

# Capital Controls or Macroprudential Regulation?\*

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## Abstract

International capital flows can create significant financial instability in emerging economies. Does this make it optimal to impose capital controls or should policymakers rely on domestic macroprudential regulation in their quest for greater financial stability? This paper shows that it is desirable to employ both instruments to mitigate contractionary exchange rate depreciations: Macroprudential regulation reduces the amount and riskiness of financial liabilities, no matter whether they are financed by domestic or foreign lenders; capital controls increase the aggregate net worth of the economy by reducing net inflows. Both types of policy measures make the economy more stable and reduce the incidence and severity of crises. They should be set higher the greater an economy's debt burden and the higher domestic inequality. In a calibration based on the East Asian crisis countries, we find that it is optimal to impose both capital controls and macroprudential regulation that amount to a 2% tax on debt flows or equivalent quantity regulations. In advanced countries where the risk of contractionary exchange rate depreciations is more limited, the role for capital controls subsides. However, macroprudential regulation remains essential to mitigate booms and busts in asset prices.

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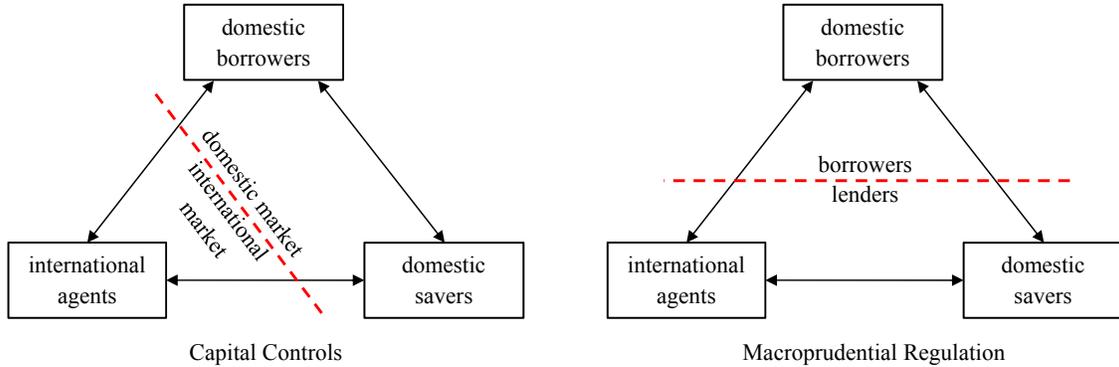
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# 1 Introduction

Fighting financial instability is one of the big policy challenges of our time. Many recent financial crises have been triggered in part by large reversals in international capital flows, even in countries that followed seemingly sound fiscal and monetary policies (see e.g. Reinhart and Rogoff, 2008). Policymakers have struggled with the question of whether to protect their economies from such instability by using macroprudential regulations on domestic financial transactions or whether to impose more heterodox policy measures such as capital controls.<sup>1</sup>

The defining feature of capital controls is that they apply exclusively to financial transactions between residents and non-residents, i.e. they discriminate based on the residency of the parties involved in a financial transaction.<sup>2</sup> For example, controls on capital inflows apply to transactions between foreign creditors and domestic debtors. Similarly, controls on capital outflows apply to transactions between domestic savers and international borrowers. Capital controls segment domestic and international financial markets, as illustrated in the left panel of Figure 1. As a result of this segmentation, international lenders and domestic agents face different effective interest rates.



**Figure 1:** Capital controls versus macroprudential regulation

Macroprudential policies, by contrast, restrict borrowing by domestic agents independently of whether credit is provided by domestic or foreign creditors. They impose a segmentation between borrowers and all types of lenders, as illustrated in the right panel of Figure 1. As a result, borrowers and lenders in the economy face different effective interest rates.<sup>3</sup>

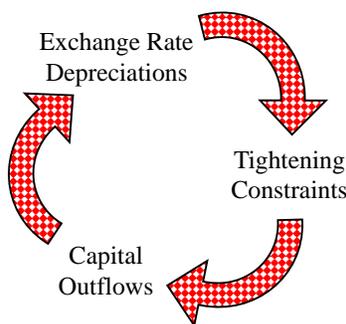
<sup>1</sup>See e.g. Ostry et al. (2011) for an overview of the use of capital controls and Galati and Moessner (2013) for a survey on macroprudential regulation. See also Ostry et al. (2014) for a detailed analysis of the policy considerations involved in choosing between capital controls and macroprudential regulation.

<sup>2</sup>More recently, the IMF (2012) has adopted the term capital flow management measures (CFMs) for capital controls to avoid the negative connotation that was attributed to controls in earlier years. Some papers, e.g. Gallagher et al. (2011), use the term capital account regulations (CARs) to hint at the close similarity to other types of financial regulation. We use the term capital controls in accordance with the tradition in the academic literature.

<sup>3</sup>In some instances, it is difficult to distinguish between capital controls and macroprudential regulation because regulators face a limited set of policy instruments and use one instrument as a substitute for the other. In the current paper, we assume that regulators have both an effective macroprudential instrument

Should countries use capital controls or macroprudential regulation when they experience capital flow-driven credit booms? Some have argued that capital controls should only be used as a measure of last resort (see e.g. IMF, 2012). Others, by contrast, have argued that capital controls are the more natural instrument when credit growth is mainly driven by capital flows from abroad (see e.g. Ostry et al., 2011). Should the two policy instruments be thought of as equivalent or close substitutes? Or alternatively, does each of the two have its own comparative advantage depending on specific circumstances?

We study these questions in a model of a small open economy with borrowers who are subject to a collateral constraint. Our key departure from the existing literature is that borrowers can access credit either domestically – from domestic savers – or from international lenders. This allows us to explicitly distinguish between capital controls and macroprudential measures. The key difference between domestic and foreign borrowing materializes when borrowers are forced to delever: repayments to domestic creditors remain in the domestic economy where they contribute to domestic aggregate demand, whereas repayments to international lenders reduce domestic aggregate demand; they lead to capital outflows and depreciate the country’s exchange rate.



**Figure 2:** Feedback loop of financial crises with exchange rate depreciations

The level of the exchange rate matters because it determines how much foreign lenders value domestic collateral. When the collateral constraint on borrowers is binding, a depreciation reduces the value of collateral and triggers a feedback loop of tightening constraints, capital outflows and further exchange rate depreciations, as illustrated in Figure 2. This describes the classic dynamics of sudden stops and financial amplification (see e.g. Korinek and Mendoza, 2014, for a summary and survey). A growing literature has shown that these dynamics give rise to excessive borrowing since private agents do not internalize that their collective actions contribute to the exchange rate declines and resulting sudden stop dynamics. This *pecuniary externality* has been proposed as a rationale for both capital

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and effective capital controls at their disposal. For a more detailed analysis of targeting problems under incomplete instruments see e.g. Ostry et al. (2014).

controls and macroprudential regulation.<sup>4,5</sup> However, in the existing literature, there is no difference between the two policy measures – both are simply restrictions on borrowing.

Our paper is the first to differentiate between macroprudential regulation and capital controls. We do so by distinguishing between domestic and foreign lending. This allows us to investigate the comparative advantages of the two types of prudential instruments and to provide policy lessons for their optimal use.

Our main result is that it is desirable to use both policy instruments in an emerging economy that is vulnerable to sudden stops. Macroprudential regulation plays the usual role of reducing the amount and riskiness of all financial liabilities, no matter whether domestic or foreign; capital controls aim to increase the aggregate net worth of the economy by reducing net inflows; they create an interest rate differential between the domestic and international credit market, which induces domestic savers to save more. This makes the economy more resilient to sudden stops, i.e. it implies that the exchange rate will depreciate less in times of crisis. Put differently, when borrowers are forced to delever, repayments to foreign lenders imply that purchasing power flows out of the economy and depreciates the exchange rate. By contrast, repayments to domestic lenders imply that the purchasing power stays at home, which increases demand for domestic goods and reduces the downward pressure on the exchange rate.

We demonstrate that it is desirable to combine capital controls and macroprudential regulation in a variety of settings. For ease of exposition, we first analyze a framework in which an emerging economy suffers a financial crisis with perfect foresight. We then show that our result continues to hold if we introduce uncertainty: if domestic agents have access to state-contingent financial instruments, the described externality induces private agents to take on excessive risk and insure too little. An immediate implication is that they take on too much dollar debt – which requires large pay-outs in low states of nature – compared to local currency debt. A planner uses *both* capital controls and macroprudential regulation to remedy this and shift the composition of borrowing towards less risky liabilities and the composition of saving towards more insurance. Third, we consider an economy with uncertainty that only has access to uncontingent bonds. We find that private agents borrow too much and increase crisis risk beyond the socially optimal level. Again, a planner would use *both* instruments to reduce borrowing and increase saving in the economy. In this setting, we also show that the planner’s intervention reduces not only the magnitude but, in general, also the probability of financial crises.

Macroprudential regulation and capital controls should be optimally adjusted to reflect the risks to financial stability in emerging economies: in an economy in which there is no

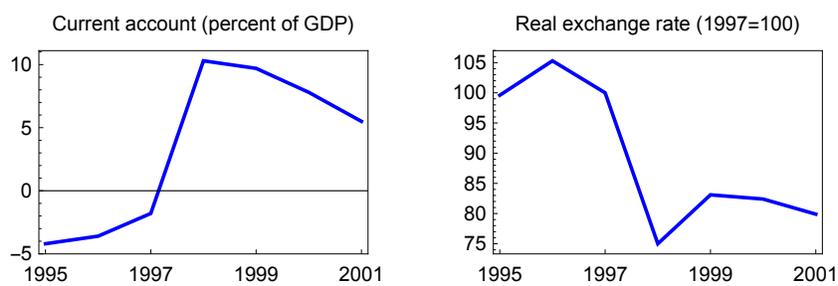
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<sup>4</sup>For a survey of this literature on capital controls see Korinek (2011a). For a survey on macroprudential regulation see Galati and Moessner (2013). A detailed analytic description of the resulting case for capital controls is provided by Korinek (2007, 2010) and Bianchi (2011) in a small open economy with a representative agent. Benigno et al. (2010, 2012, 2013a, 2013b) analyze how the same inefficiencies can be addressed using alternative policy measures. Lorenzoni (2008), Jeanne and Korinek (2010ab), Bianchi and Mendoza (2010) and Korinek (2011b) make the case for macroprudential regulation based on asset price movements that trigger feedback loops. Jeanne (2014) analyzes macroprudential regulation in a framework in which capital controls are by construction a second-best device.

<sup>5</sup>An alternative strand of the literature motivates macroprudential regulation and capital controls based on aggregate demand externalities in the presence of nominal frictions. See for example Farhi and Werning (2012, 2013, 2014), Acharya and Bengui (2015), Schmitt-Grohé and Uribe (2015) and Korinek and Simsek (2016).

risk of financial crisis, no intervention is required. Conversely, the higher the debt of an emerging economy and the larger the risk of a sudden stop, the higher the two measures should be set. Furthermore, we show that greater wealth inequality – for a given aggregate debt burden – calls for tighter regulation of both types since greater inequality implies that borrowers are more constrained.

The East Asian crisis of 1997 provides a clear example of sudden stop dynamics.<sup>6</sup> Figure 3 shows that the East Asian crisis countries experienced a sudden reversal of the current account by more than 10 percentage points of GDP within one year. Meanwhile their economies witnessed a sharp correction of the real exchange rate by about 25 percent. This severely impaired the balance sheets of borrowers and constrained their ability to raise new loans. In a calibration of our model that replicates these numbers and assumes a 5% crisis probability, we find it optimal to impose macroprudential taxes and capital controls of about 2% each or equivalent quantity regulations prior to the crisis, implying a combined tax burden on borrowers of 4%.



**Figure 3:** Sudden stop dynamics: the East Asian crisis of 1997.

To study how the role for capital controls evolves as an economy develops, we next consider an economy in which collateral constraints depend on asset prices rather than the exchange rate, capturing the situation of a typical advanced economy. As a result, borrowers become vulnerable to a feedback loop of fire sales and asset price declines that is similar to the feedback loop involving exchange rate depreciations in Figure 2: binding constraints reduce borrowers’ demand for productive assets, which in turn leads to fire sales, lower prices, and tighter borrowing constraints. In a model of such asset price externalities, macroprudential regulation is sufficient to remedy the overborrowing. There is no role for capital controls to induce greater precautionary savings for domestic lenders since lenders have no comparative advantage in holding productive assets.

This suggests that the optimal mix of capital controls and macroprudential regulation changes as an economy becomes more developed. Concerns about exchange rate volatility are particularly acute in emerging markets, especially those that have significant debt in foreign currency. In advanced economies, by contrast, the exchange rate is less relevant for financial stability, but asset price volatility remains a threat. As an emerging economy becomes more advanced, it is thus optimal to phase out capital controls and focus on macroprudential regulation.

<sup>6</sup>The East Asian crisis countries include Indonesia, Malaysia, Philippines, South Korea and Thailand.

## 2 Model

### 2.1 Setup

We consider a small open economy with three time periods  $t \in \{0, 1, 2\}$ . There is a unit mass of domestic borrowers  $B$  and a unit mass of domestic savers  $S$  in the economy. Furthermore, there is a large set of foreigners who trade bonds (i.e. they lend or borrow) at a net interest rate of zero. The two types of domestic agents  $i \in \{B, S\}$  derive utility from the consumption  $c_T^i$  of traded goods and  $c_N^i$  of non-traded goods. For simplicity, they consume non-traded goods only in period 1 so that their overall utility is given by,

$$U^i = u(c_{T,0}^i) + u(c_1^i) + u(c_{T,2}^i) \quad (1)$$

where the period utility functions  $u(c) = \ln c$  and where  $c_1^i = (c_{T,1}^i)^\alpha (c_{N,1}^i)^{1-\alpha}$  is a consumption index of traded and non-traded goods with relative expenditure shares  $\alpha$  and  $1 - \alpha$ . For simplicity, their intertemporal discount rate and the world interest rate are set to zero.

Domestic agents enter period 0 with a stock of bonds  $b_0^i$  and receive an endowment of traded goods  $y_{T,0}^i$ . They decide how much to consume and how many bonds  $b_1^i$  to carry into the next period, with  $b < 0$  corresponding to borrowing,

$$c_{T,0}^i + b_1^i = b_0^i + y_{T,0}^i \quad (2)$$

Agents also receive endowments of traded and non-traded goods  $(y_{T,1}^i, y_{N,1}^i)$  in period 1 and an endowment of traded goods  $y_{T,2}^i$  in period 2.

We denote the relative price of non-traded to traded consumption goods by  $p$  and observe that  $p$  is a measure of the country's real exchange rate.<sup>7</sup> The period 1 budget constraint of agent  $i \in \{B, L\}$  is

$$c_{T,1}^i + p c_{N,1}^i + b_2^i = y_{T,1}^i + p y_{N,1}^i + b_1^i \quad (3)$$

where  $b_2^i$  is the amount of bonds carried into the following period.

In period 2, agents finance their consumption using the traded endowment  $y_{T,2}^i$  and the bonds carried into the period,

$$c_{T,2}^i = y_{T,2}^i + b_2^i \quad (4)$$

The initial stock of debt  $b_0^i$  and the income endowments of domestic borrowers and savers are distributed such that in periods 0 and 1 borrowers find it optimal to borrow,  $b_t^B < 0$ , and savers find it optimal to save,  $b_t^S > 0$ .

**Financial constraint** After borrowers have received their loans in period 1, we assume they have an opportunity to divert their income and renege on their borrowing. However,

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<sup>7</sup>A country's real exchange rate is commonly defined as the price of a basket of domestic consumption goods in terms of a basket of international consumption goods. In accordance with our small open economy assumption, we take the price of international consumption goods and traded domestic consumption goods as exogenous. Therefore the price of a domestic consumption basket is a strictly increasing function of the relative price of domestic non-traded goods.

lenders can take them to court and recover up to a fraction  $\phi$  of their period 1 income. To rule out default, borrowing  $-b_2^B$  is limited to

$$-b_2^B \leq \phi (y_{T,1}^B + py_{N,1}^B) \quad (5)$$

We interpret the coefficient  $\phi$  as a pledgeability parameter.<sup>8</sup>

This type of financial constraint (5) is common in the literature on emerging market crises (e.g. Mendoza, 2005). The relative price  $p$  that appears in the constraint generates both financial amplification effects and pecuniary externalities. The strength of financial amplification depends crucially on the parameter  $\phi$ . For  $\phi = 0$ , there will be no amplification since the borrowing limit is constant. The higher  $\phi$ , the greater the amplification effects. To ensure that the financial amplification effects are bounded and equilibrium in our model is unique, we impose

**Assumption 1**  $\phi < \hat{\phi}$ .

where the upper limit  $\hat{\phi}$  is characterized in Appendix A.1. This is a common assumption in models of financial amplification and imposes only mild restrictions (see e.g. the detailed discussion in section 3.2 of Korinek and Mendoza, 2014).

## 2.2 Decentralized Equilibrium

An equilibrium in the described economy consists of a set of allocations and prices in which each type of agent  $i \in \{B, S\}$  maximizes her utility (1) subject to the budget constraints (2), (3) and (4) as well as the financial constraint (5) and in which markets for non-traded goods clear

$$C_{N,1}^B + C_{N,1}^S = Y_{N,1} \quad (6)$$

where we denote by  $Y_{N,1} = Y_{N,1}^B + Y_{N,1}^S$  the aggregate endowment of non-traded goods. Market clearing for traded goods is ensured by the domestic budget constraints together with the fact that foreign agents can satisfy any amount of borrowing or lending by domestic agents.

In market-clearing condition (6) and for the remainder of the paper, we follow the convention of denoting individual variables by lower-case letters and sector-wide or aggregate variables by upper-case letters, e.g.  $c_{N,1}^i$  is the non-traded consumption of an individual agent in sector  $i$  whereas  $C_{N,1}^i$  is total non-traded consumption of sector  $i$ , and so forth. In equilibrium, the two sets of variables always coincide, but the distinction will matter below when we show that individual agents impose externalities on others because they take aggregate variables as given and fail to internalize how they affect aggregate outcomes.

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<sup>8</sup>We could refine this constraint by assuming different degrees of pledgeability for traded and non-traded goods but this is not essential to our analysis. We could also impose an equivalent constraint on period 0 borrowing  $b_1^i$  but the model solution would be degenerate if this constraint is binding – all the interesting decisions of borrowers would be pre-determined by binding constraints. Without loss of generality, we focus on equilibria in which the period 0 constraint is loose.

**Equilibrium in Periods 1 and 2** We solve for the equilibrium via backward induction, starting with periods 1 and 2. It proves useful to express the period 1 welfare of domestic agents  $i \in \{B, S\}$  as a function of their period 1 liquid net worth, defined as the period 1 endowment of traded goods plus bond holdings,

$$m^i = y_{T,1}^i + b_1^i$$

The aggregate state of the economy in period 1 is fully described by the sector-wide liquid net worth positions of the two sets of domestic agents  $(M^B, M^S)$ . In equilibrium,  $m^i = M^i$  will hold.

In period 1, an individual agent in sector  $i \in \{B, S\}$  takes the state of the economy  $(M^B, M^S)$  as given and solves the utility maximization problem

$$\begin{aligned} V^i(m^i; M^B, M^S) &= \max_{c_{T,1}^i, c_{N,1}^i, b_2^i} u(c_{T,1}^i, c_{N,1}^i) + u(y_{T,2}^i + b_2^i) \\ \text{s.t.} \quad &b_2^i + \phi(y_{T,1}^i + p y_{N,1}^i) \geq 0 \\ &m^i + p(y_{N,1}^i - c_{N,1}^i) = c_{T,1}^i + b_2^i \end{aligned} \quad (7)$$

We assign shadow prices  $\lambda^i$  and  $\mu^i$  to the borrowing constraint and the period 1 budget constraint and denote by  $u_{T,1}^i = \partial u(c_1^i) / \partial c_{T,1}^i$  the marginal utility of traded consumption in period 1 and similarly for  $u_{N,1}^i, u_{T,2}^i$  etc. The optimization problem yields the Euler equation

$$u_{T,1}^i = u_{T,2}^i + \lambda^i \quad (8)$$

Domestic savers are never constrained so  $\lambda^S \equiv 0$ .

From the optimality conditions for traded and non-traded consumption in period 1, we obtain the exchange rate

$$p = \frac{u_{N,1}^i}{u_{T,1}^i} = \frac{1 - \alpha}{\alpha} \frac{c_{T,1}^i}{c_{N,1}^i}$$

Since this condition holds for both domestic agents, it also has to hold for the aggregate economy,

$$p = \frac{1 - \alpha}{\alpha} \frac{C_{T,1}^B + C_{T,1}^S}{Y_{N,1}} \quad (9)$$

where the denominator reflects market clearing for non-traded goods. In short, the real exchange rate is a strictly increasing function of aggregate spending on traded goods  $(C_{T,1}^B + C_{T,1}^S)$ .

**Unconstrained Period 1 Equilibria** We first focus on the case when the liquid net worth of the two sectors is sufficiently high so that the collateral constraint on borrowers is loose. Analytically, we denote the set of state variables  $(M^B, M^S)$  for which borrowers are unconstrained by  $\mathcal{M}^{unc}$  and the set of state variables for which borrowers are constrained by  $\mathcal{M}^{con}$ . The two sets are mutually exclusive and are described formally in Appendix A.1.

For unconstrained equilibria, i.e. for  $(M^B, M^S) \in \mathcal{M}^{unc}$ , all agents smooth consumption according to their Euler equation so  $u_{T,1}^i = u_{T,2}^i$  for  $\forall i \in \{B, S\}$ . Period 1 traded

consumption of agent  $i$  is given by

$$c_{T,1}^i = \frac{\alpha}{2} (m^i + py_{N,1}^i + y_{T,2}^i) \quad (10)$$

The agent spends half of her income in period 1, and a fraction  $\alpha$  thereof falls on traded goods. The exchange rate is a function of  $(M^B, M^S)$ ,

$$p(M^B, M^S) = \frac{1 - \alpha}{1 + \alpha} \cdot \frac{M^B + M^S + Y_{T,2}^B + Y_{T,2}^S}{Y_{N,1}}$$

An increase in the liquid net worth  $M^i$  of either domestic agent pushes up the real exchange rate by

$$\frac{\partial p}{\partial M^B} = \frac{\partial p}{\partial M^S} = \frac{1 - \alpha}{Y_{N,1}(1 + \alpha)} > 0$$

The net worth of borrowers and lenders affect the real exchange rate equally because both agents have the same marginal propensity to consume out of liquid net worth (MPC) when they are unconstrained. From equation (10), we can indeed derive

$$MPC^i = \frac{\partial [c_{T,1}^i + pc_{N,1}^i]}{\partial m^i} = \frac{1}{2}$$

**Constrained Period 1 Equilibria** For  $(M^B, M^S) \in \mathcal{M}^{con}$ , borrowers are constrained and spend their entire liquid net worth in period 1 on consumption. A fraction  $\alpha$  thereof is traded consumption,

$$c_{T,1}^B = \alpha [m^B + py_{N,1}^B + \phi(y_{T,1}^B + py_{N,1}^B)] \quad (11)$$

Spending on traded goods by savers is still given by condition (10). We can substitute the two expressions into equation (9) to obtain the real exchange rate as a function of  $(M^B, M^S)$ ,

$$p(M^B, M^S) = \frac{1 - \alpha}{D} \left( M^B + \phi Y_{T,1}^B + \frac{M^S + Y_{T,2}^S}{2} \right) \quad (12)$$

where  $D = Y_{N,1} - (1 - \alpha)[Y_{N,1}^B(1 + \phi) + Y_{N,1}^S/2] > 0$  is strictly positive under Assumption 1.

In the constrained region, an increase in either agent's net worth raises the real exchange rate. However, the net worth of borrowers has twice as strong of an effect as the net worth of savers,

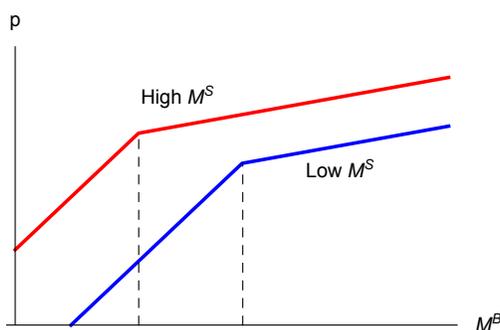
$$\frac{\partial p}{\partial M^B} = \frac{1 - \alpha}{D} > \frac{\partial p}{\partial M^S} = \frac{1 - \alpha}{2D} > 0$$

The difference results from the different marginal propensities to consume of borrowers and savers. Since they are constrained, the MPC of borrowers is now twice as high as in the unconstrained solution. Using equation (11), we indeed observe that

$$MPC^B = 1 > MPC^S = \frac{1}{2}$$

Figure 4 schematically depicts the response of the exchange rate  $p$  to varying the level of  $M^B$  for two different levels of the net worth of savers  $M^S$ . For each level of  $M^S$ , there is a

threshold value of  $M^B$  below which the equilibrium becomes constrained, indicated by the vertical dashed lines. In the constrained region, i.e. to the left, the exchange rate responds strongly to changes in  $M^B$  since financial amplification effects are at play: additional net worth allows borrowers to demand more non-traded goods, which pushes up the real exchange rate and relaxes the financial constraint, leading to a virtuous cycle of appreciating real exchange rate and loosening of the constraint.



**Figure 4:** Exchange rate  $p$  as a function of  $M^B$

We summarize our findings as follows:

**Lemma 1 (Net Worth and the Real Exchange Rate)** (i) *The economy's real exchange rate  $p$  is an increasing function of period 1 spending on traded goods, which in turn is an increasing function of liquid net worth  $M^B$  and  $M^S$ .*

(ii) *The effect of liquid net worth  $M^i$  on the exchange rate is proportional to the marginal propensity to consume ( $MPC^i$ ) out of liquid net worth for agent  $i$ .*

(ii.a) *If the economy is unconstrained, then  $MPC^B = MPC^S$  and  $\partial p / \partial M^B = \partial p / \partial M^S > 0$ .*

(ii.b) *If the economy is constrained, then  $MPC^B > MPC^S$  and  $\partial p / \partial M^B > \partial p / \partial M^S > 0$ .*

**Proof.** See discussion above. ■

**Comparative Statics of Net Worth  $M^i$**  For our subsequent analysis, it proves useful to analyze how the liquid net worth  $M^i$  of sector  $i$  affects the welfare of the two types of domestic agents  $j \in \{B, S\}$ :

$$\frac{\partial V^j}{\partial M^i} = u_{T,1}^j \cdot R_i^j + \lambda^j \cdot \Phi_i^j \quad (13)$$

$$\text{where we define} \quad R_i^j = \frac{\partial p}{\partial M^i} (Y_{N,1}^j - C_{N,1}^j)$$

$$\Phi_i^j = \frac{\partial p}{\partial M^i} \phi Y_{N,1}^j$$

The welfare effects on agent  $j$  occur solely through changes in the price of non-traded goods  $\partial p / \partial M^j$ , i.e. through pecuniary externalities. All other variables are either exogenous or optimally chosen by private agents, which allows us to apply the envelope theorem and

omit any associated derivatives in expression (13). The pecuniary externalities can be distinguished into two categories:

- The term  $R_i^j$  captures that price changes create redistributions between agents. Since non-traded goods are only traded among domestic agents, the redistributions between domestic agents always net out, i.e.  $R_i^i + R_i^j = 0$ . If agent  $j$  is a net seller of non-traded goods ( $y_{N,1}^j > c_{N,1}^j$ ) then an increase in the price of the good benefits agent  $j$  and vice versa.
- The term  $\Phi_i^j$  captures that price changes affect the tightness of the borrowing constraint. An increase in the real exchange rate relaxes the collateral constraint which provides a welfare benefit  $\lambda^j$  per unit.

For our model to be well-behaved, we impose the following assumption on the redistributive terms:

**Assumption 2**  $1 + R_B^B - R_S^B > 0$ .

This rules out “immiserizing” transfers, i.e. it ensures that transferring one dollar from savers to borrowers does not lead to price changes that reduce borrowers’ wealth.

**Period 0 Equilibrium** We now turn to the period 0 optimization problem that for both types of domestic agents is given by

$$\max_{b_1^i} u(b_0^i + y_{T,0}^i - b_1^i) + V^i(y_{T,1}^i + b_1^i; M^B, M^S)$$

and results in the Euler equation

$$u_{T,0}^i = u_{T,1}^i$$

In short, both sets of agents smooth the utility of traded consumption. Our next question is whether a planner can improve on the resulting decentralized equilibrium allocation.

### 2.3 Constrained Planning Problem

A social planner in the described economy maximizes the weighted sum of welfare of domestic agents in the economy, subject to the economy’s resource constraints. Since international lenders are indifferent between lending or borrowing, their utility is unaffected by the allocations in the domestic economy, and they can be omitted from the planning problem. By implication, any Pareto efficient allocation in the domestic economy is also a Pareto efficient global allocation.

We focus on a constrained planning problem in which the allocations of the planner are subject to the same financial constraint (5) as the allocations of private agents. Following the tradition of Stiglitz (1982) and Geanakoplos and Polemarchakis (1986), we assume that the constrained planner chooses the financial allocations of domestic agents in period 0, but leaves the remaining allocations in periods 1 and 2 to be determined under the decentralized equilibrium. In other words, the planner lets the market determine the real exchange rate according to condition (9). This captures the notion that policymakers commonly impose

financial regulation to restrict borrowing/lending but find it difficult to control prices in financial markets without giving rise to massive arbitrage behavior.<sup>9</sup>

The constrained planner chooses period 0 allocations while internalizing how the period 1 state variables  $(M^B, M^S)$  affect equilibrium and welfare in periods 1 and 2. Specifically, the social planner maximizes the sum of utilities of domestic borrowers and savers with weights  $\gamma^i$ , subject to the period 0 resource constraint,

$$\max_{C_{T,0}^i, B_1^i} \sum_{i \in \{B, S\}} \gamma^i \{u(C_{T,0}^i) + V^i(M^i; M^B, M^S)\} \quad \text{s.t.} \quad \sum_{i \in \{B, S\}} (C_{T,0}^i + B_1^i - B_0^i - Y_{T,0}^i) \leq 0 \quad (14)$$

By varying the welfare weights, we can trace the entire Pareto frontier of the economy. The continuation utility of private agents of type  $i \in \{B, S\}$  from period 1 onwards is given by the value function  $V^i(m^i; M^B, M^S)$ , which we characterized in equation (7), but the planner also internalizes that  $m^i = M^i = Y_{T,1}^i + B_1^i$ .

### Characterizing the Planning Solution

Using the envelope condition  $\partial V^i / \partial m^i = u_{T,1}^i$ , the planner's optimality conditions are

$$\gamma^i u_{T,0}^i = \gamma^j u_{T,0}^j \quad (15)$$

$$\gamma^i u_{T,0}^i = \underbrace{\gamma^i u_{T,1}^i}_{\text{private benefit}} + \underbrace{\gamma^i \frac{\partial V^i}{\partial M^i} + \gamma^j \frac{\partial V^j}{\partial M^i}}_{\text{social benefit of agent } i \text{ liquidity}} \quad (16)$$

for  $j \neq i$ . Condition (15) equates the weighted marginal utility of consumption across agents at time 0. In Euler equation (16), the usual consumption smoothing motive – captured by the marginal utilities  $u_{T,t}^i$  – is complemented by two additional terms that reflect the pecuniary externalities of type  $i$  agents carrying wealth into period 1 on their own sector and the other sector.

Using equation (13), the market clearing condition (6), and  $\lambda^S = 0$  since savers are by construction not borrowing-constrained, we rewrite the planner's Euler equation (16) as

$$\underbrace{\gamma^i u_{T,0}^i = \gamma^i u_{T,1}^i}_{\text{smoothing consumption}} + \frac{\partial p}{\partial M^i} \left[ \underbrace{(\gamma^i u_{T,1}^i - \gamma^j u_{T,1}^j)}_{\text{redistributing between agents}} (Y_{N,1}^i - C_{N,1}^i) + \underbrace{\gamma^B \lambda^B \phi Y_{N,1}^B}_{\text{relaxing constraint}} \right] \quad (17)$$

The first part captures the usual consumption smoothing motive and coincides with the Euler equation of private agents. In addition to this, liquid wealth  $M^i$  affects the real exchange rate and leads to two further effects: a higher exchange rate redistributes from net buyers to net sellers of non-traded goods, as captured by the first term in the square brackets; furthermore, a higher real exchange rate relaxes the collateral constraint of borrowers,

<sup>9</sup>The assumption that policymakers cannot directly set real exchange rates can be relaxed as long as there is a cost associated with doing so. See, for example, Benigno et al. (2013) for exchange rate intervention. Our basic results continue to hold in these cases. Our assumption that the planner cannot directly set prices is also supported by the experience of many emerging economies that were either forced to abandon nominal pegs or experienced strong real depreciations under fixed nominal exchange rates during crises.

captured by the last term. Using the notation  $R_i^j$  and  $\Phi_i^j$  that we defined in equation (13), the expression reads as

$$\gamma^i u_{T,0}^i = \gamma^i u_{T,1}^i + \left( \gamma^i u_{T,1}^i - \gamma^j u_{T,1}^j \right) R_i^i + \gamma^B \lambda^B \Phi_i^B$$

The solution to the constrained planning problem is:

**Proposition 2 (Constrained Efficient Allocations)** (i) *Any constrained efficient allocation satisfies*

$$\frac{u_{T,1}^B}{u_{T,0}^B} = 1 - \frac{\lambda^B}{u_{T,0}^B} \frac{\Phi_B^B}{1 + R_B^B - R_S^B} \quad (18)$$

$$\frac{u_{T,1}^S}{u_{T,0}^S} = 1 - \frac{\lambda^B}{u_{T,0}^B} \frac{\Phi_S^B}{1 + R_B^B - R_S^B} \quad (19)$$

(ii) *Decentralized allocations in which the financial constraint is loose,  $\lambda^B = 0$ , are constrained efficient.*

(iii) *Decentralized allocations in which the financial constraint is binding,  $\lambda^B > 0$  are constrained inefficient. The planner introduces a wedge in the marginal rate of substitution of agents and acts in a more precautionary manner than private agents in period 0, i.e.  $u_{T,0}^i > u_{T,1}^i$ . Furthermore, the wedge is larger for borrowers than for savers.*

**Proof.** For (i), we derive equations (18) and (19) by combining the planner's Euler equation (17) for both agents to obtain

$$\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S = - \frac{\gamma^B \lambda^B (\Phi_B^B - \Phi_S^B)}{1 + R_B^B - R_S^B}$$

The difference between the weighted marginal utilities of borrowers and savers reflect the difference in how much borrower and saver net worth relax the constraint  $\Phi_B^B - \Phi_S^B$  normalized by the redistributions created by moving one dollar from savers to borrowers. Substituting this expression back into the Euler equation delivers the result.

For (ii), the terms on the right-hand side of equations (18) and (19) drop out, and the optimality conditions coincide with those in the decentralized equilibrium.

For (iii), notice that all parts of the wedge terms are positive. For  $\lambda^B$  and  $u_{T,0}^B$  this holds by definition;  $\Phi_B^B > \Phi_S^B > 0$  holds because  $\partial p / \partial M^B > \partial p / \partial M^S > 0$  as shown in Lemma 1. Finally,  $1 + R_B^B - R_S^B > 0$  holds by Assumption 2. ■

Intuitively, the terms on the right-hand side of expressions (18) and (19) capture the pecuniary externalities that are internalized by the planner but neglected by private agents:  $\lambda^B / u_{T,0}^B$  captures the social cost of the financial constraint on borrowers;  $\Phi_i^B$  captures how much the net worth of agent  $i$  relaxes this constraint; and the denominator, which is generally  $1 + R_B^B - R_S^B \approx 1$ , accounts for the fact that the planner's intervention also leads to redistributions between borrowers and savers because they affect the relative price at which the two agents trade non-traded goods in the domestic economy.

If the collateral constraint on borrowers is loose, then point (ii) of the Proposition captures that the only pecuniary externalities that appear are the redistributions between borrowers and lenders  $R_i^j$ , and so the associated allocation is Pareto efficient. This reflects the standard finding that pecuniary externalities cancel out when financial markets are complete, as implied by the first welfare theorem – the gain of one type of agent is the loss of another.

By contrast, point (iii) captures that when borrowers are constrained, the planner can relax the constraint by shoring up the net worth of both borrowers and savers, since both of them consume non-traded goods and influence the real exchange rate. Higher net worth for either agent during crisis times means that they have more to spend on non-traded goods, which pushes up the real exchange rate and mitigates the contractionary depreciations. As we will emphasize more formally below, the planner introduces a larger wedge in the optimality condition of borrowers since they have a higher marginal propensity to spend.

## 2.4 Implementation

A policymaker can replicate constrained optimal allocations through either quantity-or price-based interventions – in our framework, the two are technically equivalent since price-quantity duality holds. Quantity-based regulations take the form of limits on the financial positions of domestic agents. In our model, a policymaker can control the financial position of borrowers by using a simple debt cap and the financial position of savers by imposing a saving requirement or a limit on the net external asset position of the economy. Price-based regulations take the form of taxes or subsidies on borrowing and saving. In practice, policymakers have used both types of regulation.<sup>10</sup>

The policymaker can implement a constrained efficient allocation that internalizes the pecuniary externalities without the need for lump-sum transfers. However, mitigating pecuniary externalities involves wealth redistributions: the sector who is the net buyer of non-traded goods in period 1 has to pay a higher price for them. The policymaker’s intervention may therefore increase overall efficiency at the expense of making one of the two sectors worse off. If the policymaker also has access to lump-sum transfers, then she can compensate the losers of this wealth redistribution and choose any point on the Pareto frontier, including those that generate strict Pareto improvements over the decentralized equilibrium. If the policymaker uses taxes on borrowing or on capital flows, then she can use the revenue from these to compensate the losers so that the policy intervention is generally self-financing.

In the following, we will first describe how to implement optimal price-based regulation since the resulting tax wedges shed further light on the economics of the problem.<sup>11</sup> Assume a policymaker has the ability to impose a tax or subsidy  $\tau^i$  on bond purchases by sector  $i$ .

<sup>10</sup>See Claessens et al. (2013) for a discussion of the tools used in practice in many countries. See Perotti and Suarez (2011) for examples when price-quantity duality breaks down because policymakers face incomplete instruments and have to impose a single instrument on a heterogeneous set of financial market participants.

<sup>11</sup>The tax wedges also capture the wedges in the Euler equation of private agents that are subject to the equivalent quantity regulation, and therefore they are interesting since they reflect the size of the distortion and the strength of the desire to circumvent regulation.

Then the budget constraints of individual agents in period 0 become

$$c_{T,0}^i + (1 - \tau^i) b_1^i + T^i = b_0^i + y_{T,0}^i$$

where  $T^i$  are period 0 transfers to  $i \in \{B, S\}$  that rebate the tax revenue so as to satisfy the government budget constraint  $T^B + T^S = \tau^B b_1^B + \tau^S b_1^S$ . When  $b_1^i > 0$ , then agent  $i$  is a saver and  $\tau^i > 0$  represents a subsidy to saving. When  $b_1^i < 0$ , then agent  $i$  is a borrower and  $\tau^i > 0$  constitutes a tax on borrowing. In either case, a positive value for the policy instrument  $\tau^i$  induces agent  $i$  to carry more liquid net worth into the following period. This modifies the private optimization problem of decentralized agents so their Euler equation becomes  $(1 - \tau^i) u_{T,0}^i = u_{T,1}^i$ .

**Corollary 3 (Price-Based Implementation)** *(i) A policymaker can implement any constrained efficient allocation described in Proposition 2 by imposing a pair of taxes  $(\tau^B, \tau^S)$  with  $\tau^B \geq \tau^S \geq 0$  and strict inequalities when the financial constraint is binding and by and appropriately rebating the tax revenue to borrowers and savers. The optimal tax rates satisfy*

$$\tau^B = \frac{\lambda^B}{u_{T,0}^B} \cdot \frac{\Phi_B^B}{1 + R_B^B - R_S^B} \quad \tau^S = \frac{\lambda^B}{u_{T,0}^B} \cdot \frac{\Phi_S^B}{1 + R_B^B - R_S^B} \quad (20)$$

*(ii) The relative size of taxes is pinned down by agents' marginal propensity to consume*

$$\frac{\tau^B}{\tau^S} = \frac{MPC^B}{MPC^S}$$

*(iii) The pair of taxes  $(\tau^B, \tau^S)$  is equivalent to setting a capital control  $\tau^{CC}$  and a macroprudential tax  $\tau^{MP}$  such that*

$$\tau^{CC} = \tau^S \quad \text{and} \quad 1 - \tau^{MP} = (1 - \tau^B) / (1 - \tau^S) \quad (21)$$

*which satisfy  $\tau^{CC} \geq 0$  and  $\tau^{MP} \geq 0$  with strict inequalities when the financial constraint is binding.*

**Proof.** For (i), setting the tax rates as defined in (20) ensures that the Euler equations of regulated private agents replicate the planner's intertemporal optimality conditions (18) and (19). Furthermore, the policymaker sets  $T^i$  such that the desired allocation is feasible for both agents,  $c_{T,0}^i + M^i + T^i = b_0^i + y_{T,0}^i + y_{T,1}^i \forall i$ .

For (ii), we substitute out the definition of  $\Phi_i^B$  from equation (13) in the optimal tax rates (20) to see that  $\tau^B / \tau^S = \frac{\partial p}{\partial M^B} / \frac{\partial p}{\partial M^S}$ . As shown in Lemma 1, the derivatives  $\frac{\partial p}{\partial M^i}$  are proportional to the  $MPC^i$  of agent  $i$ , delivering the result.

For (iii), observe that capital controls impose a wedge between all domestic agents and foreigners, whereas macroprudential measures impose a wedge between domestic borrowers and savers. The cumulative tax wedges faced by savers and borrowers are thus

$$\begin{aligned} 1 - \tau^S &= (1 - \tau^{CC}) \\ 1 - \tau^B &= (1 - \tau^{CC}) (1 - \tau^{MP}) \end{aligned}$$

This implies that capital controls need to be set such that  $\tau^{CC} = \tau^S$  and macroprudential measures such that they fill the remaining gap between the interest rates faced by savers and borrowers, as indicated by equation (21). The inequality holds because  $\tau^B \geq \tau^S \geq 0$ .

■

The optimal tax rates in (20) induce private agents in both sectors to internalize the pecuniary externalities that they impose on borrowers. The tax rates replicate the extra terms in the planner's intertemporal optimality conditions (18) and (19) that are neglected by private agents. They reflect that additional liquid net worth in sector  $i$  relaxes the constraint by  $\Phi_S^B / (1 + R_B^B - R_S^B)$ , which delivers welfare gain  $\lambda^B / u_{T,0}^B$ . The planner can distribute the tax revenue that she collects among the two sectors in a way that implements any desired distribution of wealth along the Pareto frontier described in Proposition 2. (If the planner desires large redistributions of wealth, then this may require negative transfers, i.e. lump-sum taxes, on one of the sectors.)

Point (ii) of the proposition reflects that what matters for the pecuniary externalities are the two sectors' marginal propensities to spend on period 1 goods – the tax burden on borrowers exceeds that of savers because borrowers are constrained and have a higher *MPC*.

Point (iii) shows how the tax instruments  $(\tau^B, \tau^S)$  can be mapped into macroprudential regulation and capital controls. As illustrated in Figure 1, capital controls impose a wedge between all domestic agents and foreigners so as to segment domestic and international financial markets. This implies that an increase in capital controls amounts to a symmetric increase in both  $\tau^B$  and  $\tau^S$ . By contrast, macroprudential measures increase the interest rate faced by borrowers compared to the rate received by savers. They increase  $\tau^B$  but do not affect  $\tau^S$ . These considerations imply that the capital controls imposed on the economy need to mirror the tax rate faced by savers in their interactions with foreign investors; the macroprudential measures imposed on borrowers need to fill the gap between the tax rate faced by borrowers and the one faced by savers.

**Corollary 4 (Quantity-Based Regulation)** *(i) A policymaker can implement a constrained optimal allocation by imposing a debt cap  $\bar{B}^B$  on borrowers and a minimum saving requirement  $\bar{B}^S$  on borrowers such that*

$$B_1^B \geq \bar{B}^B \quad \text{and} \quad B_1^S \geq \bar{B}^S \quad (22)$$

*(ii) Alternatively, she can impose the debt cap  $\bar{B}^B$  on borrowers and an aggregate limit on the net external asset position of the economy such that*

$$B_1^B + B_1^S \geq \bar{B}^A$$

*(iii) If the policymaker has access to lump-sum transfers, then she can implement any of the constrained efficient allocations described in Proposition 2, including those that generate strict Pareto improvements.*

**Proof.** For point (i), assume a policymaker sets  $(\bar{B}^B, \bar{B}^S)$  to the levels that prevail in the constrained efficient allocation in which there are zero transfers. Then the positive tax wedges in Corollary 3 imply that the inequality constraints in (22) will bind strictly and

private agents choose the constrained efficient allocation. For point (ii), setting the limit on the external asset position to  $\bar{B}^A = \bar{B}^B + \bar{B}^S$  as defined above will implement the optimal allocation.

For point (iii), the planner can engage in lump-sum transfers between the two sectors and vary the quantity limits  $(\bar{B}^B, \bar{B}^S)$  so as to trace the Pareto frontier described in Proposition 2. ■

Both the cap on borrowing and the saving requirement or limit on the net external asset position serve to increase the purchasing power of the two sectors and mitigate the real exchange rate depreciation in period 1. This makes the economy more resilient to the binding constraint on borrowers. The two policies represent quantity-based macroprudential regulation and capital flow management. In practice, they may also be implemented such that they are contingent on the size of agents to account for heterogeneity, for example by using a debt-to-income limit on  $B_1^B/Y_0^B$  if borrowers differ in size.

## 2.5 Uncertainty and Excessive Risk-Taking

It goes without saying that financial crises involve a considerable amount of uncertainty. This section extends our analysis to account for uncertainty and to show that pecuniary externalities lead to underinsurance and excessive risk-taking. We assume there is a stochastic shock  $\omega \in \Omega$  that is realized at the beginning of period 1 and that may affect both the period 1 traded income of domestic agents  $y_{T,1}^i(\omega)$  and the tightness of the financial constraint  $\phi(\omega)$ .<sup>12</sup> We assume that the lowest realization of the two shocks is sufficiently low to make the financial constraint on borrowers binding.

In the current section, we assume that domestic agents face a complete market of Arrow securities to trade with foreigners in period 0 to make their privately optimal insurance decisions. (We will consider the case that the period 0 financial market is incomplete and only bonds can be traded in the following section.) We denote the payoff that agent  $i$  has contracted to receive in state  $\omega$  by  $b_1^i(\omega)$  and observe that foreigners are willing to sell the vector of Arrow securities  $\{b_1^i(\omega)\}$  at a price of  $E[b_1^i(\omega)]$  in period 0. We use our earlier definition of the reduced-form utility  $V^i(\cdot)$  to express the optimization problem of private agents as

$$\max_{b_1^i(\omega)} u(b_0^i + y_{T,0}^i - E[b_1^i(\omega)]) + E[V^i(M^i(\omega); M^B(\omega), M^S(\omega), \phi(\omega))] \quad (23)$$

where  $m^i(\omega) = y_{T,1}^i(\omega) + b_1^i(\omega)$  and  $(M^B(\omega), M^S(\omega))$  are now stochastic and private agents take the latter as given. The utility of domestic agents and the periods 1 and 2 allocations are fully characterized by the optimization problem  $V(m^i(\omega); M^B(\omega), M^S(\omega), \phi(\omega))$ , where we extend the definition of the value function (7) by including the realization of the stochastic parameter  $\phi(\omega)$  as an argument.

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<sup>12</sup>Stochastic changes in  $\phi(\omega)$  are helpful to capture swings in international financial conditions. In particular, they may reflect changes in global risk appetite that have been found to be important drivers of international capital flows (Forbes and Warnock, 2012). For example, a loss of confidence in the repayment prospects of emerging markets would induce international investors to tighten borrowing constraints and possibly trigger the financial amplification mechanism described by our model.

Private agents choose their Arrow security holdings  $b_1^i(\omega)$  according to the standard Euler equation

$$u_{T,0}^i = u_{T,1}^i(\omega) \quad (24)$$

They find it optimal to smooth consumption between periods 0 and 1 and across all states of nature in period 1, given the risk-neutrality of foreigners and the availability of actuarially fair insurance.

Let us contrast the decentralized equilibrium with the solution chosen by a constrained planner under uncertainty. As before, a constrained social planner maximizes the weighted sum of domestic welfare

$$\begin{aligned} & \max_{C_{T,0}^i, B_1^i(\omega)} \sum_{i \in \{B, S\}} \gamma^i \{u(C_{T,0}^i) + E[V^i(M^i(\omega); M^B(\omega), M^S(\omega), \phi(\omega))]\} \\ & \text{s.t.} \quad \sum_{i \in \{B, S\}} (C_{T,0}^i + E[B_1^i(\omega)] - B_0^i - Y_{T,0}^i) \leq 0, \quad M^i(\omega) = Y_{T,1}^i(\omega) + B_1^i(\omega) \end{aligned} \quad (25)$$

The planner's intra- and inter-temporal optimality conditions can be written as a state-contingent version of equations (15) and (16) or (17). The resulting allocations mirror our findings in Proposition 2:

**Proposition 5 (Underinsurance)** *Any constrained efficient allocation in the domestic economy satisfies*

$$\frac{u_{T,1}^i(\omega)}{u_{T,0}^i} = 1 - \frac{\lambda^B(\omega)}{u_{T,0}^B} \frac{\Phi_i^B(\omega)}{1 + R_B^B(\omega) - R_S^B(\omega)} \quad \text{for } i \in \{B, S\} \quad (26)$$

**Proof.** The proof follows along the same lines as the proof of Proposition 2. ■

Equation (26) reflects that the planner does not deviate from the optimal smoothing condition (24) of private agents as long as the financial constraint of borrowers is loose so  $\lambda^B = 0$  and the last term in the equation drops out. However, in states of nature in which the financial constraint is binding,  $\lambda^B > 0$ , the planner acts in a more precautionary manner and introduces a wedge in the marginal rate of substitution of both sets of private agents in period 0, i.e.  $u_{T,0}^i > u_{T,1}^i(\omega)$ . As before, the wedge is larger for borrowers than for savers.

Intuitively, the planner insures more against states of nature with binding constraints than private agents. She carries greater net worth for both agents into constrained states of nature in period 1 in order to push up the exchange rate and relax the financial constraint. This creates a deviation from optimal smoothing between periods 0 and 1 in those states but enables better smoothing between periods 1 and 2.

**Implementation** A policymaker under uncertainty can correct the externalities of risky capital flows in a similar manner to what we described in Section 2.4 using either price- or quantity-based regulation.

Our results on uncertainty highlight that capital controls and macroprudential policy measures need to be sensitive to the riskiness of financial transactions. The pecuniary externalities that we identify are relevant in those states of nature when financial constraints

are binding. The size of externalities of a financial asset or liability therefore depends on how much it exposes its holder to those states of nature.

Dollar debt, for example, implies much larger payoffs in constrained states of nature than local currency debt or equity; therefore it is associated with much larger externalities. As a result, borrowers will take on too much dollar debt and other risky liabilities and insufficient local currency debt or equity. Conversely, savers will expose themselves to too much crisis risk in their asset purchases – they will hold insufficient dollar reserves and purchase excessively risky investments that do not provide the socially desirable level of aggregate insurance (see Caballero and Krishnamurthy, 2003).

This makes it desirable that optimal capital controls and macroprudential regulation focus on discouraging risk-taking. Macroprudential regulation should induce borrowers to shift the composition of liabilities towards contingent instruments – above and beyond reducing the total level of liabilities. This makes borrowers more resilient to crisis risk. Furthermore, capital controls should focus on inducing savers to hold more insurance, i.e. to shift their portfolio into assets that yield high payoffs when the economy experience adverse shocks, such as safe dollar reserves. For further details on the desirability of risk-sensitive capital controls and macroprudential regulations see Korinek (2010, 2011b).

## 2.6 Incomplete Markets and Excessive Crisis Probability

In practice, emerging economies frequently have limited access to insurance instruments. We capture this in the current subsection by assuming that domestic agents can only borrow or save in uncontingent bonds. We continue to assume that their traded income  $y_{T,1}^i(\omega)$  in period 1 and the tightness of the borrowing constraint  $\phi(\omega)$  are stochastic.

The optimization problem of domestic agents is identical to problem (23) except that the choice variables are now the bond holdings  $b_1^i$  instead of the Arrow security holdings  $b_1^i(\omega)$ . The liquid net worth of agent  $i$  is  $m^i(\omega) = y_{T,1}^i(\omega) + b_1^i$  and similarly for  $M^i(\omega)$ . Private agents choose their bond position  $b_1^i$  so as to smooth the expected marginal utility of traded consumption, according to the standard Euler equation

$$u_{T,0}^i = E[u_{T,1}^i(\omega)]$$

The problem of a planner can also be expressed analogously to problem (25) with the uncontingent bond holdings  $b_1^i$  replacing  $b_1^i(\omega)$ . The inter-temporal optimality condition of the planner is

$$\begin{aligned} \gamma^i u_{T,0}^i &= \gamma^i E[u_{T,1}^i] + E\left[\left(\gamma^i u_{T,1}^i - \gamma^j u_{T,1}^j\right) R_i^i\right] + \gamma^B E[\lambda^B \Phi_i^B] \\ &= \gamma^i E[u_{T,1}^i] + E\left(\gamma^i u_{T,1}^i - \gamma^j u_{T,1}^j\right) E[R_i^i] + Cov\left(\gamma^i u_{T,1}^i - \gamma^j u_{T,1}^j, R_i^i\right) + \gamma^B E[\lambda^B \Phi_i^B] \end{aligned} \tag{27}$$

As in our earlier analysis, saving one additional unit of net worth in period 0 in the un-contingent bond has three effects in period 1: it reduces the expected marginal utility of traded consumption; it leads to a change in the exchange rate and an expected redistribution between the two agents; and it leads to an expected relaxation in the collateral constraint. In the second line of the equation, we express the redistributive effect as the

sum of the expected redistribution plus a covariance term. To sign the latter, recall that  $R_i^B = \partial p / \partial M^i \cdot (y_{N,1}^B - c_{N,1}^B)$  where  $\partial p / \partial M^B > 0$  is constant. Therefore

$$Cov(\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S, R_i^B) = \partial p / \partial M^i \cdot Cov(\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S, y_{N,1}^B - c_{N,1}^B)$$

Notice that when borrowers are constrained, both the gap between marginal utilities  $\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S$  and the amount of their fire sales  $y_{N,1}^B - c_{N,1}^B$  are above average and vice versa. Therefore the covariance term is generally positive.

The following proposition characterizes how the planner will optimally intervene in such an economy:

**Proposition 6 (Excessive Leverage, Incomplete Markets)** *In an economy with uncertainty and bond markets only, any constrained efficient allocation satisfies*

$$\frac{E[u_{T,1}^i(\omega)]}{u_{T,0}^i} = 1 - \frac{E\left[\frac{\lambda^B(\omega)}{u_{T,0}^B} \cdot \Phi_i^B(\omega)\right] + Cov\left(\frac{u_{T,1}^B(\omega)}{u_{T,0}^B} - \frac{u_{T,1}^S(\omega)}{u_{T,0}^S}, R_i^B(\omega)\right)}{1 + E[R_B^B(\omega) - R_S^B(\omega)]}$$

**Proof.** We combine the inter-temporal optimality conditions (27) of the two agents to find

$$E[\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S] = - \frac{E[\gamma^B \lambda^B (\Phi_B^B - \Phi_S^B)] + Cov(\gamma^B u_{T,1}^B - \gamma^S u_{T,1}^S, R_B^B - R_S^B)}{1 + E[R_B^B - R_S^B]}$$

Plugging this expression back into (27) and simplifying terms by using  $R_S^B = R_B^B/2$  and  $\Phi_S^B = \Phi_B^B/2$  delivers the planner's optimal wedges. ■

Since the covariance term is positive, the wedge imposed by the planner is greater under incomplete markets than what is suggested by the expected tightness of constraints  $E[\lambda^B \Phi_B^B]$ . Intuitively, the covariance term captures that shoring up the net worth of domestic agents has the greatest redistributive effects when borrowers are most constrained since they cannot insure. This increases the incentive of the planner to raise the net worth of both agents.

**Implementation** In practice, the lessons on price- and quantity-based regulations from Section 2.4 carry over to the case of uncertainty and incomplete markets: a policymaker should induce borrowers to reduce the level of uncontingent liabilities that they incur, using either taxes or debt caps, and should induce savers to engage in greater precautionary saving against crisis.

So far, we have emphasized that the planner can mitigate financial crises, given that the economy experiences an adverse shock. Under incomplete financial markets, we find that the planner's intervention also reduces the likelihood of a financial crisis:

**Corollary 7 (Probability of Crisis)** *In a bond-only economy, the planner's optimal intervention lowers the probability that the borrowing constraint will become binding.*

**Proof.** Proposition 6 shows that the social planner increases the bond holdings  $(B_1^B, B_1^S)$  that domestic agents carry into period 1. In Appendix A.1, we show that higher values of  $(B_1^B, B_1^S)$  increase the range of  $y_{T,1}^i(\omega)$  and  $\phi(\omega)$  for which domestic borrowers remain unconstrained. ■

**Summary** The previous subsections have shown three closely related results: a planner in our setting would use capital controls and macroprudential regulation to (i) reduce the amount of borrowing, (ii) to reduce the riskiness of financing decisions and insure more, and (iii) to reduce the probability of financial crises. As we emphasized in Corollaries 3 and 4, these interventions can be conducted either via price-based or quantity-based regulation.

### 3 Numerical illustration

In this section, we calibrate the bond-only economy with uncertainty of Section 2.6. We choose the parameters of the economy to replicate the dynamics of the East Asian crisis countries depicted in Figure 3. This allows us to obtain the magnitude of optimal policy measures for countries at risk of comparable financial instability to the East Asian crisis countries prior in 1997.

As a baseline for our calibration, we set the endowment process of all agents so that the economy is in a steady state with constant gross borrowing and saving positions if there are no binding financial constraints. In particular, we assume that both sectors receive endowments of equal value every time period,  $Y_{T,0}^i = 1$ ,  $Y_{T,1}^i = \alpha$ ,  $Y_{N,1}^i = 1 - \alpha$ , and  $Y_{T,2} = 1$ , where we use  $\alpha = 0.3$  for the share of traded goods in period 1 consumption. Moreover, we assume that agents exit period 2 with the same amount of debt  $B_3^i = B_0^i$  that they enter with in period 0.<sup>13</sup> This ensures that gross debt and savings remain constant over time so that  $B_0^i = B_1^i = B_2^i = B_3^i$  for  $i \in \{B, S\}$  if financial constraints are non-binding, that the real exchange rate in period 1 is  $p = 1$ , and that GDP in every period is 2.

We calibrate the initial debt of borrowers and the initial savings of savers to replicate the average net foreign asset (NFA) position of East Asian crisis countries over the five years prior to the crisis of -40% of GDP. Initially, we take the most conservative approach and assume that borrowers carry all this debt (so  $B_0^B = -0.8$ ) and savers have no asset holdings (so  $B_0^S = 0$ ). Then we show that increasing wealth inequality, i.e. a parallel increase in the debt of borrowers and the assets of savers while holding the net foreign asset position of the economy constant, requires higher optimal capital controls and macroprudential taxes.

We assume that there are two states of nature in period 1 so that the financial constraint parameter  $\phi$  can take a high or low (sudden stop) value. We set the probability of the sudden stop state equal to  $\pi = 5\%$ , consistent with a long-run crisis probability of 5% per year (see Reinhart and Rogoff, 2008). In our baseline, we calibrate  $\phi(L) = 0.65$  so the model matches the current account surplus of 10% and the exchange rate depreciation of 25% during the East Asian crisis, as illustrated in Figure 3. In the high state of nature, we assume that the borrowing constraint is loose so  $\phi(H) = \infty$ , representing good times when world capital markets are flush with liquidity. The parameter values are summarized in Table 1.<sup>14</sup>

**Sufficient Statistics** We follow the literature on sufficient statistics in optimal policy analysis (e.g. Chetty, 2009) and decompose the optimal tax wedge on borrowers that we

<sup>13</sup>In the model setup described above, this is equivalent to setting  $Y_{T,2}^i = 1 - B_0^i$ .

<sup>14</sup>In the described policy exercise, we assume that the planner rebates tax revenue to the set of agents from whom it was received but does not engage in lump-sum transfers across agents. Formally, this corresponds to choosing welfare weights that satisfy the planner's period 0 intratemporal optimality condition (15) while respecting the period 0 budget constraints (2) of private agents.

$\alpha$	$Y_{T,0}^i$	$Y_{T,1}^i$	$Y_{N,1}^i$	$Y_{T,2}^i$	$B_0^B$	$B_0^S$	$\pi$	$\phi(L)$	$\phi(H)$
0.3	1	$\alpha$	$1 - \alpha$	1	-0.8	0	0.05	0.65	$\infty$

**Table 1:** Baseline Calibration

described in Proposition 6 into the following terms, which can be quantified independently:

$$\underbrace{\tau^B}_{\approx 3.9\%} = \underbrace{\pi}_{(i)} \cdot \underbrace{\frac{\lambda^B(L)}{u_{T,0}^B}}_{(ii)} \cdot \underbrace{\frac{\partial p / \partial M^B(L)}{1 + E[R_B^B - R_S^B]}}_{(iii)} \cdot \underbrace{\phi y_{N,1}^B}_{(iv)} + \underbrace{\frac{Cov\left(\frac{u_{T,1}^B}{u_{T,0}^B} - \frac{u_{T,1}^S}{u_{T,0}^S}, R_B^B\right)}{1 + E[R_B^B - R_S^B]}}_{(v)}$$

$\approx 5\%$        $\approx 0.72$        $\approx 2.0$        $\approx 0.455$        $\approx 0.58\%$

(28)

The term (i) is the crisis probability; (ii) measures the shadow cost of the binding borrowing constraint in the low state; (iii) captures how much an increase in borrower net worth  $M^B$  appreciates the exchange rate in the low state (the denominator is close to unity,  $1 + E[R_B^B - R_S^B] \approx 1.006$ ); (iv) reflects the amount of non-traded collateral that is affected by the appreciation. The terms (ii) to (iv) are the same in all versions of our model, including under perfect foresight in Proposition 2 and under stochastic shocks with complete markets in Proposition 5. They also mirror the sufficient statistics identified in Korinek (2010) to quantify optimal capital controls by looking directly at the data, with the exception of the denominator in (iii) which is quantitatively negligible. Korinek and Mendoza (2014) show that a similar set of sufficient statistics applies to a broad class of models of pecuniary externalities, including in infinite horizon settings.<sup>15</sup>

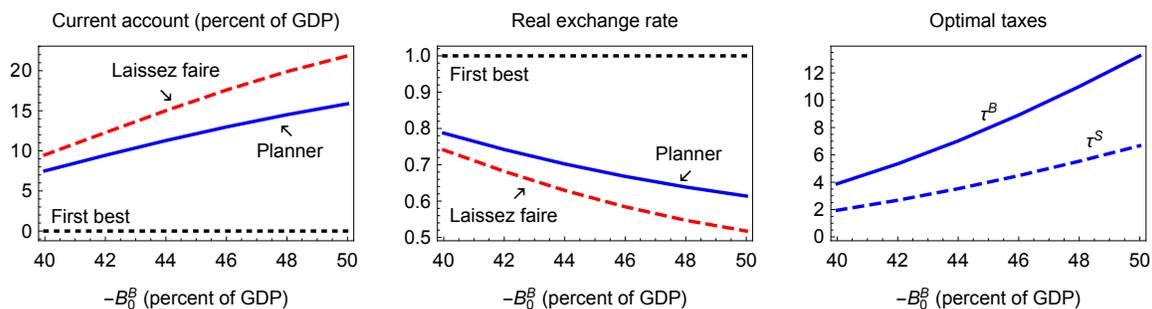
The tax formula (28) contains an additional novel covariance term (v) that reflects the desirability of wealth redistributions within the domestic economy when financial markets are incomplete. In particular, borrowers are net sellers of non-traded goods in state  $L$  when the financial constraint binds. If borrowers carry more wealth into period 1, the resulting exchange rate appreciation allows them to fetch a higher price for the non-traded goods that they sell. Since they are comparatively worse off than savers in the low state of nature, this is beneficial and increases the optimal tax rate by 0.58%. The optimal tax on savers is given by  $\tau^S = \tau^B \cdot \frac{MPC^S}{MPC^B} \approx 1.95\%$ . Following Corollary 3, the measures can be implemented using capital controls and macroprudential taxes of about 2% each.

**Equilibrium Effects of Optimal Policy** Implementing the optimal policy reduces the current account reversal during the crisis by about 2% of GDP and keeps the real exchange rate by about 4% more appreciated.<sup>16</sup> These effects may seem small when compared with

<sup>15</sup>Our focus on calibrating sufficient statistics rather than an infinite-horizon version of the model also side-steps many of the criticisms leveled on calibrated infinite-horizon DSGE models of the economy (see e.g. Korinek, 2015).

<sup>16</sup>In the described numerical example capital controls and macroprudential taxes have no effects on the crisis probability because of the simplifying assumption that there are only two states of nature. As shown in Corollary 7, the crisis probability can be endogenized by making the shock to traded consumption or to the credit limit more continuous.

the overall adjustment of the current account and exchange rate. However, it is important to keep in mind that the purpose of prudential policy intervention is not to completely avoid macroeconomic adjustment, but to reduce excess volatility by internalizing the externalities of contractionary depreciations. Effects of similar magnitude are consistent with the existing quantitative literature (as surveyed, e.g., by Korinek and Mendoza, 2014).

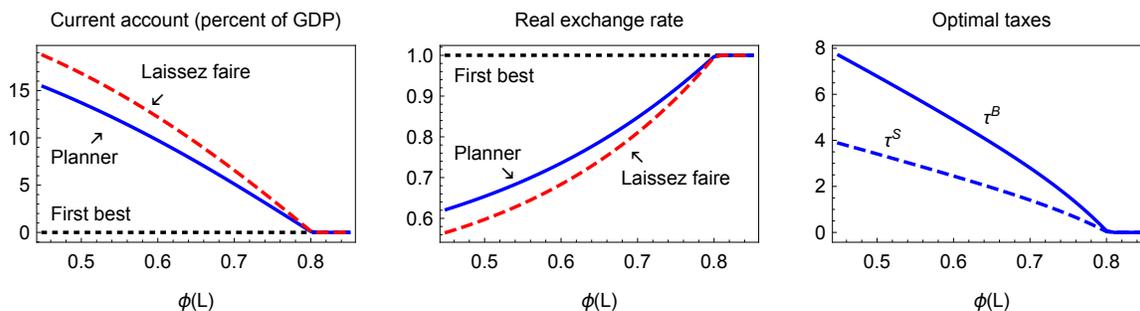


**Figure 5:** Effects of increasing wealth inequality

**Greater Inequality** Figure 5 shows the implications of increases in wealth inequality while holding all other parameters constant. In particular, we increase both the initial debt stock of borrowers  $B_0^B$  from 40 to 50 percent of GDP and the initial savings of savers  $B_0^S$  from 0 to 10 percent of GDP. The left two panels of the figure show the current account and the real exchange rate in the low state of period 1 as a function of wealth heterogeneity. The dashed (red) lines depict the decentralized equilibrium allocation, whereas the solid (blue) lines depict the planner’s optimal allocation. For comparison, the dotted (black) lines indicate what the first-best equilibrium in the absence of financial constraints would look like. The third panel indicates the optimal taxes on borrowers (solid lines) and savers (dashed lines) that implement the planner’s allocation. The vertical axis (at a 40% debt/GDP ratio) corresponds to our baseline calibration. As we increase wealth heterogeneity from there, borrowers become more and more constrained, leading to deeper crises, i.e. greater current account reversals and real exchange rate depreciations. This in turn calls for higher optimal macroprudential taxes and capital controls. Increasing wealth heterogeneity by just 10% of GDP substantially magnifies the current account reversal and the real depreciation, and it increases the optimal taxes more than threefold.<sup>17</sup>

**Size of Sudden Stops** We vary the tightness of the borrowing constraint  $\phi(L)$  during sudden stops in the comparative static depicted in Figure 6. The constraint is loose for  $\phi(L) \geq 0.8$ , allowing the economy to replicate the first-best allocation so no policy intervention is required. For lower values of  $\phi(L)$ , the economy experiences a current account reversal and a real depreciation as borrowers are forced to delever, with the magnitude of the effect increasing with the tightness of the borrowing limit, i.e. the lower  $\phi(L)$ .

<sup>17</sup>If the increase in wealth heterogeneity is accompanied by a simultaneous increase in borrowing capacity in the low state to  $\phi(L) = 0.9$  in order to match the current account and real depreciation from the 1997 crisis, the optimal capital controls and macroprudential taxes would increase only to 3.1%. The intuition is that borrowers are less constrained, the crisis is less severe, and so the required policy intervention is less.



**Figure 6:** Effects of increasing borrowing limit

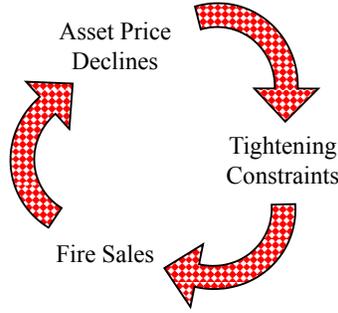
The general lesson of our numerical illustration is that there is a role for both capital controls and macroprudential measures of a similar level to what the existing literature has found in analyzing the two policy measures in isolation. Furthermore, we find that the two measures are increasing in the overall debt burden as well as in the degree of inequality in the economy. The sufficient statistics that make up the optimal tax formula (28) expose in a transparent manner how the optimal rate is affected by changes in the environment. To mention just two examples, a more careful calibration of the marginal propensities to spend of sector  $i$  would affect the exchange rate response to net worth  $\partial p / \partial M^i$ . Modeling the shock process as a more continuous variable would allow us to capture endogenous changes in crisis risk.

## 4 Asset Price Externalities

Borrowing constraints that are linked to asset prices can give rise to vicious cycles and pecuniary externalities similar to those that arise from exchange rate depreciations. We have shown so far that externalities linked to contractionary exchange rate depreciations call for both macroprudential regulation and capital controls. Although such contractionary depreciations are relevant in emerging markets economies (especially those with significant foreign currency debts), they play less of a role in advanced economies where exchange rates tend to be more stable and debt is issued in domestic currency. However, advanced economies are nonetheless vulnerable to feedback loops triggered by falling asset prices, tightening collateral constraints, and fire sales, as illustrated in Figure 7. These can also give rise to pecuniary externalities.

This section shows that macroprudential regulation alone is sufficient to address pecuniary externalities linked to fire sales in asset prices. This contrasts with our baseline model in which pecuniary externalities are driven by exchange rate depreciations. The key insight of the section is that fire sales and asset prices are determined solely by the net worth of borrowers; therefore there is no economic rationale for shoring up the net worth of savers, and capital controls are superfluous.

We drop non-traded goods from our baseline model and assume instead that agents obtain an endowment  $k_1^i$  of capital goods that are traded domestically in period 1 and produce output according to a production function  $F^i(k_2^i)$  in period 2. In order to generate the potential for fire sales, we assume that the production function of savers is inferior to that



**Figure 7:** Feedback loop of financial crises with deflation of capital prices

of borrowers. Specifically, we assume  $F^B(k_2^B) = Ak_2^B$  and  $F^{S'}(0) = A$  but  $F^{S''}(k_2^S) < 0$ , where we use one and two prime symbols to denote the first and second derivative. In other words, borrowers have a linear production function; savers are equally productive in employing the first marginal unit of capital but experience decreasing returns thereafter.

The utility function and the budget constraints of domestic agents  $i \in \{B, S\}$  define the following optimization problem:

$$\begin{aligned} \max U^i \quad \text{s.t.} \quad & c_{T,0}^i + b_1^i = b_0^i + y_{T,0}^i \\ & c_{T,1}^i + b_2^i = b_1^i + y_{T,1}^i + q(k_1^i - k_2^i) \\ & c_{T,2}^i = b_2^i + y_{T,2}^i + F^i(k_2^i) \end{aligned}$$

where  $q$  is the price at which capital goods trade in period 1 so that  $q(k_1^i - k_2^i)$  constitutes the revenue derived from fire sales.

We follow Jeanne and Korinek (2010ab) in assuming that borrowers can borrow up to a fraction  $\phi$  of the period 1 value of their capital asset holdings,

$$-b_2^B \leq \phi q k_2^B$$

The first order conditions of private agents include the standard Euler conditions

$$\begin{aligned} u_{T,0}^i &= u_{T,1}^i \\ u_{T,1}^i &= u_{T,2}^i + \lambda^i \end{aligned}$$

and the optimality condition for capital asset purchases, which pins down the price of capital

$$q = \frac{u_{T,2}^i F^{i'}(K_2^i)}{(1-\phi)u_{T,1}^i + \phi u_{T,2}^i} = \frac{F^{i'}(K_2^i)}{\phi + (1-\phi)u_{T,1}^i/u_{T,2}^i} \quad (29)$$

The price  $q$  equals the marginal product of capital discounted by the marginal rate of substitution, where only a fraction  $(1-\phi)$  of the asset needs to be financed with period 1 funds and a fraction  $\phi$  can be financed by borrowing from period 2. The asset price is therefore inversely related to consumption growth between period 1 and 2, which reflects the tightness of the borrowing constraint.

## Characterizing the Decentralized Equilibrium

Since savers are unconstrained, it follows that  $\lambda^S = 0$  and  $u_{T,1}^S = u_{T,2}^S$ . This also implies that savers simply set the marginal product of capital equal to the market price

$$q = F^{S'}(k_2^S)$$

This is an implication of the Fisherian separation between consumption and investment that applies to unconstrained agents. Therefore, changes in the net worth of savers  $M^S$  have no impact on asset prices

$$\frac{\partial q}{\partial M^S} = 0$$

Similarly, changes in net worth of borrowers  $M^B$  have no effect on asset prices if the financial constraint is loose. In this case, borrowers purchase the whole stock of capital since they have a better production technology, and the unconstrained asset price is given by  $q = A$ .

If instead borrowers are constrained, they face a trade-off between consuming and purchasing capital. Savers still set their marginal product of capital equal to  $q$ , but borrowers reduce capital in proportion to the tightness of the constraint as in equation (29). This generates a reallocation of capital from borrowers to savers which lowers asset prices below their unconstrained level.

As shown in Appendix A.2, an increase in the net worth  $M^B$  of constrained borrowers leads under mild regularity conditions to higher capital prices,

$$\frac{\partial q}{\partial M^B} > 0$$

Higher net worth raises borrowers' demand for capital, increases asset prices and in turn relaxes borrowing constraints. We summarize the above considerations in the following lemma:

**Lemma 8 (Net Worth and Asset Prices)** *(i) The asset price  $q$  is independent of the liquid net worth  $M^S$  of savers, i.e.  $\partial q / \partial M^S = 0$ .*

*(ii) As long as borrowers are unconstrained, the asset price equals  $q = A$  and is independent of the net worth of borrowers. If borrowers are constrained, the asset price is an increasing function of the liquid net worth of borrowers,*

$$\frac{\partial q}{\partial M^B} > 0 \tag{30}$$

**Proof.** See discussion above. ■

When borrowers are constrained, an increase in  $M^B$ , by raising asset prices, triggers redistributive effects and relaxes the borrowing constraint. The redistributive effect on borrowers is captured by:

$$R_B^B = \frac{\partial q}{\partial M^B} (K_1^B - K_2^B)$$

which is positive if borrowers are net sellers of capital and negative otherwise. Similarly to the model with exchange rate externalities, we assume

**Assumption 3**  $1 + R_B^B > 0$

This ensures that providing one extra dollar to borrowers does not immiserize them by reducing their wealth through large negative redistributive effects. The impact of higher  $M^B$  on the borrowing constraint is captured by

$$\Phi_B^B = \frac{\partial q}{\partial M^B} \phi K_2^B > 0$$

### Characterizing the Planner Solution

The planning problem is analogous to Section 2.3. However, the planner observes that changes in  $M^S$  have no effect on asset prices and have neither redistributive effects,  $R_S^B = 0$ , nor collateral effects,  $\Phi_S^B = 0$ . The planner has therefore no reason to distort savers' intertemporal decisions and follows the Euler equation,

$$u_{T,0}^S = u_{T,1}^S$$

The willingness of savers to purchase assets in period 1 depends solely on their production function and on the interest rate at which they can fund asset purchases, which is determined on world markets and does not depend on their net worth since savers are unconstrained.

The planner still intervenes in the financial decisions of borrowers when the constraint is binding. Greater liquidity  $M^B$  increases borrowers' demand for capital and raises asset prices. The planner's Euler equation for borrowers (18) is:

$$u_{T,0}^B = u_{T,1}^B + \lambda^B \frac{\Phi_B^B}{1 + R_B^B}$$

Given Assumption 3 and  $\lambda^B \Phi_B^B > 0$ , the planner's wedge raises  $u_{T,0}^B/u_{T,1}^B$ , which amounts to limiting borrowing at time 0. Intuitively, the social planner shores up the liquid net worth of borrowers so as to reduce asset fire sales, support asset prices, and relax borrowing constraints.

**Corollary 9 (Asset Price Externalities)** *In a model in which financial constraints are linked to asset prices, a planner imposes macroprudential restrictions on borrowers,*

$$\tau^{MP} = \tau^B = \frac{\lambda^B}{u_{T,0}^B} \cdot \frac{\Phi_B^B}{1 + R_B^B} > 0,$$

*but does not impose capital controls so  $\tau^{CC} = \tau^S = 0$ .*

**Proof.** See discussion above and Corollary 3. ■

## 5 Conclusions

This paper has analyzed the desirability of capital controls versus macroprudential regulation in mitigating financial instability. Our main finding is that it is optimal to use both instruments in emerging economies that are at risk of contractionary exchange rate depreciations. To limit such depreciations, a planner imposes both capital controls and macroprudential regulation. Capital control raise the net worth of both domestic borrowers and savers. Macroprudential regulation raises the net worth of borrowers even further, which is desirable because constrained borrowers have a higher marginal propensity to consume than unconstrained savers. Both capital control and macroprudential taxes should be optimally varied over time depending on the risk of financial instability. In our model, this risk is primarily affected by the aggregate level of debt, the degree of wealth inequality, and the incidence of adverse shocks.

We have also considered the case of pecuniary externalities linked to asset prices. In advanced economies, where fluctuations in real exchange rates are less destabilizing, there is still a role for policy intervention in order to avoid boom and bust cycles in asset prices. To address these externalities, a planner finds it optimal to increase the net worth of domestic borrowers, but she has no reason to intervene on domestic savers. This is because their net worth has no influence on their demand for capital and thus on asset prices because of the Fisherian separation between consumption and investment decisions. Macroprudential regulation is thus sufficient to deal with externalities linked to asset prices.

There are a number of issues that are beyond the scope of the current paper. First, our paper distinguishes between capital controls and macroprudential regulation based on one specific dimension along which borrowing from foreign and domestic lenders differs – the exchange rate effects that they generate. Although contractionary movements in exchange rates are of utmost importance during financial crises, there is a range of additional dimensions that are relevant. For example, borrowing from domestic and foreign lenders likely leads to different bailout and risk-shifting probabilities and generates different incentive effects. They also lead to different aggregate demand effects. Furthermore, when interacting with international lenders, considerations about market power that are absent in domestic lending relationships may come into play. Finally, it may be desirable to regulate borrowing from domestic or foreign lenders differently when the residency of the lender correlates with features that cannot be directly observed, such as the flightiness of funds, or that cannot be targeted directly because restrictions on regulatory instruments. These considerations are analyzed in detail in Ostry et al. (2015).

Secondly, there are additional policy measures that have sometimes been used in a prudential manner. For example, reserve accumulation may be helpful to stem real appreciation if international capital markets are sufficiently segmented to prevent arbitrage; contractionary monetary policy may be able to prick bubbles; fiscal consolidation may prevent an economy from overheating. Ostry et al. (2010) and Blanchard et al. (2015) discuss several of these options. However, following the principle that a distortion is best addressed directly at its source, capital controls or macroprudential regulation may be better-suited than other instruments to deal with the pecuniary externalities generated by financial crises. For example, Korinek and Simsek (2016) show that monetary policy is not a well-suited instrument to stem against excessive leverage.

Thirdly, our paper focuses on prudential interventions to mitigate crisis risk, i.e. policy measures that are taken in good times in order to reduce the risk and magnitude of crises in response to bad shocks in the future. There is a complementary strand of literature that focuses on ex-post policy measures (see e.g. Benigno et al., 2010, 2012, 2013ab; Jeanne and Korinek, 2013) that are taken if a country experiences a financial crisis. This is particularly relevant for the analysis of capital controls since many countries (including e.g. Iceland and Cyprus) have used controls on outflows as a crisis management tool.

Finally, the analysis has been developed in the context of a real model. To the extent that monetary policy is constrained, for example because of a pegged exchange rate regime or the zero lower bound on nominal rates, capital controls and macroprudential policies would have also an important role to play in addressing externalities linked to aggregate demand (Farhi and Werning, 2013; Korinek and Simsek, 2016; Schmitt-Grohé and Uribe, 2015).

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## A Mathematical Appendix

### A.1 Model with Non-Traded Goods

The technical condition that characterizes the upper limit  $\hat{\phi}$  on the pledgeability parameter in the model with non-traded goods is

$$Y_{N,1} - (1 - \alpha) \left[ Y_{N,1}^B (1 + \hat{\phi}) + Y_{N,1}^S / 2 \right] = 0$$

Given this definition, the assumption  $\phi < \hat{\phi}$  implies that the denominator  $D$  in expression (12) is strictly positive so as to avoid degenerate equilibria.

The unconstrained region, i.e. the set of  $(M^B, M^S) \in \mathcal{M}^{unc}$ , is determined by the fact that the borrowing level that ensures perfect consumption smoothing is no greater than the constraint,

$$\frac{1}{2} (M^B + pY_{N,1}^B - Y_{T,2}^B) \geq -\phi (Y_{T,1}^B + pY_{N,1}^B)$$

By substituting out the definition of the price level in the unconstrained region,

$$p = \frac{1 - \alpha}{1 + \alpha} (M^B + M^S + Y_{T,2})$$

where  $Y_{T,2} = Y_{T,2}^B + Y_{T,2}^S$ , we derive the following inequality that characterizes the set  $(M^B, M^S) \in \mathcal{M}^{unc}$ ,

$$M^B \left( \frac{1}{2} + Y_{N,1}^B \frac{1 - \alpha}{1 + \alpha} \left( \frac{1}{2} + \phi \right) \right) + M^S Y_{N,1}^B \frac{1 - \alpha}{1 + \alpha} \left( \frac{1}{2} + \phi \right) \geq \frac{Y_{T,2}^B}{2} - \phi Y_{T,1}^B - Y_{T,2} Y_{N,1}^B \frac{1 - \alpha}{1 + \alpha} \left( \frac{1}{2} + \phi \right) \quad (\text{A.1})$$

The above condition is instrumental to establish the result in Corollary 7. If traded endowments  $y_{T,1}^i(\omega)$  or the tightness of the constraint  $\phi(\omega)$  are stochastic, by increasing  $(B_1^B, B_1^S)$ , the planner's intervention reduces the probability that borrowing constraints will become binding. Recalling that  $M^i(\omega) = B_1^i + Y_{T,1}^i(\omega)$ , this is evident from equation (A.1), since higher levels of  $(B_1^B, B_1^S)$  require worse realizations of  $Y_{T,1}^i(\omega)$  and  $\phi(\omega)$  for borrowing constraints to become binding.

### A.2 Model with Capital Goods

To see how  $M^B$  affects the price of capital goods when borrowers are constrained, note that savers set their marginal product of capital equal to the price  $q$ . Using the market clearing condition  $K_2^S = K - K_2^B$ , where  $K$  is the total stock of capital, we infer that

$$\frac{\partial q}{\partial M^B} = -F^{S''} \frac{\partial K_2^B}{\partial M^B}$$

Since  $F^{S''} < 0$ , we see that  $\partial q / \partial M^B > 0$  if and only if  $\partial K_2^B / \partial M^B > 0$ . This latter derivative can be analyzed by considering that the optimality condition (29) implies

$$F^{S'} = \frac{F^{B'}}{\phi + (1 - \phi) u_{T,1}^B / u_{T,2}^B}$$

where the consumption levels of constrained borrowers are given by

$$\begin{aligned} C_{T,1}^B &= M^B + q(K_1^B - K_2^B) + \phi(Y_{T,1}^B + qK_2^B) \\ C_{T,2}^B &= F^B + Y_{T,2}^B - \phi(Y_{T,1}^B + qK_2^B) \end{aligned}$$

The implicit function theorem implies

$$\frac{\partial K_2^B}{\partial M^B} > 0$$

if the following (sufficient but not necessary) conditions are satisfied,

$$\begin{aligned} \frac{\partial C_{T,1}^B}{\partial K_2^B} &= -F^{S''}(K_1^B - K_2^B + \phi K_2^B) - F^{S'}(1 - \phi) < 0 \\ \frac{\partial C_{T,2}^B}{\partial K_2^B} &= A - \phi(-F^{S''}K_2^B + F^{S'}) > 0 \end{aligned}$$

The first condition implies that an increase in  $K_2^B$  should come at the cost of a reduction in  $C_{T,1}^B$ . This requires placing an upper bound on the collateral parameter  $\phi$  and ensuring that the second derivative of the savers' production function is not too high in order to limit the responsiveness of prices to the demand for capital. The second condition requires that a marginal increase in  $K_2^B$  should lead to greater net worth at time 2 and thus higher  $C_{T,2}^B$ . This condition also places an upper bound on  $\phi$ .