi_t^{HH}) \right] - \frac{\phi_l}{\theta_{HH}} \frac{E_t}{\theta_{HH}} \left\{ \rho_{t,t+1} \pi_{t+1}^{HH} (1 + \pi_{t+1}^{HH}) \frac{Y_{t+1}^{HH}}{Y_t^{HH}} \right\},$$

where \( \rho_{t,t+1} = \beta \lambda_t / \lambda_{t+1} \). Thus, the steady-state value of the marginal cost is

$$\tilde{mc}^H = \frac{\theta_{HH} - 1}{\theta_{HH}}.$$  

(2.76)

In the steady state, with \( K_{t+1}^H = K_t^H \), \( 0.5 \Theta (\tilde{K}^H / \tilde{K}^H - 1)^2 \tilde{K}^H = 0 \); thus, capital adjustment costs are zero. Substituting this result in (2.29) yields

$$\tilde{i}^H = \delta \tilde{K}^H.$$  

(2.77)

Using (2.30) and (2.63) gives the steady-state value of the rental rate of capital:

$$\tilde{r}^{HK} = \tilde{q}^H (1 + \tilde{i}^{HL}) (\beta^{-1} - 1 + \delta).$$  

(2.78)

From (2.35) and (2.36), the steady-state values of the deposit and loan rates are

$$\tilde{i}^{HD} = (1 + \frac{1}{\eta_D})^{-1} (1 - \tilde{\mu}^H) \tilde{r}^C,$$  

(2.79)

$$1 + \tilde{i}^{HL} = \frac{1 + \tilde{r}^C}{(1 + \eta_l^{-1}) \tilde{q}^H}.$$  

(2.80)

Setting \( Y_t^H = \tilde{Y}^H \) in (2.37), the steady-state value of the repayment probability is

$$\tilde{q}^H = \left( \frac{\kappa_z^{HA} \tilde{A}^H}{\tilde{l}^H} \right)^{\gamma_1}.$$  

(2.81)
The amount of loans demanded by the capital good producer is \( i^H = \tilde{I}^H \). From (2.31) and (2.32), the steady-state level of the home commercial bank’s borrowing from the common central bank is

\[
\tilde{i}^{HB} = \tilde{i}^H - (1 - \tilde{\mu}^H)\tilde{d}^H. \tag{2.82}
\]

From (2.43) and (2.44), the steady-state value of the cost of borrowing from the central bank is

\[
1 + \tilde{i}^C = (1 + \tilde{i}^R)(1 + \theta_0^{CB}). \tag{2.83}
\]

With again \( \tilde{\pi}^H = \pi^T = 0 \), from (2.38) and (2.39), the steady-state value of lump-sum taxes is

\[
\tilde{T}^H = \psi\tilde{Y}^H + \tilde{i}^{HB}\tilde{b}^H - \tilde{C}\tilde{i}^{HB}. \tag{2.84}
\]

The equilibrium condition of the final good market, equation (2.46), yields the steady-state condition \( \tilde{Y}^H = \tilde{C}^H + \tilde{G}^H + \tilde{I}^H \), which can be rearranged, using (2.77) and (2.39), to give

\[
\tilde{Y}^H = \frac{\tilde{C}^H + \delta\tilde{K}^H}{1 - \psi}. \tag{2.85}
\]

From (2.48), the equilibrium condition of the market for cash yields

\[
\tilde{m}^H = \tilde{m}^{HP} + \tilde{i}^H. \tag{2.86}
\]

Given (2.69), condition (2.49) gives

\[
\tilde{b}^{FF} = -\tilde{b}^{HF} = \frac{\tilde{i}^{HB} - \tilde{i}^{FB}}{\theta_0^B(1 + \tilde{i}^{FB})}. \tag{2.87}
\]

Finally, from (2.51) the home country’s current account is

\[
\tilde{C}A^H = \tilde{P}^{HH}\tilde{Y}^{HF} - \tilde{P}^{FF}\tilde{Y}^{FH} + \tilde{i}^F\tilde{P}^H\tilde{b}^{HF} - \tilde{\pi}^H\tilde{P}^H\tilde{b}^{FH}, \tag{2.88}
\]
which from (2.50) implies that $CA^F = -CA^H$. 
Appendix B

Log-linearized Equations

Based on the results of Appendix A, the log-linearized equations of the model are presented below. Variables with a hat denote percentage point deviations of the related variables for interest rates and inflation, and log-deviations for the others, from steady-state levels.\(^\text{30}\)

From the first-order condition (2.6), private consumption is driven by

\[ \mathbb{E}_t \hat{C}_t^H = \hat{C}_t^H + \varsigma(t_t^{HB} - \mathbb{E}_t \hat{\pi}_t^H), \tag{2.89} \]

where \(\mathbb{E}_t \hat{\pi}_t^H\) is defined as, given that \(\hat{\pi} = \pi^T = 0\),

\[ \mathbb{E}_t \hat{\pi}_t^H = \mathbb{E}_t \hat{p}_t^H - \hat{p}_t^H. \tag{2.90} \]

From (2.7), labor supply is

\[ \hat{N}_t^H \hat{N}_t^H = \eta_N(\hat{C}_t^H)^{1/\varsigma} \hat{w}_t^H - \eta_N(\hat{C}_t^H)^{1/\varsigma} \hat{C}_t^H \frac{\hat{w}_t^H}{\varsigma \hat{w}_t^H}, \]

that is, using the steady-state value of \(\hat{N}_t^H\) in (2.65),

\[ \hat{N}_t^H = \left( \frac{\eta_N(\hat{C}_t^H)^{1/\varsigma}}{\hat{w}_t^H - \eta_N(\hat{C}_t^H)^{1/\varsigma} \hat{C}_t^H / \varsigma} \right)(\hat{w}_t^H - \hat{C}_t^H / \varsigma). \tag{2.91} \]

From (2.8) the demand for cash is

\[ \hat{m}_t^{HP} \hat{m}_t^{HP} = \eta_e \nu(\hat{C}_t^H)^{1/\varsigma} \left[ \frac{\hat{C}_t^H}{\varsigma} - (\frac{\beta}{1 - \beta} t_t^{HB}) \right], \]

that is, by using the steady-state value of \(\hat{m}_t^{HP}\) in (2.66),

\[ \hat{m}_t^{HP} = \frac{\hat{C}_t^H}{\varsigma} - (\frac{\beta}{1 - \beta} t_t^{HB}). \tag{2.92} \]

\(^{30}\)Net interest rates are thus used as approximations of the log gross interest rates.
Similarly, from (2.9) and (2.67), the demand for deposits is

\[ d_t^H = \frac{\hat{C}_t^H}{\varsigma} + (1 - \frac{1}{\hat{\gamma}^HB - \hat{\gamma}^HD})i_t^H + \frac{1}{\hat{\gamma}^HB - \hat{\gamma}^HD}z_t^H. \]  

(2.93)

From equation (2.10), the demand for housing services is

\[ \hat{A}_t^H = \hat{P}_t^H - \hat{P}_t^HA + \frac{\hat{\pi}^HA(\hat{\pi}_t^HA - i_t^H)}{\hat{\gamma}^HB - \hat{\gamma}^HA} + \frac{\hat{C}_t^H}{\varsigma}, \]

(2.94)

whereas from (2.11), the household demand for foreign bonds is

\[ \hat{b}_t^{HF} = \left(\frac{1 - \theta_0B^H}{\theta_0B^{HF}}\right) (i_t^{FB} - i_t^H), \]

or equivalently, given that from (2.69) \( \theta_0B^H = (i_t^{FB} - i_t^H)/(1 + i_t^{FB}) \),

\[ \hat{b}_t^{HF} = \left(\frac{1 + i_t^H}{i_t^{FB} - i_t^H}\right) (i_t^{FB} - i_t^H). \]

(2.95)

From (2.17) the linearized demand for domestic and foreign intermediate goods is

\[ \hat{Y}_t^{HH} = \eta(\hat{P}_t^H - \hat{P}_t^{HH}) + \hat{Y}_t^H, \quad \hat{Y}_t^{FH} = \eta(\hat{P}_t^H - \hat{P}_t^{FH}) + \hat{Y}_t^H, \]

(2.96)

respectively, whereas from (2.18) the linearized price of final good as a linear function of \( \hat{P}_t^{HH} \) and \( \hat{P}_t^{FH} \) can be derived as

\[ \hat{P}_t^H = [\Lambda_l(\frac{\hat{P}_t^{HH}}{P^H})^{1-\eta}]\hat{P}_t^{HH} + [(1 - \Lambda_l)^{\eta}(\frac{\hat{P}_t^{FH}}{P^H})^{1-\eta}]\hat{P}_t^{FH}, \]

(2.97)

where, from (2.19), \( \hat{P}_t^{FH} = \hat{P}_t^{FF} \).

From the production function (2.20), output of intermediate goods is

\[ \hat{Y}_t^{HI} = (1 - \alpha)\hat{N}_t^H + \alpha\hat{K}_t^H. \]

(2.98)
From (2.21), labor demand by IG producers can be derived as

$$\hat{N}_t^H = \hat{K}_t^H - \bar{w}_t^H + \frac{1 + \hat{r}_t^{HK}}{\hat{p}_t^{HK}} \hat{r}_t^{HK}. \quad (2.99)$$

A log-linear approximation around the steady state of the price adjustment equation (2.25) yields

$$\hat{\pi}_t^{HH} = \left( \frac{\theta^{HH} - 1}{\phi^I} \right) \hat{m}_t^H + \beta \pi_t \hat{\pi}_{t+1}^{HH}, \quad (2.100)$$

whereas, from (2.22),

$$\hat{m}_t^H = (1 - \alpha) \bar{w}_t^H + \alpha \left( \frac{\hat{r}_t^{HK}}{\hat{p}_t^{HK} - 1} \right) \hat{r}_t^{HK}. \quad (2.101)$$

With $\hat{\pi}_t^{HH}$ determined by (2.100), the log-linearized price of domestic intermediate goods is solved backward as

$$\hat{P}_t^{HH} = \hat{\pi}_t^{HH} + \hat{P}_{t-1}^{HH}. \quad (2.102)$$

From (2.29), investment can be log-linearized as

$$\hat{I}_t^H = \frac{1}{\delta} \left[ \mathbb{E}_t \hat{K}_{t+1}^H - (1 - \delta) \hat{K}_t^H \right]. \quad (2.103)$$

From (2.30), the log-linearized law of motion for the rate of return of capital is

$$\hat{r}_t^{HK} = \hat{q}^H \left( \frac{1 + \hat{r}_t^{HL}}{1 + \hat{r}_t^{HK}} \right) \left[ \hat{r}_t^{HL} + \hat{r}_t^{HB} - \mathbb{E}_t \hat{\pi}_{t+1}^H + \Theta_K (\mathbb{E}_t \hat{K}_{t+1}^H - \hat{K}_t^H) + \hat{q}_t^H \right]$$

$$- \hat{q}^H \left( \frac{1 + \hat{r}_t^{HL}}{1 + \hat{r}_t^{HK}} \right) \left\{ (1 - \delta) \mathbb{E}_t \hat{\pi}_{t+1}^H + \Theta_K (\mathbb{E}_t \hat{K}_{t+2}^H - \mathbb{E}_t \hat{K}_{t+1}^H) + (1 - \delta) \mathbb{E}_t \hat{q}_{t+1}^H \right\}. \quad (2.104)$$

From (2.35) and (2.36), together with (2.79) and (2.80) the log-linearized equations for the deposit rate and the loan rate by the domestic bank are given by

$$\hat{r}_t^{HD} = (1 - \hat{\mu}_t^H) \hat{r}_t^C - \hat{\mu}_t^H \hat{r}_t^H, \quad (2.105)$$
\[ z_t^{HL} = z_t^C - q_t^H, \quad (2.106) \]

From (2.37), the linearized equation for the probability of repayment is

\[ q_t^H = \varphi_1(z_t^{HA} - \hat{i}_t^H) + \varphi_2 \hat{Y}_t^H, \quad (2.107) \]

where

\[ z_t^{HA} = \hat{P}_t^{HA} - \hat{P}_t^H. \quad (2.108) \]

Capital good producer firms’ demand for credit is

\[ \hat{i}_t^H = \check{i}_t^H. \quad (2.109) \]

From (2.31), the bank’s borrowing from the common central bank is

\[ \hat{i}_{t}^{HB} = \frac{1}{\check{i}_{t}^{HB}} \left[ \hat{i}_t^{HB} - (1 - \check{\mu}_t^H)\check{d}_t^H + \check{d}_t^H \check{\mu}_t^H \right], \quad (2.110) \]

From (2.41), the supply of cash evolves as

\[ \check{m}_t^H = \check{m}_{t-1}^H + \frac{\hat{i}_{t}^{HB}}{\check{m}_t^H} (\hat{i}_{t}^{HB} - \hat{i}_{t-1}^{HB}) \]

\[ -\check{\mu}_t^H \check{d}_t^H \left[ (\check{\mu}_t^H - \check{\mu}_{t-1}^H) + (\check{d}_t^H - \check{d}_{t-1}^H) \right]. \quad (2.111) \]

From (2.42), the common central bank base policy rate is determined by

\[ \check{i}_t^R = \chi \check{i}_{t-1}^R + (1 - \chi)(\varepsilon_1 \hat{\pi}_t + \varepsilon_2 \hat{Y}_t) + \varepsilon_t, \quad (2.112) \]

where, in the benchmark case where \( v = 1 \),

\[ \hat{\pi}_t = 0.5(\hat{\pi}_t^H + \hat{\pi}_t^F), \quad \check{Y}_t = 0.5(\check{Y}_t^H + \check{Y}_t^F). \]
From (2.32), (2.43), and (2.44) the refinance rate is

\[ i_t^C = i_t^R + \hat{\theta}_t^{CB}, \]  

(2.113)

where, again in the benchmark case where \( v = 1 \),

\[ \hat{\theta}_t^{CB} = \chi^{CB}[\hat{\theta}_t - \hat{d}_t - 0.5(\hat{\mu}_t^H + \hat{\rho}_t^F)], \]

and

\[ \hat{i}_t^H = 0.5(\hat{i}_t^{HB} + \hat{i}_t^{FB}), \quad \hat{d}_t = 0.5(\hat{d}_t^H + \hat{d}_t^F), \]

The equilibrium condition of the final good market, equation (2.46), is, using (2.39) and noting that \( \tilde{I}_H = \delta \tilde{K}^H \),

\[ \dot{Y}_t^H = \frac{\dot{C}_t^H + \dot{I}_t^H}{(1 - \psi)}Y^H. \]  

(2.114)

The equilibrium condition of the market for cash, (2.48), yields \( \tilde{m}_t^H \tilde{m}_t^H = \tilde{m}_t^{HP} \tilde{m}_t^{HP} + \tilde{I}_t^H \tilde{I}_t^H \), that is,

\[ \tilde{m}_t^{HP} = \left( \frac{\tilde{m}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{m}_t^H - \left( \frac{\tilde{I}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{I}_t^H. \]

With (2.111) used to determine \( \tilde{m}_t^H \), substituting out for \( \tilde{m}_t^{HP} \) from (2.92) in the above expression yields

\[ \tilde{i}_t^{HB} = \left( \frac{1 - \beta}{\beta} \right) \left\{ \left( \frac{\tilde{I}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{m}_t^H - \left( \frac{\tilde{m}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{m}_t^H + \frac{\hat{C}_t^H}{\zeta} \right\}, \]  

(2.115)

which determines the behavior of the bond rate.

With constant supply, the equilibrium condition for the housing market takes

\[ \tilde{m}_t^{HP} = \left( \frac{\tilde{m}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{m}_t^H - \left( \frac{\tilde{I}_t^H}{\tilde{m}_t^{HP}} \right) \tilde{I}_t^H. \]

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\[ \text{The quadratic specification of price adjustment costs in (2.24) implies that they are of second order. Thus, to a first-order approximation, output is equal to consumption, investment, and government spending only.} \]
the form \( \hat{A}_t^H = 0 \), which implies, using (2.10),
\[
\hat{P}_t^HA = \hat{P}_t^H + \frac{\hat{\pi}_t^H A_{t+1}^H - \hat{\pi}_t^H A_t^H}{\hat{g}_H - \hat{\pi}_t^H A_t^H} + \hat{C}_t^H.
\] (2.116)

The linearized form of the equilibrium condition of the current account of the home country is given by
\[
\tilde{C}_{Ct}^H = \hat{P}_t^H \tilde{Y}_t^H (\hat{P}_t^H + \hat{Y}_t^H) - \hat{P}_t^F \tilde{Y}_t^F (\hat{P}_t^F + \hat{Y}_t^F)
\] (2.117)

\[+
\tilde{P}_t^H \hat{P}_t^H (i_{t-1}^F + \hat{P}_t^H + \hat{b}_t^H) - \tilde{P}_t^H \hat{P}_t^F (i_{t-1}^H + \hat{P}_t^H + \hat{b}_t^H),
\]

and for the foreign country
\[
\tilde{C}_{Ct}^F = -\tilde{C}_{Ct}^H.
\] (2.118)

Finally, the log-linearized form of the countercyclical reserve requirement rule (2.54) is given by
\[
\hat{\mu}_t^i = \chi_1 \hat{\mu}_{t-1}^i + (1 - \chi_1) \chi_2 (\hat{I}_t^i - \hat{Y}_t^i),
\] (2.119)

for \( i = H, F \), whereas for (2.56) and separate instrument setting,
\[
\hat{\mu}_t^i = \chi_1 \hat{\mu}_{t-1}^i + (1 - \chi_1) \chi_2 (\hat{I}_t - \hat{Y}_t),
\]

where, in the benchmark case where \( \nu = 1, \hat{I}_t = 0.5(\hat{I}_t^H + \hat{I}_t^F) \) and \( \hat{Y}_t = 0.5(\hat{Y}_t^H + \hat{Y}_t^F) \).
Table 2.1: Benchmark Parameterization: Key Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
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<tr>
<td>$\beta$</td>
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<td>Discount factor</td>
</tr>
<tr>
<td>$\zeta$</td>
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<td>Elasticity of intertemporal substitution</td>
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<td>$\eta_N$</td>
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<td>Preference parameter for leisure</td>
</tr>
<tr>
<td>$\eta_x$</td>
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<td>Preference parameter for money holdings</td>
</tr>
<tr>
<td>$\eta_A$</td>
<td>0.02</td>
<td>Preference parameter for housing</td>
</tr>
<tr>
<td>$\nu$</td>
<td>0.2</td>
<td>Share parameter in index of money holdings</td>
</tr>
<tr>
<td>$\theta_0$</td>
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<td>Sensitivity of risk premium, bond holdings</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Lambda_I$</td>
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<td>Share of home IG goods in final output</td>
</tr>
<tr>
<td>$\eta$</td>
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<td>Elasticity of substitution, baskets of IG goods</td>
</tr>
<tr>
<td>$\theta_{HH}, \theta_{FF}$</td>
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<td>Elasticity of demand, intermediate goods</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.35</td>
<td>Share of capital, domestic intermediate goods</td>
</tr>
<tr>
<td>$\phi_D$</td>
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<td>Adjustment cost parameter, domestic IG prices</td>
</tr>
<tr>
<td>$\delta$</td>
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<td>Depreciation rate of capital</td>
</tr>
<tr>
<td>$\Theta_K$</td>
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<td>Adjustment cost parameter, investment</td>
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<tr>
<td>Commercial Bank</td>
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<td></td>
</tr>
<tr>
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<td>Effective collateral-loan ratio</td>
</tr>
<tr>
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<td>Elasticity of repayment probability, collateral</td>
</tr>
<tr>
<td>$\varphi_2$</td>
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<td>Elasticity of repayment probability, cyclical output</td>
</tr>
<tr>
<td>Common central bank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.08</td>
<td>Reserve requirement rate</td>
</tr>
<tr>
<td>$\chi$</td>
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<td>Degree of interest rate smoothing</td>
</tr>
<tr>
<td>$\epsilon_1$</td>
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<td>Response of base policy rate to inflation deviations</td>
</tr>
<tr>
<td>$\epsilon_2$</td>
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<td>Response of base policy rate to output deviations</td>
</tr>
<tr>
<td>$\theta_{CB}^C$</td>
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<td>Steady-state penalty rate</td>
</tr>
<tr>
<td>$\chi_{CB}$</td>
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<td>Elasticity of penalty rate to borrowing-reserves ratio</td>
</tr>
<tr>
<td>$\lambda_1$</td>
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<td>Persistence parameter, reserve requirements rule</td>
</tr>
<tr>
<td>Government</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.18</td>
<td>Share of government spending in domestic output sales</td>
</tr>
<tr>
<td>Shocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho^Y$</td>
<td>0.8</td>
<td>Persistence parameter, productivity shock</td>
</tr>
<tr>
<td>$\rho^Q$</td>
<td>0.57</td>
<td>Persistence parameter, financial shock</td>
</tr>
</tbody>
</table>
Table 2.2: Optimal Policy Responses and Policy Gains or Losses under Centralized and Decentralized Regimes: Narrow and Broad Measures of Financial Stability

<table>
<thead>
<tr>
<th>No countercyclical policy response</th>
<th>Narrow Measure of Financial Stability</th>
<th>Broad Measure of Financial Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productivity shock</td>
<td>Financial shock</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0063</td>
<td>0.0012</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0038</td>
<td>0.0007</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0060</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Decentralized regime (Nash)

<table>
<thead>
<tr>
<th>Optimal response parameters, $z_1^1$, $z_2^1$</th>
<th>Narrow Measure of Financial Stability</th>
<th>Broad Measure of Financial Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy loss-Home member</td>
<td>0.0062</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0025</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0043</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

Centralized regime (Cooperation)

<table>
<thead>
<tr>
<th>Uniform instrument</th>
<th>Narrow Measure of Financial Stability</th>
<th>Broad Measure of Financial Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal response parameter, $z_1$</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0004</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0020</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0042</td>
<td>0.0006</td>
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</tbody>
</table>

Separate instruments

<table>
<thead>
<tr>
<th>Optimal response parameters, $z_1^0$, $z_2^0$</th>
<th>Narrow Measure of Financial Stability</th>
<th>Broad Measure of Financial Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy loss-Home member</td>
<td>0.0063</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0019</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0041</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

Net gain or loss from coordination

<table>
<thead>
<tr>
<th>Uniform instrument</th>
<th>Narrow Measure of Financial Stability</th>
<th>Broad Measure of Financial Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home member</td>
<td>0.0351</td>
<td>-0.0036</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.1933</td>
<td>-0.0299</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0300</td>
<td>-0.0113</td>
</tr>
</tbody>
</table>

Separate instruments

| Home member        | 0.0235               | -0.0073           | 0.0199              | -0.0036           |
| Foreign member     | -0.2117              | -0.0469           | -0.0820             | -0.0225           |
| Union              | -0.0435               | -0.0188           | -0.0100             | -0.0054           |

Note: As defined in the text, the narrow measure of financial stability involves only the volatility of the credit-to-output ratio, whereas the broad measure of financial stability attaches weights of 0.85 to the volatility of the credit-to-output ratio and 0.15 to the volatility of real house prices.

1In percent. A negative entry means a net policy gain from cooperation relative to Nash.

Source: Authors’ calculations.
Table 2.3: Optimal Policy Responses and Policy Gains or Losses under Centralized and Decentralized Regimes: Symmetric and Asymmetric Policy Preferences for Output Stability

<table>
<thead>
<tr>
<th></th>
<th>Symmetric Preferences, Output Stability</th>
<th>Asymmetric Preferences, Output Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productivity shock</td>
<td>Financial shock</td>
</tr>
<tr>
<td>No counter-cyclical policy response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy loss-Home member</td>
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<td>0.0034</td>
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<tr>
<td>Policy loss-Foreign member</td>
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<tr>
<td>Policy loss-Union</td>
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<td>0.0022</td>
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<tr>
<td>Decentralized regime (Nash)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameters, ( \rho^* ), ( \gamma^* )</td>
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<td>4.0</td>
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<tr>
<td>Policy loss-Home member</td>
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<td>0.0033</td>
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<tr>
<td>Policy loss-Foreign member</td>
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<tr>
<td>Policy loss-Union</td>
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<td>0.0020</td>
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<tr>
<td>Centralized regime (Cooperation)</td>
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<td></td>
</tr>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameter, ( \gamma )</td>
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<td>3</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
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<td>0.0033</td>
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<tr>
<td>Policy loss-Foreign member</td>
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<tr>
<td>Policy loss-Union</td>
<td>0.0075</td>
<td>0.0020</td>
</tr>
<tr>
<td>Separate instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameters, ( \gamma^* ), ( \gamma^* )</td>
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<td>5.5, 0.5</td>
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<tr>
<td>Policy loss-Foreign member</td>
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<tr>
<td>Policy loss-Union</td>
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<td>0.0020</td>
</tr>
<tr>
<td>Net gain or loss from coordination 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform instrument</td>
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<td></td>
</tr>
<tr>
<td>Home member</td>
<td>0.0308</td>
<td>-0.0026</td>
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<tr>
<td>Foreign member</td>
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<td>-0.0487</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0163</td>
<td>-0.0102</td>
</tr>
<tr>
<td>Separate instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home member</td>
<td>0.0073</td>
<td>-0.0040</td>
</tr>
<tr>
<td>Foreign member</td>
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<td>-0.0759</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0189</td>
<td>-0.0159</td>
</tr>
</tbody>
</table>

Note: As discussed in the text, symmetric policy preferences with respect to output stability involve both national regulators and the common regulator attaching a weight of 0.9 to financial stability, measured in terms of the volatility of the credit-to-output ratio of 0.1, to output volatility. Under asymmetric policy preferences, national regulators use the exact same weights, whereas the common regulator attaches a weight of 0.95 to financial stability and 0.05 to output volatility. 

1In percent. A negative entry means a net policy gain from cooperation relative to Nash.

Source: Authors’ calculations.
Table 2.4: Optimal Policy Responses and Policy Gains or Losses under Centralized and Decentralized Regimes: Greater Financial Integration and Degree of Credit Market Imperfections

<table>
<thead>
<tr>
<th></th>
<th>Greater Financial Integration ((\delta_f = 0.05))</th>
<th>Credit Market Imperfections ((\theta_p = 0.28))</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Productivity shock</td>
<td>Financial shock</td>
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<tr>
<td><strong>No countercyclical policy response</strong></td>
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<tr>
<td>Policy loss-Home member</td>
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<tr>
<td>Policy loss-foreign member</td>
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<tr>
<td>Policy loss-Union</td>
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<td>0.0009</td>
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<tr>
<td><strong>Decentralized regime (Nash)</strong></td>
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<td></td>
</tr>
<tr>
<td>Optimal response parameters, (\bar{z}_1^c, \bar{z}_1^f)</td>
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<td>Policy loss-Union</td>
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<td>0.0021</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0042</td>
<td>0.0005</td>
</tr>
<tr>
<td>Separate instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameters, (\bar{z}_1^c, \bar{z}_1^f)</td>
<td>18.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0060</td>
<td>0.0007</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0021</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0041</td>
<td>0.0005</td>
</tr>
<tr>
<td><strong>Net gain or loss from coordination</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home member</td>
<td>-0.0019</td>
<td>-0.0251</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.0296</td>
<td>-0.0806</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0622</td>
<td>-0.0443</td>
</tr>
<tr>
<td>Separate instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home member</td>
<td>-0.0265</td>
<td>-0.0247</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.2165</td>
<td>-0.0888</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0835</td>
<td>-0.0479</td>
</tr>
</tbody>
</table>

Note: As defined in the text, the degree of financial integration is measured by \(\delta_f\), the sensitivity of the risk premium to bond holdings; whereas the degree of credit market imperfections is measured by \(\theta_p\), the sensitivity of the repayment probability with respect to cyclical output.

1In percent. A negative entry means a net policy gain from cooperation relative to Nash.

Source: Authors’ calculations.
Table 2.5: Optimal Policy Responses and Policy Gains or Losses under Centralized and Decentralized Regimes: Asymmetric Size for Common Loss Function, Equal Size for Monetary Policy Rule

<table>
<thead>
<tr>
<th></th>
<th>Shock Originating in the Home country</th>
<th>Shock Originating in the Foreign country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productivity shock</td>
<td>Financial shock</td>
</tr>
<tr>
<td>No countercycled policy response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0083</td>
<td>0.0012</td>
</tr>
<tr>
<td>Policy loss-Foreign member</td>
<td>0.0338</td>
<td>0.0007</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0074</td>
<td>0.0011</td>
</tr>
<tr>
<td>Decentralised regime (Nash)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameters, $z_i^H, z_i^F$</td>
<td>37.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0062</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-Foreign member</td>
<td>0.0035</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0054</td>
<td>0.0008</td>
</tr>
<tr>
<td>Centralised regime (Cooperation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameter, $z_d$</td>
<td>16.5</td>
<td>6</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0054</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-Foreign member</td>
<td>0.0021</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0055</td>
<td>0.0008</td>
</tr>
<tr>
<td>Separate instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameters, $x_i^H &gt; x_i^F$</td>
<td>21.3</td>
<td>6.5</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0062</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-Foreign member</td>
<td>0.0031</td>
<td>0.0003</td>
</tr>
<tr>
<td>Policy loss-Union</td>
<td>0.0054</td>
<td>0.0008</td>
</tr>
<tr>
<td>Net gain or loss from coordination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home member</td>
<td>0.0337</td>
<td>0.0301</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.1453</td>
<td>-0.0601</td>
</tr>
<tr>
<td>Union</td>
<td>0.0175</td>
<td>0.0217</td>
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<tr>
<td>Separate instruments</td>
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<td></td>
</tr>
<tr>
<td>Home member</td>
<td>0.0083</td>
<td>-0.0032</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.1367</td>
<td>-0.0621</td>
</tr>
<tr>
<td>Union</td>
<td>-0.0048</td>
<td>-0.0086</td>
</tr>
</tbody>
</table>

Note: Weights in the policy loss function are 0.8 for the home member and 0.2 for the foreign member.

1In percent. A negative entry means a net policy gain from cooperation relative to Nash.

Source: Authors’ calculations.
Table 2.6: Optimal Policy Responses and Policy Gains or Losses under Centralized and Decentralized Regimes: Asymmetric Size for both Common Loss Function and Monetary Policy Rule

<table>
<thead>
<tr>
<th>No countercyclical policy response</th>
<th>Shock Originating in the Home country</th>
<th>Shock Originating in the Foreign country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productivity shock</td>
<td>Financial shock</td>
</tr>
<tr>
<td>Policy loss-Home member</td>
<td>0.0080</td>
<td>0.0012</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0041</td>
<td>0.0008</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0077</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decentralized regime (Nash)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal response parameters, $z^h$, $z^f$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>policy loss-Home member</td>
<td>27.0</td>
<td>7.5, 0</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0061</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0023</td>
<td>0.0001</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0064</td>
<td>0.0008</td>
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</table>

<table>
<thead>
<tr>
<th>Centralized regime (Cooperation)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal response parameter, $\gamma$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>policy loss-Home member</td>
<td>18</td>
<td>6.5</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0063</td>
<td>0.0010</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0020</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0055</td>
<td>0.0008</td>
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</table>

<table>
<thead>
<tr>
<th>Separate instruments</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal response parameters, $z^h$, $z^f$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>policy loss-Home member</td>
<td>24.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Policy loss-foreign member</td>
<td>0.0061</td>
<td>0.0009</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0021</td>
<td>0.0004</td>
</tr>
<tr>
<td>Policy loss-union</td>
<td>0.0053</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Net gain or loss from coordination</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform instrument</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home member</td>
<td>0.0324</td>
<td>-0.0565</td>
</tr>
<tr>
<td>Foreign member</td>
<td>-0.1200</td>
<td>0.0650</td>
</tr>
<tr>
<td>Union</td>
<td>0.0193</td>
<td>0.0272</td>
</tr>
</tbody>
</table>

| Separate instruments              |                         |                                           |
| Home member                       | 0.0035                  | -0.0044                                  |
| Foreign member                    | -0.0812                 | -0.0237                                  |
| Union                             | -0.0038                 | -0.0034                                  |

Note: Weights in the policy loss function and the interest rate rule are 0.8 for the home member and 0.2 for the foreign member.

*In percent. A negative entry means a net policy gain from cooperation relative to Nash.

Source: Authors’ calculations.
Figure 2.1: Model Structure: Home Economy
Figure 2.2: Positive Productivity Shock in Home Country

Note: Interest rates, inflation rate and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms.
Figure 2.3: Negative Financial Shock in Home Country

Note: See note for Figure 2.
Figure 2.4: Centralized Regime, Uniform Required Reserve Ratio

Productivity Shock

![Graph showing productivity shock]

Financial shock

![Graph showing financial shock]

Note: In each panel the vertical axis represents the value of the union-wide policy loss function defined as a weighted average of the policy loss of the two members, under cooperation.
Figure 2.5: Centralized Regime, Separate Required Reserve Ratio

Productivity Shock

Financial shock

Note: See note for Figure 4.
Figure 2.6: Union-wide Gains from Coordination, Separate Required Reserve Ratios

Note: The horizontal axis shows the behaviour of the elasticity of the repayment probability with respect to cyclical output, $\varphi_2$. The vertical axis shows the gain from coordination relative to Nash, when separate required reserve ratios are set by the common regulator. A negative number means a net policy gain from cooperation.
Summary and Conclusion

In the aftermath of the global financial crisis, researchers and policymakers have shown a renewed interest in the role of capital controls as a macroprudential instrument as well as the international dimensions of macroprudential policies. This thesis discusses macroprudential regulation and financial stability in open economies. The content of each chapter has been briefly summarized below.

Chapter 1 studies the performance of time-varying capital controls on cross-border bank borrowing in an open-economy, dynamic stochastic general equilibrium model with credit market frictions and imperfect capital mobility. The analysis differs from existing studies in several important ways. First, this study uses an open-economy stochastic general equilibrium model to examine the benefits of time-varying capital controls; however, unlike these contributions, this study does so in a model with financial frictions, a feature that is important to understand some of the negative externalities associated with capital flows from the perspective of financial volatility. Second, in contrast to all existing contributions, which tend to focus on controls on households or the nonfinancial sector, this study focuses on capital controls on bank-related short-term capital flows. Third, the optimal, welfare-maximizing capital controls simple rule is solved, using a second-order approximation of the utility function and the model itself. The analysis shows that temporary capital controls can indeed lead to a significant welfare improvement in response to external financial shocks. In addition, the optimal simple rule performs well relative to the Ramsey policy, both in terms of impulse responses and volatility.

Fourth, this study investigates the joint optimal determination of simple, implementable countercyclical rules in terms of both reserve requirements and capital controls. It shows that a more aggressive reserve requirement rule (which responds to credit growth) requires less reliance on capital controls. Thus, the two instruments are substitutes at the margin, at least in response to external financial shocks.
This is an important result because a common criticism of capital controls (especially when they begin to take a more permanent form) is that private agents find ways to evade them. At the same time, it may be more difficult to do so for reserve requirements.

Chapter 2 evaluates, using a game-theoretic approach, the benefits of coordinating macroprudential policy (in the form of reserve requirements) in a two-country model of a currency union with credit market imperfections. A key question in this context has been the level (national or supranational) at which macroprudential regulation should be conducted. Specifically, the purpose of this paper is twofold. First, it aims to contribute to a better understanding of the cross-border spillover effects of macroprudential policy in a currency union where credit and capital markets are imperfect and housing plays a key role as collateral. Second, it aims to quantify the gains (or lack thereof) associated with countercyclical macroprudential policy coordination in a currency union, relative to the case where countries pursue independently their own policies, and to assess how these gains depend on how financial stability is measured, the degree of asymmetry in preferences between national regulators and the common regulator, the degree of financial integration, and the degree of heterogeneity in credit market imperfections across countries.

In contrast to the existing literature, this study focuses on reserve requirements as the instrument of macroprudential regulation. Also in contrast with most existing contributions, this study addresses this issue in an explicit game-theoretic framework. This allows us to account for strategic interactions between countries when they choose their policies in the absence of cooperation. The gains from coordination are measured by comparing outcomes under a centralized regime, where a common regulator sets the required reserve ratio to minimize union-wide financial volatility, and a decentralized (Nash) regime, where each country regulator sets that ratio to minimize its own policy loss. Experiments show that, under asymmetric real and financial shocks, the gains from coordination are significant at the union level.
Moreover, these gains are higher when the common and national regulators have asymmetric preferences with respect to output stability, when financial markets are more integrated, and when the degree of asymmetry in credit markets between members is larger. Implications of the analysis for macroprudential policy coordination in the euro area are also discussed.
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