Regulating Capital Flows to Emerging Markets: An Externality View

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Abstract

This paper provides foundations for prudential capital controls to reduce the risk of financial crises in emerging economies. Such crises typically involve a feedback loop of capital outflows, depreciating exchange rates and tightening financial constraints. Rational private agents who issue external liabilities do not internalize that they contribute to the feedback loop because of pecuniary externalities. We construct an externality pricing kernel and use a sufficient statistics approach to find externalities of 45% for dollar debt but close to zero for FDI during past financial crises. We confirm our estimates using calibrated DSGE simulations.

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1 Introduction

In the aftermath of the 2008/09 global financial crisis, regulations on capital flows to emerging market economies have experienced a renaissance. Emerging economies around the world have faced a resumption of strong capital inflows as their growth prospects appeared superior to those of the industrialized world. This has led to renewed concern among academics and policymakers that the strong boom in capital inflows would create financial fragilities that could lead to a painful bust when capital flows reverse. As a consequence, a number of countries, including Brazil, Indonesia, Korea, Taiwan and Thailand have imposed restrictions on capital inflows in recent years.

In standard neoclassical models, there is no role for restrictions on capital flows, since free international capital markets allow poor countries to increase their capital stock and to insure against idiosyncratic shocks, thereby raising growth and reducing consumption volatility (see e.g. Obstfeld and Rogoff, 1996). However, empirical evidence such as Reinhart and Reinhart (2008) suggests that large capital inflows make emerging market economies vulnerable to financial crises that both increase consumption volatility and hurt growth prospects. Recently, this has induced even the IMF (2012) to change its long-standing policy and permit the use of capital controls (see also Ostry et al., 2010; Gallagher and Tian, 2014).

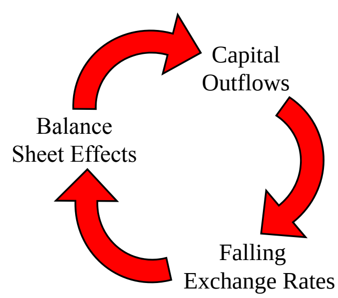

Figure 1: Financial Amplification Effects

This paper provides welfare theoretic foundations for prudential capital controls to mitigate a the vulnerability of emerging market economies to financial crises. We analyze the effects and the desirability of private capital flows within the leading class of models to describe such financial crises: models of balance sheet effects. In such models, financial crises occur when an adverse shock triggers a feedback loop of capital outflows, depreciations in the exchange rate, and tightening financial constraints due to adverse balance sheet effects, as illustrated in Figure 1.[1]

We capture these dynamics in a model of a small open economy in which domestic agents trade financial claims with international investors but are subject to a collateral constraint. The value of the collateral that domestic agents carry on their balance sheets depends on the country's exchange rate. If the exchange rate depreciates, the borrowing capacity of domestic agents contracts and international investors pull their funds from the domestic economy. Depreciations thus have contractionary effects when the collateral constraint is binding.[2] This introduces the critical part of the feedback loop in Figure 1.

If international investors experience an increase in risk aversion or if the domestic economy is hit by a negative output shock, capital flows out of the economy, the exchange rate depreciates, the financial constraint tightens, and these dynamics feed on each other to amplify the initial shock. This phenomenon of financial amplification captures the typical dynamics of the exchange rate, the current account, and aggregate demand during emerging market crises.

Our main finding is that rational private agents do not optimally solve the trade-off between the benefits of foreign capital and the risks of financial crises in such an environment. The inefficiency arises from a pecuniary externality: Individual agents take the country's exchange rate as given and do not internalize that their collective behavior leads to contractionary depreciations when the collateral constraint is binding. In short, they neglect their individual contribution to the feedback loop. Private agents therefore undervalue the social cost of financial liabilities that mandate repayments in constrained states of nature.

We constrast the decentralized equilibrium with the allocation chosen by a Ramsey planner who internalizes these general equilibrium effects. A

[1] In the emerging market context, such models were first introduced by Calvo (1998) and Krugman (1999). More recent contributions include Christiano et al. (2004); Jeanne and Zettelmeyer (2005); Mendoza (2005); Céspedes et al. (2012). They are successful at capturing both the qualitative and quantitative aspects of emerging market financial crises. For surveys of the literature see Korinek and Mendoza (2014) and Lorenzoni (2015).

[2] Observe that the contractionary effects of depreciations when the collateral constraint binds contrast strongly with the expansionary effects of depreciations in standard macroeconomic models (see e.g. Obstfeld and Rogoff, 1996). For a comprehensive review of the role of contractionary exchange rate depreciations in emerging market crises see e.g. Frankel (2005). This literature also documents that sharp exchange rate depreciations are a systematic feature of emerging market financial crises, even though exchange rates are largely disconnected from fundamentals in normal times.

planner reduces the financial liabilities that agents carry into constrained states of nature, which leads to smaller capital outflows, a more appreciated exchange rate, and a relaxation of the collateral constraint compared to the decentralized equilibrium. In short, the planner shifts the liability structure of the economy towards more insurance and less risk-taking. This reduces the incidence and severity of financial crises.

We construct an externality pricing kernel to quantify the magnitude of the externalities of different types of capital flows. This kernel is a stochastic variable that captures the uninternalized social cost of payoffs in different states of nature. It is zero in states of nature in which agents are unconstrained and positive when the financial constraint in the economy is binding and externalities are present. The externality pricing kernel allows us to express the optimal Pigovian taxes necessary to internalize the externalities of capital flows with different payoff profile, such as dollar debt, local currency debt, or portfolio equity investment.

We follow two complementary approaches to quantify the externalities of capital flows:

(1) We develop a sufficient statistics approach based on Chetty (2008, 2009). We show that we can quantify the externalities of capital flows using three statistics that can be readily obtained from the data: (i) the tightness of financial constraints, (ii) the extent of financial amplification, and (iii) the payoff profile of different types of capital flows during a crisis. Aside from the simplicity of implementation, the main benefits of this approach are that it is very transparent, that it is robust to many changes in the model structure, and that it obviates the need to calibrate and simulate a full structural DSGE model, which relies on many assumptions about parameters and structural relationships that are difficult to verify (Chetty, 2009). We also show that the methodology is robust to a range of model extensions in section 5.

We apply this approach to quantify the externalities from capital flows in a number of emerging market crises identified by Korinek and Mendoza (2014). We find that there is a clear pecking order of different types of capital flows: Dollar debt imposes the greatest externalities during financial crises, with magnitudes of up to 45 cent per dollar borrowed. Local currency debt leads to externalities that are about half the size of those of dollar debt since crises go hand in hand with exchange rate depreciations that reduce the value of local currency liabilities. Equity portfolio investments generate even lower externalities since asset price declines during crises reduce the external liabilities of emerging market agents. We also translate these externalities into Pigovian taxes.

(2) We complement these findings with conventional DSGE model simulations. We introduce a numerical algorithm based on the endogenous gridpoints method of Carroll (2006) and its extension to occasionally binding constraints by Jeanne and Korinek (2010b). We calibrate the model to replicate the dynamics of the Thai financial crisis of 1997/98. We find that the externalities obtained from our DSGE simulation closely correspond to those obtained from the sufficient statistics approach.

Furthermore, we employ model simulations to investigate the effects of implementing the planner's optimal borrowing decisions on the equilibrium allocations of the economy. If a planner corrects the externalities, the economy accumulates 5% of GDP in additional insurance against sudden stop shocks. Given the financial amplification effects, this reduces the current account reversal and the decline in domestic absorption in the event of a sudden stop by more than half. The welfare gains from optimal capital flow regulation are of the same magnitude as Lucas's estimate of the welfare cost of business cycles.

We also simulate a planner who is unable to distinguish between different types of capital flows and is restricted to impose a Pigovian tax corresponding to the average externality of all types of flows. We find that the resulting allocation is close to the unregulated decentralized equilibrium and that there are scant welfare gains from this type of intervention. This underlines that it is critical to distinguish between safe and risky forms of finance when regulating capital flows.

We analyze a number of extensions to investigate the robustness of our model setup and our quantitative approach: We discuss how several types of ex-post crisis management policies interact with the optimal ex-ante prudential regulation of capital flows. We extend our framework to account for a more general maturity structure of financial liabilities. We show that controls on capital inflows are equivalent to controls on outflows under certain conditions, but that the latter raise problems of time consistency. We introduce capital investment and time-varying leverage ratios and show that our formula for the optimal level of capital controls is robust. We also investigate how to regulate capital flows when domestic agents take on risk because of over-optimism.

Related Literature Our work is related to a growing literature that analyzes the implications of market frictions for the optimality of financing decisions of private agents. One strand in this literature motivates capital controls from pecuniary externalities. In this context, our paper is most closely related to Caballero and Krishnamurthy (2001, 2003).[3] Our approach differs from theirs in two respects: First, building on Korinek (2007), the pecuniary externalities in our framework arise from changes in the value of collateral, capturing the role of balance sheet effects, rather than from limitations on the risk-sharing capacity of domestic agents. Secondly, we quantify the externalities of different types of capital flows. Other recent papers motivate capital controls based on pecuniary externalities but in environments in which dollar debt is the only financial contract available. See for example Jeanne and Korinek (2010a), Aizenman (2011), Bianchi (2011), Korinek (2011) and Benigno et al. (2013a). We show in our quantitative analysis below that it is critical to account for different types of liabilities since the main welfare benefits from regulating capital flows arise from shifting the liability composition of emerging market agents towards more crisis insurance. Benigno et al. (2013a,b) and Caballero and Lorenzoni (2014) compare the role of prudential intervention with crisis mitigation policies.

Another strand of literature analyzes how aggregate demand externalities in the presence of nominal price stickiness may justify the imposition of capital controls. See for example Farhi and Werning (2012, 2013) and Schmitt-Grohé and Uribe (2012). Costinot et al. (2014) and De Paoli and Lipinska (2013) investigate how capital controls can be used to exert monopoly power over a country's terms-of-trade, i.e. to distort world interest rates and prices. The externalities that we investigate are distinct from these and put the focus on preserving financial stability and avoiding adverse balance sheet effects.

A more general aspect that we add to the literature on capital controls is that we introduce an externality pricing kernel to discriminate among various forms of capital flows according to their social risk profile. We also develop a sufficient statistics approach that allows us to calibrate this externality pricing kernel in a robust and transparent manner with minimal data requirements.

There are three themes in the empirical literature that support our approach and our findings. First, a number of recent papers, esp. Burger et al. (2012) and Forbes and Warnock (2013), document that emerging market economies issue a wide variety of liabilities, including dollar debt, local currency debt, equity, FDI etc.[4] This underlines the importance of theo-

[3] For a related analysis of excessive risk-taking and overborrowing in a closed economy based on fire sale externalities see Lorenzoni (2008) and Korinek (2010).

[4] This contrasts with the experience of emerging market economies in earlier decades when dollar-denominated debt was the only financial liability available. Eichengreen and Hausmann (2005) termed this phenomenon the "original sin" of emerging economies.

retical research to compare the relative social benefits and costs of different types of financial liabilities.

Secondly, a growing body of empirical literature, surveyed by Magud et al. (2011), finds robust evidence that capital controls are successful in changing the type of financial liabilities that emerging market agents issue. This is the main objective of capital flow regulation in our framework.

Finally, a number of papers provide indirect evidence for our finding that contingent capital flows lead to lower externalities than uncontingent ones: Calvo et al. (2004) and Levy Yeyati (2006) show that dollar debts significantly raise the risk of financial crisis without yielding benefits in terms of higher growth. By contrast, Mauro et al. (2007) show that financial flows that are conducive to risk-sharing, such as foreign direct investment, are positively associated with both macroeconomic stability and long-run growth.

2 Baseline Model Setup

We assume a small open economy in infinite discrete time $t = 0, 1, \ldots$. The economy is inhabited by a unit mass of representative domestic agents that interact with large international investors in a market of state-contingent securities. Domestic agents derive utility from their consumption of traded and non-traded goods $(c_{T,t}, c_{N,t})$ according to a utility function

$$U = E \sum_{t=0}^{\infty} \beta^t u\left(c_{T,t}, c_{N,t}\right) \tag{1}$$

where $\beta < 1$ is their time discount factor, and the period utility function $u\left(c_T, c_N\right)$ is strictly increasing in each element, quasiconcave and homothetic. Each period, a state of nature $\omega_t \in \Omega_t$ is realized and observed by all agents. The period budget constraint of domestic agents is

$$c_{T,t} + p_t c_{N,t} + E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] = y_{T,t} + p_t y_{N,t} + b_t \tag{2}$$

where all variables are contingent on the state of nature ω_t. For simplicity of notation, we omit the argument ω_t for variables that only depend on the contemporaneous state of nature, for example $c_{T,t} = c_{T,t}\left(\omega_t\right)$, but we include a superscript for random variables that depend on the realization of future states of nature, e.g. $b_{t+1}^{\omega} = b_{t+1}\left(\omega_{t+1}\right)$ for the security holdings of domestic agents that are contingent on the future state ω_{t+1}. The pair $(y_{T,t}, y_{N,t})$ denotes the stochastic endowment of domestic agents, and p_t is the relative price of non-traded goods in terms of traded goods, which we use as a numeraire. This relative price p_t represents the country's real exchange rate.[5]

The term $E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right]$ denotes the total amount of finance that domestic agents save in state-contingent securities if $b_{t+1}^{\omega} > 0$ or raise from international investors if $b_{t+1}^{\omega} < 0$ where the pricing kernel of international investors $m_{t+1}^{\omega} = m_{t+1}(\omega_{t+1})$ is a random variable contingent on the next-period state of nature and is exogenous for the domestic economy. To map our framework of state-contingent securities into emerging market liabilities that are used in practice, let us provide a few examples: A unit of foreign currency-denominated bond corresponds to a bundle $b_{t+1}^{\omega} = 1 \forall \omega_{t+1}$ in our framework; a unit of local currency bond corresponds to a bundle $b_{t+1}^{\omega} = p_{t+1}^{\omega} \forall \omega_{t+1}$; etc.

We impose the following assumption, which captures that domestic agents have an incentive to decumulate wealth over time so that b_{t+1}^{ω} will generally be negative:

Assumption 1 (Impatience) *Domestic agents are impatient compared to international investors,*

$$\beta < E\left[m_{t+1}^{\omega}\right] \qquad \forall t, \omega_t$$

where $E\left[m_{t+1}^{\omega}\right] = 1/R$ *is the inverse of the risk-free interest rate in international capital markets.*

However, to capture that there are limits on the external liabilities that domestic agents can incur, we assume that domestic financial markets are subject to a financial constraint: domestic agents suffer from a moral hazard problem that limits the total amount of financial liabilities that they can incur in period t to a fraction ϕ of their total income,

$$-E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] \leq \phi\left[y_{T,t} + p_t y_{N,t}\right] \tag{3}$$

A micro-foundation for this constraint is that domestic agents can divert their wealth but investors can seize up to a fraction ϕ of their income. An analytic description of this moral hazard problem is given in Appendix A.1. Since the borrowing capacity of private agents depends on p_t, we observe

[5] It is straightforward to extend the model to explicitly include a nominal exchange rate. See e.g. Végh (2012).

that the financial constraint creates the risk of contractionary depreciations in the exchange rate.[6]

Given their impatience, domestic agents decumulate wealth until they reach the neighborhood of the binding constraint (3). In the ergodic equilibrium, the economy will fluctuate between periods of binding constraints and periods of loose constraints in that neighborhood.

The strategy of domestic agents is to choose a path of consumtion $(c_{T,t}, c_{N,t})$ and state-contingent security holdings $\{b^{\omega}_{t+1}\}$ so as to maximize utility (1) subject to the budget constraint (2) and the financial constraint (3). We assign the shadow prices λ_t and μ_t to the two constraints and report the Lagrangian to the optimization problem in the appendix. The optimality conditions of domestic agents are

$$\begin{aligned} FOC\left(c_{T,t}\right) &: \quad \lambda_t = u_{T,t} \\ FOC\left(c_{N,t}\right) &: \quad p_t \lambda_t = u_{N,t} \\ FOC\left(b^{\omega}_{t+1}\right) &: \quad m^{\omega}_{t+1}\left(\lambda_t - \mu_t\right) = \beta \lambda^{\omega}_{t+1} \end{aligned} \tag{4}$$

where we denote by $u_{T,t} = \partial u\left(c_{T,t}, c_{N,t}\right)/\partial c_{T,t}$ the partial derivative of the period utility with respect to traded consumption and similar for $u_{N,t}$.

2.1 Decentralized Equilibrium

The decentralized equilibrium in the described economy consists of a sequence of allocations $\left(c_{T,t}, c_{N,t}, b^{\omega}_{t+1}\right)$ and real exchange rates (p_t) that satisfy the optimization problem of domestic agents and that clear the market for non-traded goods $c_{N,t} = y_{N,t}$ and for traded goods every period, with the latter being guaranteed by the economy's external budget constraint (2).

In solving for the equilibrium, we observe:

Lemma 1 (Real Exchange Rate) *The economy's real exchange rate is a strictly increasing function of the ratio $c_{T,t}/y_{N,t}$, i.e.*

$$p_t = p\left(c_{T,t}/y_{N,t}\right) \tag{5}$$

[6] The feature that depreciations in the exchange rate reduce the borrowing ability of domestic agents is shared with much of the literature on balance sheet crises in emerging economies (see citations in footnote 1). For empirical evidence that the majority of collateral in emerging economies derives from non-traded goods, see e.g. Calomiris et al. (2014).

Proof. The result follows from combining the first two optimality conditions, the non-traded market-clearing condition $c_{N,t} = y_{N,t}$, and the homotheticity of the utility function. ■

Intuitively, the real exchange rate adjusts to reflect the relative scarcity of traded goods in the economy. For example, when there are large capital inflows, the domestic absorption of traded goods increases. Since traded and non-traded goods are complements, this increases the demand for non-traded goods, and domestic agents bid up the relative price p_t of the non-traded goods as described in the lemma, leading to a real exchange rate appreciation and vice versa for capital outflows.[7]

Risk-sharing The Euler equation of decentralized agents describes how domestic agents share risk with international lenders. For any state $\omega_{t+1} \in \Omega_{t+1}$, optimal risk-sharing requires that

$$u_{T,t} = \frac{\beta u^{\omega}_{T,t+1}}{m^{\omega}_{t+1}} + \mu_t \tag{6}$$

i.e. the marginal rates of substitution between domestic agents and international investors are equated across all states of nature ω_{t+1} in period $t+1$. In addition, if the financial constraint in period t is loose, then $\mu_t = 0$ and domestic agents also equate their intertemporal marginal rate of substitution with that of international investors, $\beta u^{\omega}_{T,t+1}/u_{T,t} = m^{\omega}_{t+1} \forall \omega_{t+1}$.

If international investors were risk-neutral, domestic agents obtain perfect consumption insurance across all states of nature. If insurance from international investors is costly, domestic agents choose an unsmooth consumption profile that optimally trades off risk versus return. In good states of nature when international investors put a low price on consumption (low m^{ω}_{t+1}), domestic agents choose high consumption (low $u^{\omega}_{T,t+1}$). Conversely, in states of nature towards which international investors are highly risk-averse (high m^{ω}_{t+1}), domestic agents choose low consumption (high $u^{\omega}_{T,t+1}$).

[7] Although exchange rates are notoriously disconnected from fundamentals during normal times (see Meese and Rogoff, 1983), they systematically experience sharp depreciations during emerging market financial crises (see e.g. Reinhart and Rogoff, 2009). In countries with pegged nominal exchange rates, real exchange rates still depreciate due to deflationary pressures, and the peg frequently collapses during crises, giving way to strong depreciations.

Our model does not aim to describe exchange rate fluctuations during normal times. Instead, the exchange rate in our model only matters during crises, i.e. when the financial constraint is binding and financial amplification dynamics play out. And under those circumstances, the exchange rate predictions of our model are consistent with the evidence.

Capital market integration with risk-averse international capital markets may therefore involve significant consumption fluctuations across different states of nature.

Financial Amplification When the financial constraint on domestic agents is binding, a marginal change in the wealth of domestic agents leads to financial amplification, as we illustrated in Figure 1. We show this analytically by focusing on a state of nature and period in which the economy is constrained and substituting the collateral constraint (3) and the non-traded market-clearing condition into the budget constraint (2):

$$c_{T,t} = y_{T,t} + b_t + \phi \left[y_{T,t} + p\left(c_{T,t}/y_{N,t} \right) y_{N,t} \right] \tag{7}$$

Then we obtain the following characterization:

Lemma 2 (Financial Amplification) *In a constrained period, a marginal increase in aggregate wealth b_t relaxes the financial constraint by*

$$\frac{-dE\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right]}{db_t} = \frac{\phi p'}{1-\phi p'} \tag{8}$$

and raises traded consumption by

$$\frac{dc_{T,t}}{db_t} = 1 + \frac{-dE\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right]}{db_t} = \frac{1}{1-\phi p'} > 1 \tag{9}$$

Proof. The results obtain from implicitly differentiating expression (7). ■

The inequality captures the phenomenon of financial amplification when the constraint is binding. We can disentangle the effect of higher net worth b_t into two parts. First, it leads to a direct one-for-one increase in consumption. Secondly, it relaxes the constraint and triggers financial amplification effects: higher consumption appreciates the exchange rate, captured by p', which in turn allows for more borrowing $\phi p'$, a further increase in consumption and so on. We can re-write expression (9) as a geometric sum of the initial effect of increasing net worth 1 plus successive rounds of relaxing the financial constraint, $1+\phi p'+(\phi p')^2+... = \frac{1}{1-\phi p'}$. (The successive rounds of relaxation of the constraint all occur instantaneously in period t.)

We observe another insight by taking the inverse of equation (9). For any increase in traded consumption dc_T when the constraint is binding, a fraction $1-\phi p'$ is financed by higher net worth db and the remaining fraction $\phi p'$ is financed by additional borrowing. We will use this result below to quantify the strength $\phi p'$ of financial amplification effects.

Assumption 2 (Uniqueness of Equilibrium) *The utility function and endowments are such that* $\phi p' < 1$ $\forall \omega, t$.

If this condition was violated, the economy would be prone to multiple equilibria: starting from a given constrained allocation at which $\phi p' \geq 1$, a coordinated increase in the consumption of all agents by a marginal unit would appreciate the real exchange rate and relax the constraint by at least one unit so that the increase in consumption can be financed by issuing additional securities without violating the financial constraint. This can be repeated either until domestic agents reach their optimal unconstrained level of consumption or until the economy becomes constrained at higher levels of consumption at which $\phi p' < 1$ is satisfied. In both cases, there exists another equilibrium in addition to the original equilibrium at which $\phi p' \geq 1$.

This multiplicity is a well-known property of models of endogenous financial constraints (see e.g. the discussion in Korinek and Mendoza, 2014). Assumption 2 rules out multiple equilibria to simplify our analysis, but for $\phi p' \to 1$ our model comes arbitrarily close to the case of multiple equilibria, i.e. arbitrarily small shocks can cause large shifts in equilibrium allocations. In our numerical simulations below, we find that Assumption 2 is satisfied if $\phi \leq .41$, corresponding to an external debt level at which many emerging economies have experienced financial difficulties (see Reinhart et al., 2003).

2.2 Constrained Ramsey Planner

We determine the scope for capital flow regulation in the described economy by introducing a Ramsey planner who is subject to the same financial constraint (3) as private agents. We assume that the planner has the power to determine the financial market allocations of the economy b^ω_{t+1}. We will show below that this is equivalent to allowing the planner to impose taxes/regulations on b^ω_{t+1}. However, private agents continue to choose how to allocate their income to the consumption of traded and non-traded goods. As a result, the planner needs to respect the optimality condition (5) of private agents, which pins down the real exchange rate and serves as an implementability constraint on the planning problem.[8]

[8] This setup follows the tradition of Stiglitz (1982) and Geanakoplos and Polemarchakis (1986) and captures that policymakers have instruments to regulate financial market allocations, but that they are subject to the laws of demand and supply when they attempt to manipulate market prices such as the exchange rate. We will consider additional policy instruments below in Section 5.

The problem of the planner is to pick a path of real variables $\left(c_{T,t}, c_{N,t}, b^{\omega}_{t+1}\right)$ that maximize utility (1) subject to the resource constraints given by $c_{N,t} = y_{N,t}$ and (2), as well as subject to the financial constraint (3) and the implementability constraint (5). Given that non-traded consumption is pinned down by non-traded endowment, the planner has a single relevant decision margin every period: how much traded wealth to consume versus how much to save in different state-contingent securities.

$$\max_{c_{T,t}, b^{\omega}_{t+1}} E \sum_{t=0}^{\infty} \beta^t u\left(c_{T,t}, y_{N,t}\right) \text{ s.t. } c_{T,t} + E\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] = y_{T,t} + b_t \tag{P1}$$

$$E\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] + \phi\left[y_{T,t} + p\left(c_{T,t}/y_{N,t}\right) y_{N,t}\right] \geq 0$$

The critical difference between the planner's problem (P1) and the optimization problem of decentralized agents is that the planner internalizes the effects of aggregate traded consumption on the real exchange rate p and therefore on the financial constraint, as captured in the second line of the problem. Assigning the shadow prices $\tilde{\lambda}_t$ and $\tilde{\mu}_t$ to the two constraints, the planner's optimality conditions are

$$\begin{aligned} FOC\left(c_{T,t}\right) &: \quad \tilde{\lambda}_t = u_{T,t} + \phi \tilde{\mu}_t p'\left(c_{T,t}/y_{N,t}\right) \\ FOC\left(b^{\omega}_{t+1}\right) &: \quad m^{\omega}_{t+1}\left(\tilde{\lambda}_t - \tilde{\mu}_t\right) = \beta \tilde{\lambda}^{\omega}_{t+1} \end{aligned}$$

The first optimality condition highlights that the social value of additional wealth consists not only of the marginal utility $u_{T,t}$ of consuming it, as in the private optimality condition (4), but also of relaxing the financial constraint. When the financial constraint is loose so $\tilde{\mu}_t = 0$, observe that the expressions for the social and private value of additional wealth are identical so $\tilde{\lambda}_t = \lambda_t$.

Combining the two optimality conditions, we obtain

$$u_{T,t} - \tilde{\mu}_t\left(1 - \phi p'\right) = \frac{\beta\left(u^{\omega}_{T,t+1} + \phi \tilde{\mu}^{\omega}_{t+1} p'\right)}{m^{\omega}_{t+1}} \tag{10}$$

In every period, the planner equates the social marginal rates of substitution between domestic agents and international investors across all states of nature ω_{t+1} for the following period. The social marginal benefit of wealth of domestic agents includes the effects of additional wealth on the constraint.

Implementation via Taxes The planner can equivalently implement her optimal allocations by using taxes on the security issuance of domestic agents in a decentralized setting.

Proposition 3 (Constrained Efficient Allocation) *The planner implements the constrained socially efficient allocation in the economy by imposing taxes on the sale of state-contingent Arrow securities b_{t+1}^{ω} of*

$$\tau_{t+1}^{\omega} = \frac{\phi p' \left(c_{T,t+1}/y_{N,t+1}\right) \tilde{\mu}_{t+1}^{\omega}}{u_{T,t+1}^{\omega}} \tag{11}$$

Proof. We can replicate the Euler equation of the planner by substituting the tax rates τ_{t+1}^{ω} into the Euler equation of private agents and observing that the planner's shadow price of being constrained will satisfy

$$\tilde{\mu}_t \left(1 - \phi p'\right) = \mu_t \tag{12}$$

in that equilibrium. A detailed derivation is reported in appendix A.3. ■

Observe that the optimal tax (11) can be described as a *prudential* policy instrument: it depends not on the whether the economy is presently constrained but on whether the economy is at risk of hitting binding constraints in the future. Specifically, the tax rate τ_{t+1}^{ω} is zero for securities that are contingent on states of nature ω_{t+1} in which the financial constraint will be loose. It is positive and reflects the uninternalized social benefit of carrying additional wealth into states ω_{t+1} of period $t+1$ in which the financial constraint will be binding.

The expression for the optimal tax rate (11) consists of three elements: the term $p'(\cdot)$ captures how much an additional unit of liquid wealth in period $t+1$ will appreciate the value of non-traded collateral; the term ϕ captures how much additional borrowing capacity this will deliver; the term $\tilde{\mu}_{t+1}/u_{T,t+1}$ captures the welfare benefit of relaxing the binding constraint normalized by the marginal utility of traded consumption, i.e. expressed in terms of the numeraire good. This latter term will be zero if the economy is unconstrained in state ω_{t+1}.

The allocation implemented by the Ramsey planner achieves a Pareto improvement: The welfare of domestic agents is higher by revealed preference of the planner: the planner could pick the allocation of decentralized agents by setting zero taxes but instead chooses to pick the positive tax rates (11) that alter this allocation. International lenders are large and are indifferent between purchasing securities or not so their welfare is unchanged.

Regulating Composite Securities In practice, policymakers are interested in regulating real-world securities, such as different types of debt or equity, rather than Arrow securities. In our framework, we can view such securities as composite bundles of state-contingent Arrow securities, and we can easily extend our analysis to this case.

We denote the state-contingent payoff profile of a given composite security by a payoff vector X^{ω}_{t+1}. For example, the payoff profile of a dollar-denominated discount bond $\mathcal{D}$ can be denoted by a vector $X^{\omega}_{t+1}(\mathcal{D}) = \{1\}$ since it pays one unit of traded good in all states of nature in the following period. Similarly, a local currency-denominated discount bond $\mathcal{L}$ or a GDP-indexed discount bonds $\mathcal{Y}$ can be denoted by the vectors $X^{\omega}_{t+1}(\mathcal{L}) = \left\{p^{\omega}_{t+1}\right\}$ and $X^{\omega}_{t+1}(\mathcal{Y}) = \left\{y^{\omega}_{T,t+1} + p^{\omega}_{t+1} y^{\omega}_{N,t+1}\right\}$, respectively, since the payoffs of the two correspond to the value of the exchange rate and of aggregate output. This allows us to extend our results on capital flow regulation to securities with arbitrary payoff profiles:

Corollary 4 (Regulating Capital Flows) *The optimal specific tax on a capital flow with payoff vector X^{ω}_{t+1} is*

$$t\left(X^{\omega}_{t+1}\right) = E\left[\eta^{\omega}_{t+1} X^{\omega}_{t+1}\right] \qquad \text{where} \qquad \eta^{\omega}_{t+1} = \frac{\tau^{\omega}_{t+1}}{1+\tau^{\omega}_{t+1}} m^{\omega}_{t+1} \tag{13}$$

where we define η^{ω}_{t+1} as the ***externality pricing kernel*** *of the economy.*

Proof. The optimal specific tax t ensures that the no-arbitrage condition for the purchase of a corresponding bundle of Arrow securities $b^{\omega}_{t+1} = X^{\omega}_{t+1}$ is satisfied. A detailed derivation is reported in appendix A.3. ■

This optimal tax reflects the social cost of the externalities created by issuing one unit of a security with payoffs X^{ω}_{t+1} in terms of the numeraire good. Conversely, it also reflects the social benefit of saving one unit of a security with payoffs X^{ω}_{t+1}.

Observe that the expression takes on a very similar form to standard asset pricing conditions, making it natural to define the term η^{ω}_{t+1} as the externality pricing kernel of the economy. Just like a regular pricing kernel, the externality pricing kernel is a state-contingent variable that quantifies the externality of a unit payoff in state ω_{t+1} of period $t+1$. The externality pricing kernel is zero when the financial constraint in period $t+1$ is loose and no externalities occur; it is positive and captures the cost that the tightening constraint imposes on other domestic agents when the financial constraint in period $t+1$ is binding.

International lenders are willing to pay $q\left(X^{\omega}_{t+1}\right) = E\left[m^{\omega}_{t+1} X^{\omega}_{t+1}\right]$ for a payoff vector X^{ω}_{t+1}, but the social benefit to the domestic economy is

$q\left(X_{t+1}^{\omega}\right)+t\left(X_{t+1}^{\omega}\right)=E\left[\left(m_{t+1}^{\omega}+\eta_{t+1}^{\omega}\right)X_{t+1}^{\omega}\right]$. We can therefore view the stochastic variable $\left(m_{t+1}^{\omega}+\eta_{t+1}^{\omega}\right)$ as the *social pricing kernel* of the domestic economy. The social benefit of a marginal unit of wealth is equal to the private benefit in those states ω_{t+1} in which the financial constraint is loose. It is increased by the value of relaxing the constraint when the financial constraint is binding.

3 Empirical Analysis Using Sufficient Statistics

We quantify the externalities from international capital flows using a sufficient statistics approach in the spirit of Chetty (2009). In other words, we map the mathematical terms that describe optimal policy into empirically observable magnitudes that can be obtained directly from the data. This minimizes the data required to calculate optimal policy measures.

There are two important benefits to such a sufficient statistics approach: First, it does not require estimating all of the structural parameters of our model, some of which are difficult to obtain empirically and subject to considerable uncertainty. Second, it is more robust, since multiple different model structures lead to the same sufficient statistics for optimal policy analysis. For example, we show in section 5 that the numbers obtained from our sufficient statistics approach are robust to several modifications and extensions of our benchmark model. Our sufficient statistics approach therefore provides for a more direct, transparent and robust quantitative analysis of the described externalities.

Naturally, there is also a caveat: it is more difficult to use sufficient statistics to perform a counterfactual analysis of how the equilibrium of the economy will change in response to changes in fundamental parameters or policies. For robustness and to address this concern, we will complement and compare the sufficient statistics approach in the current section with quantitative simulations in a calibrated DSGE version of our model in the following section 4.

Finally, there are some limitations that apply to both approaches but that become more transparent under the sufficient statistics approach: Our analysis is based on data from historical financial crises, which are (fortunately) rare events. Our estimates are therefore point estimates that capture the specific circumstances of the economies and events under consideration. They are only applicable to the future in the absence of structural changes in the described economies. However, the same caveat applies to the policy measures that are obtained from the DSGE model that is calibrated to replicate past crises in the following section.

List of Sudden Stop Episodes We apply our sufficient statistics analysis to a sample of Sudden Stop episodes during the period of 1994 – 2013 based on the dataset of Korinek and Mendoza (2014). Table 1 reports our list of sudden stop episodes. In the spirit of Calvo (1998), we define the peak quarter of each episode as the quarter within each episode in which the greatest current account reversal occurred compared to four quarters before. For example, in Thailand the greatest current account/GDP reversal occured from a CA/Y ratio of -4.7% in 1997Q1 to 16.3% in 1998Q1. The third column lists the magnitude of the current account reversal $\Delta CA/Y$ in that quarter.

Country	Peak Quarter	$\Delta CA/Y$
Thailand	$1998Q1$	20.9%
S Korea	$1998Q1$	20.8%
Malaysia	$1998Q2$	21.8%
Indonesia	$1998Q3$	10.0%
Russia	$1998Q4$	13.9%
Turkey	$2001Q2$	8.2%
Argentina	$2002Q3$	3.1%

Table 1: List of sudden stop episodes

Sufficient Statistics In order to characterize the externalities associated with capital flows in the year leading up to the peak period of each sudden stop episode, we use equation (12) for $\tilde{\mu}$ to express the externality term τ that we described in equation (11) as the product of the following two terms,

$$\tau = \frac{\mu}{u_T} \cdot \frac{\phi p' \left(c_T/y_N\right)}{1 - \phi p' \left(c_T/y_N\right)}$$

The first term, μ/u_T, expresses the tightness of the financial constraint normalized by marginal utility. This captures the percentage private benefit of relaxing the constraint by one marginal dollar. The expression can equivalently be interpreted as the shadow interest rate premium of domestic private agents, i.e. the interest rate premium that would have to prevail so they are indifferent between being constrained or not.

We determine μ/u_T by measuring how much domestic consumption deviates from its HP-filtered trend. Specifically, we assume that domestic agents are on their Euler equation $u_T(c_T, \cdot) = \beta E[u'_T/m']$ if consumption c_T equals trend consumption $\bar{c}_T$ and that the deviation from this trend is driven by binding financial constraints. A first-order Taylor approximation to the Euler equation of domestic agents then implies[9]

$$\frac{\mu}{u_T} \approx -\sigma \cdot \frac{\Delta c_T}{\bar{c}_T} \tag{14}$$

where we define $\Delta c_T/\bar{c}_T = (c_T - \bar{c}_T)/\bar{c}_T$ the deviation of consumption from trend and where σ is the elasticity of intertemporal substitution of traded consumption, $\sigma = -\bar{c}_T \cdot u_{TT}/u_T$.

Mapping expression (14) to the data, we assume the standard value $\sigma = 2$ from the macro literature and equate consumption with domestic absorption.[10] We determine the deviation from trend by looking at the average deviation during the year (four quarters) starting with the peak of the sudden stop. In Thailand, for example, we date the peak of the sudden stop as 1998Q1 and we find absorption to be on average 15.0% below trend during the four quarters of 1998. We list the corresponding values for μ/u_T for different sudden stop episodes in Table 2.

[9] To obtain the approximation, we express the shadow price of domestic agents from the wedge in their Euler equation as

$$\mu = u_T(c_T, \cdot) - \beta E[u'_T/m'] = u_T(c_T, \cdot) - u_T(\bar{c}_T, \cdot)$$

where the second step follows from the assumption that trend consumption satisfies the Euler equation with equality. Then we approximate the right-hand side around $c_T = \bar{c}_T$ and divide by u_T.

[10] In our model, consumption equals absorption since we describe an endowment economy. More generally, absorption is defined as the sum of consumption, investment and government spending, and equals GDP minus net exports. We prefer using absorption over consumption for our sufficient statistics and, later, for the calibration of our quantitative model since this allows us to map the budget constraint in the model $c_T = y_T - (E[m'b'] - b)$ to the accounting identity in the data that absorption equals GDP minus net exports, $Ab = Y - (NX)$. Otherwise there is a discrepancy between consumption and current account movements and the mapping from the data to our model is not as clean. Furthermore, during sudden stops, all three components of absorption are typically subject to severe constraints. We performed robustness tests using consumption data instead of absorption data and obtained estimates of similar magnitude.

Country	Date	μ/u_T	$\frac{\phi p'}{1-\phi p'}$	τ
Thailand	$1998Q1$	30.0%	1.21	36.3%
S Korea	$1998Q1$	31.6%	1.39	44.1%
Malaysia	$1998Q2$	31.6%	.39	12.2%
Indonesia	$1998Q3$	16.8%	.30	5.1%
Russia	$1998Q4$	14.9%	.46	6.8%
Turkey	$2001Q2$	19.1%	.54	10.3%
Argentina	$2002Q3$	21.0%	.17	3.6%

Table 2: Sufficient statistics and externality

The second term, $\phi p'/(1-\phi p')$, captures how much additional net worth will relax the constraint. Specifically, the numerator of the expression, $\phi p'$, describes by how much the constraint is relaxed in response to an increase in domestic consumption. The denominator reflects that an increase in net worth increases consumption not only directly but also indirectly via amplification effects, as described in Lemma 2. We use this lemma to quantify the term in the equation: we divide the two expressions (8) and (9) from the lemma to obtain

$$\frac{-dE\left[m'b'\right]}{dc_T} = \phi p' \approx \frac{-\Delta E\left[m'b'\right]}{\Delta c_T} \tag{15}$$

Intuitively, the expression describes how external financial liabilities and traded consumption co-move when the economy experiences wealth shocks and the financial constraint is binding: a fraction $\phi p'$ of any change in consumption dc_T is due to the tightening financial constraint $-dE\left[m'b'\right]$. Conversely, the remaining fraction $1-\phi p'$ is due to the wealth shock itself. We approximate the marginal effect in equation (15) by the average effect.

We map the right-hand side of expression (15) to the data by observing that the current account is defined as the change in the net external wealth of a country in a given time period. We equate the change in external wealth $-\Delta E\left[m'b'\right]$ to the deviation in the current account from its HP-filtered trend in the year starting with the peak of the sudden stop. Furthermore, we map Δc_T to the decline in absorption over the same period. For example, in Thailand, the current account declined by 8.2% in 1998. Absorption declined by 15.0% of GDP, implying an estimate for $\phi p' \approx .55$ and $\phi p'/(1-\phi p') \approx 1.21$. The estimates for other countries are listed in column 4 of Table 2.

The externality term τ is obtained by multiplying the two terms and is listed in the last column of the table. It reflects the percentage social cost of a marginal capital outflow during the described sudden stop episodes.

For example, we estimate the externality of capital outflows in Thailand 1998Q1 as 36% of the outflow – in other words, the total social cost of a capital outflow was more than one third larger than the private cost.

The externalities in South Korea's sudden stop of 1998Q1 were of similar magnitude. Malaysia experienced somewhat smaller externalities in 1998Q2, potentially due to the use of restrictions on capital outflows that mitigated the factor of amplification $\frac{\phi p'}{1-\phi p'}$. In both the sudden stops of Indonesia 1998Q3 and Russia 1998Q4, the externalities are estimated to be lower because both absorption and the current account deviated less from their HP-filtered trend during their sudden stops – the crises in the two countries were so prolongued that the trend on both variables dipped significantly.[11] Turkey in 2001Q2 exhibited externalities of similar scale to Malaysia. Interestingly, our estimates for the externalities of capital flows to Argentina are comparably small – presumably because the main problem in Argentina's sudden stop of 2002 was sovereign default rather than private balance sheet problems.

Payoff Profile of Different Categories of Capital Flows We describe the return profile of five different categories of capital flows during our sudden stop episodes. Table 3 lists the depreciation of the local currency e/e_{t-4} (with higher values indicating greater depreciation) as well as consumer price inflation p/p_{t-4} over the four quarters leading up to the peak quarter. For example, in the case of Thailand, the exchange rate depreciated from 25.86 THB/USD at the end of 1997Q1 to 47.09 THB/USD at the end of 1998Q1, and consumer prices rose by 9%. In the ensuing five columns, the table lists the real gross returns of five categories of capital flows in terms of a domestic consumption basket:

Dollar debt $R_\$$: When domestic agents borrow in dollars, they expose themselves to exchange rate risk. The real gross return on dollar debt consists of the principal plus the dollar interest rate $1 + r_\$$ times the increase in the value of foreign currency e/e_{t-4} deflated by the increase in consumer prices p/p_{t-4}, or $R_\$ = (1 + r_\$)\,(e/e_{t-4})/(p/p_{t-4})$.

[11] This observation suggests that it may be desirable to use a slightly higher smoothing parameter λ in the HP-filter to determine deviations from trend in countries that suffered prolonged crisis, as also recommended by Drehmann, Borio and Tsatsaronis (2012) to measure financial cycles. The resulting estimates of externalities are somewhat larger than those reported in Table 2 – detailed results are available from the author upon request. However, for consistency with the existing literature, we used the standard smoothing parameter for quarterly data $\lambda = 1600$.

GDP-indexed debt R_Y: GDP-indexed dollar debt adjusts the returns on dollar debt for unexpected shocks to GDP. We multiply the gross return on dollar debt by the deviation in GDP from its expectation, $R_Y = R_\$ \cdot Y/E[Y]$, where we approximate expected output $E[Y]$ as HP-filtered trend output.

CPI-indexed debt R_Π: The real return on CPI-indexed local currency debt consists of the contractual interest rate adjusted for expected inflation, $R_\Pi = (1 + r_L)/\,(1 + E[\pi])$ where we approximate expected inflation $E[\pi]$ by the rise in the HP-filtered consumer price index.

Local currency debt R_L: Regular (non-indexed) local currency debt returns the local currency interest rate r_L deflated by the actual increase in consumer prices, $R_L = (1 + r_L)/(p/p_{t-4})$.

Equity investment R_Q: Finally, for the average real gross returns on equity investments, we deflate the nominal return on the country's main stock market index Q by the CPI, $R_Q = (Q/Q_{t-4})/(p/p_{t-4})$.

Country	Date	e/e_{t-4}	p/p_{t-4}	$R_\$$	R_Y	R_Π	R_L	R_Q
Thailand	1998Q1	1.82	1.09	1.77	1.64	1.05	1.01	.59
S Korea	1998Q1	1.84	1.09	1.79	1.69	1.06	1.01	.69
Malaysia	1998Q2	1.53	1.06	1.53	1.44	1.04	1.02	.49
Indonesia	1998Q3	4.39	1.76	2.63	2.20	1.01	.69	.35
Russia	1998Q4	3.46	1.70	2.15	1.97	.81	.65	.26
Turkey	2001Q2	2.03	1.52	1.42	1.33	.99	.93	.43
Argentina	2002Q3	3.69	1.36	2.80	2.53	1.12	.90	.89

Table 3: Gross returns on different asset categories during sudden stops

Externalities of Capital Flows We combine the externalities we measured with the returns data during sudden stops in Table 3 to quantify the realized externalities and the resulting optimal taxes on different types of capital flows. We estimate the externality kernel $\eta = m \cdot \frac{\tau}{1+\tau}$ by using our estimate for τ and approximating the discount factor of global investors by $m \approx \beta = .96$. The result is listed in the third column of Table 4 for each of our sudden stop episodes.

To obtain the Pigovian tax to offset the externality on a security with payoff profile X, we need to characterize the expectation $E[\eta X]$. Recall that the externality kernel in unconstrained time periods is zero; therefore the returns in unconstrained periods are irrelevant for our calculation. In sudden stop periods, by contrast, we multiply the externality kernel with the realized returns and, to obtain an expectation, with the ex-ante probability of sudden stops. Our sample period spans 1993 – 2012, and each of the countries experienced only one sudden stop episode in which financial constraints were clearly binding at the aggregate level. We set the probability of crisis in each country to $\pi = 5\%$, corresponding to a crisis incidence of once every twenty years.[12] In summary, our assumptions imply

$$E[\eta X] = \pi \eta R_X$$

Table 4 lists the Pigovian taxes required to offset the externalities of different types of capital flows. These can equivalently be interpreted as long-run percentage externalities:

Country	π	η	$E[\eta R_\$]$	$E[\eta R_Y]$	$E[\eta R_\Pi]$	$E[\eta R_L]$	$E[\eta R_Q]$
Thailand	5%	25.6%	2.26%	2.17%	1.34%	1.29%	0.75%
S Korea	5%	29.4%	2.62%	2.46%	1.55%	1.49%	1.02%
Malaysia	5%	10.5%	0.80%	0.77%	0.54%	0.53%	0.26%
Indonesia	5%	4.7%	0.61%	0.57%	0.24%	0.16%	0.08%
Russia	5%	6.1%	0.66%	0.61%	0.25%	0.20%	0.08%
Turkey	5%	8.9%	0.63%	0.60%	0.44%	0.41%	0.19%
Argentina	5%	3.4%	0.47%	0.42%	0.19%	0.15%	0.15%

Table 4: Pigovian taxes on different categories of capital flows

The table displays a clear ranking: Dollar debt imposes the greatest externalities among the capital flows under consideration. Emerging market crises involve significant depreciations in the exchange rate which multiply the value of the debt obligations from the point of view of domestic agents and lead to adverse balance sheet effects (cp. Table 3) and feedback loops. This is the opposite of what a good insurance contract would look like and has induced some researchers to call dollar borrowing the "original sin" of emerging market economies (see Eichengreen and Hausmann, 2005). In the case of Thailand 1998Q1, for example, the baht exchange rate rose by 82%, creating an externality of 45.2% per unit of dollar debt during the sudden stop, which we translate into a long-run externality of 2.26% of the value of dollar debt.

[12] Eichengreen et al. (2008) estimates the long-run incidence of sudden stops in an emerging economy to be 5.5%. Our results can easily be adjusted for time variation in the probability of a sudden stop, for example if an emerging economy has recently experienced a large credit boom.

The long-run externalities from GDP-linked debt are somewhat lower but not much – 2.17% in the case of Thailand. GDP-linked debt provides for some insurance – the coupon is reduced by the same percentage as the growth rate of the country – but is typically still denominated in foreign currency, giving rise to adverse valuation effects. In all of the countries in our list, these adverse valuation effects trumped the insurance effect.[13]

CPI-indexed local currency debt allocates the risk of exchange rate depreciations to international investors but protects them from inflation risk. In the event of a crisis, international investors suffer considerable losses – 55% during the sudden stop in Thailand 1998Q1 – but it does not subject domestic agents to the risk of contractionary depreciations and therefore imposes considerably lower long-run externalities on the economy – 1.34% based on the long-run estimate derived from Thailand's 1998Q1 sudden stop.

Unindexed local currency debt allocates the risk of both currency depreciation and inflation to international investors. Since severe sudden stops frequently trigger a spike in inflation, this provides domestic agents with additional insurance. In Thailand, inflation was relatively moderate during the 1998Q1 sudden stop, but Indonesia, for example, experienced a 76% increase in consumer prices during the sudden stop of 1998Q3, implying that domestic agents who had borrowed in local currency saw the nominal value of their debts decline to $1/1.76 = 57\%$ of its original real value.

Finally, equity investments expose international investors not only to exchange rate risk but also to the business risk of domestic agents. Sudden stops and the ensuing financial crises lead to sharp declines in economic activity and corporate profits and therefore to negative returns on equity investments. In the case of Thailand, for example, the country's main stock market index declined by 41%. This leads to an estimate of the long-run externalities of foreign equity investments of 0.75%. Note that this is only about one third of the externalities of dollar debt.

We have not included greenfield foreign direct investment (FDI) in the Table. Such investment occurs when foreign investors construct new operational facilities in a foreign country from the ground up. Greenfield FDI exposes foreign investors to exchange rate and business risk and is also quite illiquid. Since installed capital cannot easily be repatriated and is unlikely to yield significant dividends in the event of a sudden stop, the externalities from greenfield FDI are close to zero. This type of foreign investment is

[13] In principle, this problem could be addressed by making GDP-linked bonds a levered bet on GDP. However, in practice, GDP-linked bonds are structured such that only the coupon is linked to GDP growth and the principal is returned in full in order for the security to be treated as a bond and make it appealing to a broader class of investors.

therefore the most benign.

4 Quantitative Simulations

This section performs quantitative simulations of a calibrated version of our baseline model. The objective of our simulations is twofold. First, we examine how closely the results from the sufficient statistics approach and the simulations correspond to each other to check the robustness of the two methodologies. Secondly, we use model simulations to analyze counterfactual policy experiments. We implement our numerical simulations using an endogenous gridpoints method for occasionally binding collateral constraints, as described in Jeanne and Korinek (2010b), extended to the case of state-contingent financial markets.

4.1 Calibration

We calibrate our baseline model to yearly data with the objective of capturing the main macroeconomic dynamics of Thailand since the country liberalized its capital account 20 years ago, with special focus on replicating the sudden stop in 1997/98. For the utility function, we choose $\beta = 0.96$ and period utility $u(c) = c^{1-\gamma}/(1-\gamma)$ over a composite good in which traded and non-traded goods enter in CES fashion $c = c(c_T, c_N) = \left[ac_{T,t}^r + (1-a)c_{N,t}^r\right]^{1/r}$. We pick the standard value $\gamma = 2$ from the macro literature to replicate an elasticity of intertemporal substitution of 1/2, a traded goods share $a = 0.4$, and an elasticity of substitution $\frac{1}{1-r} = 0.8$ between traded and non-traded goods (see e.g. Mendoza, 2005).

We assume the output of both traded and non-traded goods follows a binary stochastic process $y_{T,t} = y_{N,t} \in \{y_H, y_L\}$, where we equate the low realization of the output shock with sudden stop episodes, which arise with i.i.d. probability $\pi_L = 5\%$ to capture an average incidence of once every 20 years.[14] We normalize $y_H = 1$ and choose $y_L = .93$ so as to replicate a decline in output of 7% during sudden stops (see Table 1). We set the pledgeability parameter $\phi = 0.20$ in accordance with the finding that emerging economies frequently run into financial trouble when their net external debts exceed 20% of GDP (see e.g. Reinhart et al., 2003). Finally, we set the pricing kernel of foreign investors $m_H = .97$ to replicate a risk-free interest rate of 3% in normal times. We calibrate $m_L = 1.25$ so as to

[14] This also corresponds closely to the long-run probability of sudden stops in emerging economies as identified by Eichengreen et al. (2008).

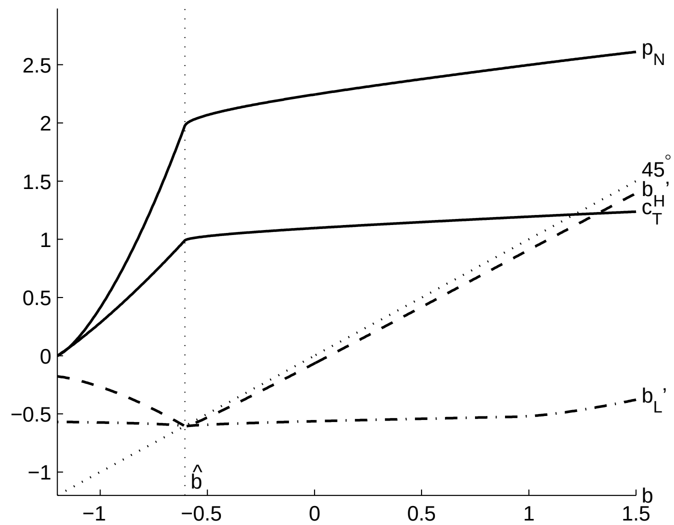

Figure 2: Policy Functions

replicate a current account reversal of $\Delta E[mb]/y_H = 8.2\%$ in the event of a sudden stop shock, as experienced by Thailand in 1998.

4.2 Policy Functions

Figure 2 depicts the policy functions for c_T, p and $b^{\omega\prime}$ as a function of beginning-of-period financial wealth b for $y = y_H$. The dotted vertical line indicates the threshold $\hat{b}$ at which the financial constraint becomes loose: to the left of this threshold, consumption c_T increases more than one-for-one in financial wealth b since domestic agents are constrained and financial amplification effects are at work (cp. Lemma 2), and similar for the exchange rate p. To the right of the threshold, additional wealth is spread across current and future consumption and both policy functions are much flatter. Furthermore, when the constraint is binding, the financial wealth $b^{\omega\prime}$ carried into future periods is a declining function of current wealth – greater current wealth relaxes the constraint and allows for greater liabilities.

The two lines $\left(b^{H\prime}, b^{L\prime}\right)$ indicate how domestic agents allocate their liabilities between the two future states (H, L): in the given calibration, the next-period constraint is loose (or only marginally binding) for any wealth level $b^{H\prime}$ carried into the high state of nature. Therefore $b^{H\prime}$ is V-shaped: it moves inversely to consumption in the constrained region and is close to but below the 45°-line in the unconstrained region, indicating a strong consumption smoothing motive and a bit of impatience.

In the absence of binding financial constraints in the following period, the $b^{L\prime}$-line would be parallel to the $b^{H\prime}$-line, with the distance between the two governed by the relative insurance motives of domestic agents versus international lenders. However, given the financial constraint, the $b^{L\prime}$-line is only slightly V-shaped and looks close to flat over the interval $[-1.2, 1]$. Since the next-period constraint is binding in the low output state over this interval, small changes in $b^{L\prime}$ lead to financial amplification and large changes in marginal utility $u_T^{L\prime}$. For $b > 1$, additional wealth is invested roughly equally in the two securities $\left(b^{H\prime}, b^{L\prime}\right)$. Intuitively speaking, this reflects that domestic agents willingly take on exposure to sudden stop risk for $b < 1$ in low states of nature. By contrast, if their wealth is sufficiently high $(b > 1)$, they carry enough savings into the bad state of nature to ensure that the economy will be unconstrained.

In Figure 3 we show the impulse response of an economy starting from the steady state that is reached after a number of periods of high output shocks. We simulate a sudden stop shock in period 5: The top panel depicts the output shock (dashed line) and the response of traded consumption (solid line), which is greater than the output shock because of financial amplification. The middle panel shows that the real exchange rate moves in tandem with traded consumption – it depreciates by 12%.

The third panel indicates the financial decisions of private agents: the solid line $E[m'b']$ shows that domestic agents are forced to delever, i.e. to reduce their financial liabilities, during the sudden stop. Looking at the individual components $\left(b^{H\prime}, b^{L\prime}\right)$, we find that domestic agents are willing to take on a certain amount of sudden stop risk because $b^{H\prime} > b^{L\prime} \forall t$. Once the sudden stop hits in period 5, the deleveraging is stronger for $b^{H\prime}$ than $b^{L\prime}$: domestic agents delever in both $b^{H\prime}$ and $b^{L\prime}$ such that their marginal utilties in states H and L of the next period decline by the same percentage. Since domestic agents experience binding constraint in the L-state, consumption is much more sensitive to changes in $b^{L\prime}$ and they adjust $b^{L\prime}$ only little when they have to delever. This mirrors the flatness of the policy function $b^{L\prime}$ in Figure 2.

4.3 Externalities

We quantify the externalities by calculating the tax wedges according to equation (11). The two tax wedges $\left(\tau^H, \tau^L\right)$ on claims contingent on states H and L are depicted in the fourth panel of Figure 3. The externalities in the high state of nature are close to zero. By contrast, in the low (sudden stop)

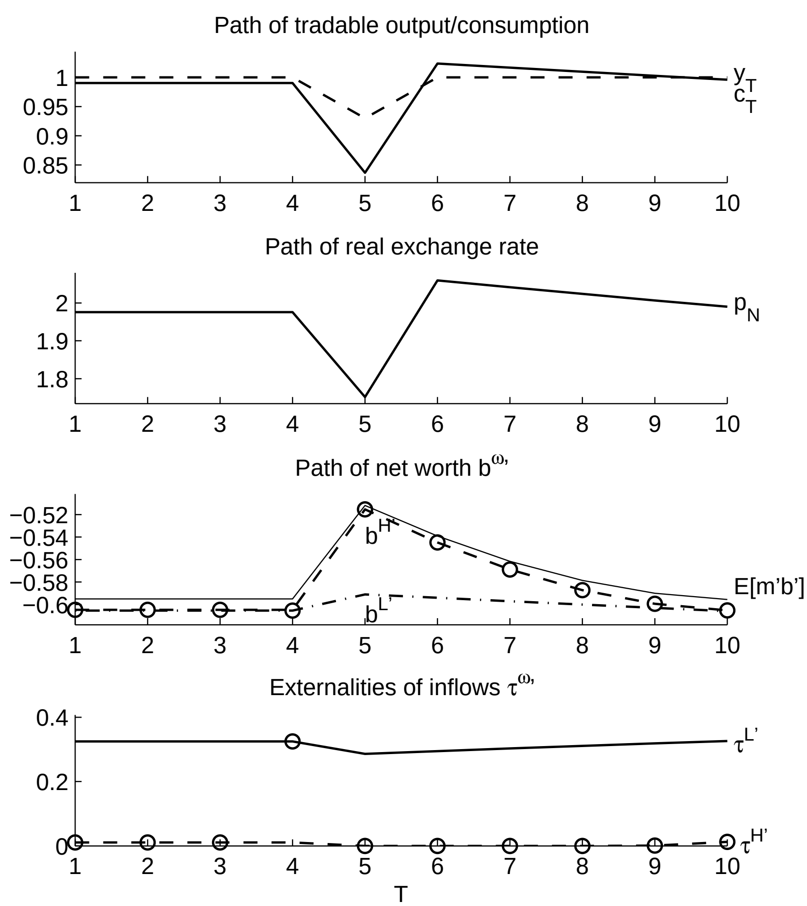

Figure 3: Impulse Response to Low-Output Shock

state of nature, the externalities are 32.5% in steady state and temporarily decline to 28.6% after the deleveraging has reduced the liabilities in the sudden stop of period 5.

We can map the externalities of the Arrow securities $\left(b^H, b^L\right)$ into those of real-world composite securities in the same manner as in the previous section using the returns data from Table 3. For example, a one dollar bond in our calibration of Thailand amounts to a bundle $(1.05, 1.76)$ of Arrow securities where 1.05 reflects principal and interest in normal times and 1.76 reflects the increased repayment due to the currency depreciation during sudden stops. The optimal tax to internalize the externalities is given by Corollary 4.

Comparison with Sufficient Statistics In Table 5, we compare the tax wedge τ^L and its components in our calibrated DSGE model with the wedge obtained from the sufficient statistics approach in the previous section.

	$\frac{\mu}{u_T}$	$\phi p'$	$\frac{\phi p'}{1-\phi p'}$	τ^L	η^L
Sufficient statistics approach	30%	0.56	1.21	36.3%	25.6%
Calibrated DSGE model	30%	0.52	1.08	32.5%	30.6%

Table 5: Comparison of the externality wedge τ^L and its components using alternative quantitative approaches

The term μ/u_T is almost identical using the two approaches. Since the DSGE model was calibrated to replicate the current account reversal that was observed in the data, domestic consumption declines by the same amount and the tightness of the financial constraint is the same. There is a small discrepancy in the value of $\phi p'$ estimated by the sufficient statistics approach and by the calibrated model and, by implication, in the factor of amplification $\phi p' / (1 - \phi p')$, which derives from the linear approximation of p'. The resulting estimates for the externality wedge τ^L differ only by 10%. We use the $\{\tau^\omega\}$ and the resulting $\{\eta^\omega\}$ from our simulated model and to estimate the externalities of composite capital flows such as dollar debt, which had a crisis payoff $b^L_\$ = 1.77$ in Thailand 1998Q1 according to Table 3. The resulting Pigovian tax is $E\left[\eta R_\$\right] = 2.71\%$, which differs only by about one sixth from the Pigovian tax using the sufficient statistics approach in Table 4.

4.4 Counterfactuals

One of the benefits of simulated DSGE models is that it is easy to conduct counterfactual policy experiments and welfare calculations within the model once it is parameterized and the simulation is implemented. This section presents two such counterfactual simulations: an experiment to study how the equilibrium changes if a planner imposes optimal Pigovian taxes to internalize all externalities and a second experiment in which a planner is restricted to impose a constant tax rate on all types of capital flows. In both experiments, we calculate the welfare gains from implementing the policy.

Effects of Implementing Optimal Pigouvian Taxes

Our first counterfactual examines how the equilibrium will change if a planner implements her optimal financial allocations by imposing optimal Pigovian taxes. We simulate an economy with the same parameter values as above and let the social planner implement her optimal choices of $\left(b^H, b^L\right)$ by setting the optimal tax rates $\left(\tau^H, \tau^L\right)$ every period.

Compared to the decentralized equilibrium depicted in Figure 3, the planner carries significantly more insurance into the low state of nature – she leaves savings in the high steady-state, b^H, roughly unchanged but increases b^L by 4.6% of output, providing insurance against two thirds of the decline in output during a sudden stop shock. As a result, financial amplification effects are significantly mitigated: the current account reversal $\Delta E[mb]$ is reduced from 8.2% to 3.6% of GDP and the decline in domestic absorption is mitigated from 15.6% to 6.0% of GDP. The additional precautionary savings fully avoid the sharp decline in the real exchange rate. (Impulse responses to a sudden stop shock under the social planner's allocation are reported in Figure 4 in the appendix.)

The tax rate τ^L that the planner needs to impose in steady state is only 18.1%. This is significantly less than the externality of $\tau^L = 32.5\%$ in the decentralized equilibrium when no policy measures are imposed. The difference arises because the financial constraint is much less tight in the event of a sudden stop under the planner's allocation than in the decentralized equilibrium – μ/u_T falls from 0.30 during a sudden stop in the decentralized equilibrium to 0.16 in the planner's allocation. The term $\phi p'/(1-\phi p')$ is little changed at 1.16.[15]

[15] Note that we can also estimate the counterfactual effects of imposing the optimal tax on the equilibrium in the economy using a sufficient statistics approach. We use two observations: First, the optimal tax wedge according to equation (11) satisfies $\tau =$

Finally, we compare welfare in the decentralized equilibrium and the planner's allocation in terms of the equivalent increase in consumption. We run 10,000 simulations of 100 periods each and calculate the average welfare under the policy functions corresponding to the decentralized equilibrium and the social planner's allocations. We find average welfare to be $W = -25.76$ in the decentralized equilibrium versus $W = -25.75$ in the planner's allocation. This amounts to an equivalent increase in consumption of 0.04% – on par with Lucas's estimate of the gains from eliminating the business cycle. This welfare gain is achieved even though domestic agents already face a complete set of state-contingent securities to insure against crisis risk in the laissez-faire equilibrium.

Restricting Taxes

Our second counterfactual assumes that the planner does not have the ability to differentiate between different types of capital flows and imposes the same tax rate $\bar{\tau} = E[\tau^{\omega}]$ on all state-contingent securities.

The resulting equilibrium is much closer to the decentralized equilibrium than to the optimal planning allocation: the planner's tax rate is $\bar{\tau} = 1.5\%$ in steady state – this is too high for liabilities contingent on the good state (which have zero externalities) and far too low for liabilities contingent on the sudden stop state (which impose externalities of 30.5% in the equilibrium under consideration). The tax inefficiently raises b^H by 3% of GDP but b^L only by 0.2% of GDP. As a result, the policy has only small effects on the decline in consumption and in the exchange rate during sudden stops.

We calculate the welfare effects of imposing the fixed tax $\bar{\tau}$ on all types of flows but do not find any welfare gain compared to the decentralized equilibrium up to five significant digits. This suggests that the potential welfare gains from regulating capital flows in our model come from distinguishing between safe and risky flows, not from imposing uniform controls.

$(\mu + \Delta\mu)/u_T \cdot \phi p'/(1 - \phi p')$ where $\Delta\mu = \Delta u_T$ indicates the change in μ in going from the decentralized equilibrium to the planner's allocation. Secondly, the effect of imposing a tax on borrowing is to manipulate the marginal utility of borrowers by the same proportion – a first-order approximation to the Euler equation of domestic agents yields $\Delta\mu/u_T = \Delta u_T/u_T \approx -\tau$. Substituting the second into the first equation, we find

$$\tau = \left(\frac{\mu}{u_T} - \tau\right) \cdot \frac{\phi p'}{1 - \phi p'} \approx \frac{\frac{\mu}{u_T} \cdot \frac{\phi p'}{1-\phi p'}}{1 + \frac{\phi p'}{1-\phi p'}} = \frac{\mu}{u_T} \cdot \phi p'$$

The sufficient statistics from Table 2 therefore imply that the optimal tax rate in the counterfactual planner's equilibrium should be $\tau^{L*} = 16.5\%$. This compares to 18.1% in the calibrated model – a difference of less than 10%.

Our finding thus underlines the importance of adjusting optimal capital flow regulations by the type of capital inflows.

5 Extensions

This section extends our baseline setup in a number of directions and observes the implications for the optimal capital controls and the sufficient statistics approach that we introduced in section 3. We start by introducing a number of ex-post policy measures to mitigate binding financial constraints and investigate the implications for the optimal tax formula on capital flows. Then we look at the role of different maturities of financial liabilities, we study outflow controls, we add capital investment and time-varying leverage ratios, and we study how a planner can best deal with capital flows that are driven by over-optimism of domestic investors.

5.1 Ex-Post Policy Measures

We consider two different types of ex-post policy measures to mitigate binding constraints. First, we analyze the implications of accumulating reserves in good times and distributing them as lump-sum transfers (or "bailouts") to domestic agents in bad times when the financial constraint binds. Next we analyze a generic second-best policy measure that relaxes the financial constraint at the cost of introducing another distortion into the economy.

5.1.1 Reserve Accumulation and Bailouts

Policymakers frequently prefer to accumulate reserves rather than to impose capital controls as a precaution against sudden stops (see e.g. IMF, 2013). We analyze this view in our framework by studying a planner who accumulates savings (foreign reserves) with a state-contingent payoff $T^{\omega}_{t+1} \geq 0$ with international lenders and distributes them back to domestic agents when they face binding constraints. In order to give such a scheme the highest possible chance of success, we assume (i) that the planner can raise the funds $E\left[m^{\omega}_{t+1}T^{\omega}_{t+1}\right]$ required to purchase the reserves by imposing a non-distortionary lump sum tax on domestic agents in period t and (ii) that the bailouts are provided in lump-sum fashion so that they do not distort the optimality conditions of domestic agents. Nonetheless we find the following result:

Proposition 5 (Bailout Neutrality) *Unconstrained domestic agents will* *fully undo any anticipated state-contingent transfer $T^{\omega}_{t+1} \geq 0$ that is financed by lump-sum taxation in period t.*

Proof. Subtracting a lump-sum tax $E\left[m^{\omega}_{t+1}T^{\omega}_{t+1}\right]$ in the budget constraint of domestic agents in period t and adding a transfer T^{ω}_{t+1} in period $t+1$ while reducing private savings by $\Delta b^{\omega}_{t+1} = -T^{\omega}_{t+1}$ implements the same allocation as in the absence of the transfer. The optimality conditions of private agents are still satisfied in that equilibrium; therefore undoing the transfer T^{ω}_{t+1} is optimal. ■

The result represents a form of Ricardian equivalence: since domestic agents trade in a full set of state-contingent Arrow securities, they have both the incentive and the capacity to undo any trade that a policymaker conducts on their behalf. Rational private agents recognize that the governmental budget constraint is ultimately part of their own budget constraint.

The usual limitations to Ricardian equivalence apply: if agents are constrained and the future transfer income is not pledgeable, then a tax-cum-transfer scheme changes their feasible allocations; if agents do not have access to the same set of investment opportunities as government, the result breaks down; if there is heterogeneity in the economy, then government transfers may introduce additional redistributive considerations; etc. However, even if our proposition captures an idealized situation, there is ample evidence that private agents engage in a significant amount of offsetting behavior in response to governmental reserve accumulation. See e.g. Benigno and Fornaro (2014) for a detailed analysis of this phenomenon and its limitations.

5.1.2 Second-Best Policy Measures

Since lump-sum transfers are difficult to implement in practice, we next analyze a generic second-best policy intervention that allows the planner to relax binding constraints at the cost of introducing some distortions into the economy. This can be interpreted, for example, as exchange rate intervention that keeps up the value of the domestic currency in order to avoid adverse balance sheet effects. Our main interest here lies in examining the robustness of our sufficient statistics formula to ex-post policy intervention. For a more comprehensive analysis of different types of second-best policy interventions to mitigate binding financial constraints in a setting similar to ours, including micro-foundations, see Benigno et al. (2013a,b) or Jeanne and Korinek (2011).

For simplicity, we employ a reduced-form specification for such policy interventions: we assume the policymaker can relax the financial constraint by ψ units at a cost given by the function $c(\psi)$, which satisfies $c(0) = c'(0) = 0$ and is increasing $c'(\psi) > 0$ and convex $c''(\psi) > 0$ for $\psi > 0$. This cost can be interpreted, for example, as the cost of an exchange rate that is artificially propped up, as a distortion generated by higher taxation to finance stimulus, as the cost of an emergency credit line, or as an auditing cost.[16] The resulting budget and borrowing constraints are

$$\begin{aligned} c_{T,t} + p_t c_{N,t} + E\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] &= y_{T,t} + p_t y_{N,t} + b_t - c(\psi_t) \\ -E\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] &\leq \phi\left[y_{T,t} + p_t y_{N,t}\right] + \psi_t \end{aligned}$$

The optimal degree of intervention is determined such that the marginal resource cost equals the marginal benefit of relaxing the constraint,

$$\tilde{\lambda}_t c'(\psi_t) = \tilde{\mu}_t$$

When the financial constraint is loose, the planner does not spend any resources on ψ_t; when the constraint is binding, the planner will engage in some of the mitigating action $\psi_t > 0$ in order to relax the constraint.

The optimal financing decisions of domestic private agents and the planner are still given by equations (6) and (10); therefore the expression for the optimal taxation of financial claims continues to remain (11), and the quantitative analysis of externalities using the sufficient statistics approach of section 3 continues to apply.

The equilibrium when policymakers employ mitigating measures generally differs from the equilibrium when such measures are absent, for two reasons: (i) the policy intervention mitigates the externalities for given net worth b; (ii) the mitigating action induces domestic agents to take on greater risk, which increases the externalities. The sufficient statistics are agnostic about how equilibrium is affected by introducing various mitigating policy measures; they simply pick up the externalities in the realized equilibrium given the realized mitigating policy measures.[17]

[16] Benigno et al. (2013ab) describe second-best interventions to prop up the exchange rate so as counter adverse balance sheet effects and relax binding constraints. Jeanne and Korinek (2013) describe second-best interventions to relax binding constraints that rely on government borrowing and introduce tax distortions. Sandri and Valencia (2013) distinguish between financial intermediaries and study optimal recapitalization policies.

[17] For example, our estimates of externalities in Thailand in Table 4 represent the externalities realized in 1998Q1 given that Thailand had used up most of its reserves to mitigate the crisis, had received a rescue package from the IMF, and had engaged in various other crisis management measures. See Furman and Stiglitz (1998) for a detailed description.

5.2 Maturity Structure

This section examines how to vary the optimal regulation of capital flows by maturity. Our baseline setup implicitly assumes that all securities have a maturity of one period, which we calibrate to one year. We now extend our baseline model to allow for an arbitrary maturity structure. Denote by $m^{\omega}_{t,t+s} = m_{t,t+s}(\omega_{t+s})$ and $b^{\omega}_{t,t+s} = b_{t,t+s}(\omega_{t+s})$ the period t state price density and amount of securities held by the domestic agent that pay off in state of nature ω_{t+s} of time period $t+s$ for $s \geq 1$ where the state price densities need to satisfy the no-arbitrage condition $m^{\omega}_{t,t+s} = m^{\omega}_{t,t+r} m^{\omega}_{t+r,t+s}$ for any $1 < r < s$. This leads to an extended budget constraint of domestic agents of

$$c_{T,t} + p_t c_{N,t} + \sum_{s=1}^{\infty} E\left[m^{\omega}_{t,t+s}\left(b^{\omega}_{t,t+s} - b^{\omega}_{t-1,t+s}\right)\right] = y_{T,t} + p_t y_{N,t} + b_{t-1,t}$$

We modify the financial constraint (3) so that it limits total security issuance at all maturities to the period t collateral. This is justified by the same incentive problem as the one that motivated the financinal constraint in our baseline model (see appendix A.1),

$$\sum_{s=1}^{\infty} E\left[m^{\omega}_{t,t+s} b^{\omega}_{t,t+s}\right] \geq -\phi\left[y_{T,t} + p_t y_{N,t}\right] \qquad (16)$$

The first result in our model of general maturity structure is the following:

Lemma 6 *Any maturity structure in the general maturity structure model maps into a unique structure of one-period securities in our baseline model.*

Proof. For any general maturity structure $\{b_{t,t+s}(\omega_{t+s})\}$, let us define the one-period security holdings at time t by

$$b_{t+1}(\omega_{t+1}) = b_{t,t+1}(\omega_{t+1}) + \sum_{s=2}^{\infty} E\left[m_{t+1,t+s}(\omega_{t+s})\, b_{t,t+s}(\omega_{t+s})\, |\omega_{t+1}\right]$$

If we substitute this definition into the above budget and borrowing constraints, we replicate the constraints and allocations of our baseline model.

■

Intuitively, the result holds since the market in our baseline economy already is dynamically complete up to the financial constraint. Any additional securities – even if they have longer maturity – are redundant.

The finding of the lemma makes it straightforward to determine the optimal regulation of multi-period securities. Denote by $\left\{X_{t+s}^{\omega}\right\}$ the contingent payoff of a multi-period bundled security in state ω_{t+s} of period $t+s$. For example, a consol would be represented by a payoff sequence $\{1, 1, 1...\}$ in all states of nature. Then we find:

Proposition 7 (Maturity-Based Regulation) *The optimal specific tax on a multi-period capital flow with payoff vector* $\left\{X_{t+s}^{\omega}\right\}$ *is*

$$t\left(X_{t+s}^{\omega}\right) = \sum_{s=1}^{\infty} E\left[\eta_{t+s}^{\omega} X_{t+s}^{\omega}\right] \qquad \textit{where} \qquad \eta_{t+s}^{\omega} = \frac{\tau_{t+s}^{\omega}}{1+\tau_{t+s}^{\omega}} m_{t,t+s}^{\omega}$$

Proof. The result follows from combining Lemma 6 and Corollary 4. ■

In short, the optimal tax on multi-period securities simply consists of the present discounted stream of future payoffs, with the externality pricing kernel η_{t+s}^{ω} serving as the stochastic discount factor.

An important implication is that capital flow regulations on short-term maturities should be adjusted counter-cyclically, whereas regulations on long-term flows can be held constant. The reason is as follows: in the short run, the externality kernel is determined to a significant extent by the current level of debt and the current state of the economy – the probability of crisis is high when the economy has lots of debt and/or is in a state of nature in which declines in output are very likely. Over longer maturities, the externality kernel converges towards an ergodic steady state that describes the long-run externalities in the economy. By implication, when crisis risk is building up, the externalities on short-term flows are significantly higher than those on long-term flows and warrant higher capital flow regulations. Conversely, when crisis risk is low in the near term, the externalities on short-term flows are lower than on long-term flows.

Let us discuss a caveat to our model on long-term maturities. As long as domestic agents have a sufficient amount of short-term debt come due in each period, the financial constraint (16) captures simultaneously a constraint on debt rollover and a constraint on total debt — new security issuance is the margin of adjustment that guarantees that the constraint is satisfied every period. A considerable fraction of aggregate debt to emerging economies is indeed short-term, for example in the form of trade credit, providing some justification for our approach. However, if borrowers have issued mostly long-term securities, then the constraint may be violated even if new security issuance is zero. In that case, it would be reasonable to modify the constraint such that the existing liabilities can always be rolled over as long as new security issuance is zero (see e.g. Komatsuzaki, 2011, for a detailed analysis).

5.3 Outflow Controls

In a rational expectations world, the effects of imposing Pigovian taxes on capital when it flows into a country or once it flows out again are identical. In this section, we first show the equivalence formally; then we discuss the practical benefits and disadvantages of inflow vs. outflow controls.

Proposition 8 (Equivalence of Inflow and Outflow Controls) *Imposing a capital control in period t on the issuance of a security contingent on state ω_{t+1} as described in Proposition 3 is equivalent to imposing an identical tax on repayments in state ω_{t+1} of period $t+1$.*

Proof. Both ways of imposing capital controls lead to identical optimality conditions for all agents. Furthermore, the tax revenue is assumed to be rebated in lump-sum fashion in both cases, which makes the interventions wealth-neutral. Therefore the two measures implement identical allocations.

■

One important practical benefit of outflow controls is that they can be imposed ex-post, i.e. once a sudden stop arises. If policymakers do not have sufficiently fine ex-ante instruments or sufficient knowledge of the state space to differentially target different types of capital flows ex-ante, then ex-post intervention can make up for the lack of instruments for ex-ante intervention. This point is discussed in more depth in Jeanne and Korinek (2011) in the context of a closed-economy framework with asset price externalities.

An important disadvantage of outflow controls is that they create a time consistency problem. Ex-post, policymakers face a temptation to raise the maximum tax possible on capital outflows in order to expropriate international investors. However, if investors rationally anticipate this, they will not provide finance to the emerging economy. As a result, outflow controls frequently give rise to large controversy and, in practice, are only used as exceptional measures during severe crises (see e.g. IMF, 2012).

5.4 Capital Investment

This section analyzes the implictions of introducing capital investment in our baseline framework. We assume that domestic agents produce traded goods using a standard neoclassical production function $y_{T,t} = f(k_t)$ where capital k_t is subject to the accumulation constraint $k_{t+1} = (1-\delta)k_t + i_t$ and i_t represents investment. This modifies the period budget constraint of domestic agents to

$$c_{T,t} + p_t c_{N,t} + i_t + E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] = f(k_t) + p_t y_{N,t} + b_t$$

The optimization problem is detailed in appendix B.1. The investment decision adds an additional optimality condition to the problem,

$$f'(k_{t+1}) = \frac{\lambda_t/\beta E\left[\lambda_{t+1}^{\omega}\right] - (1-\delta)}{1 + \phi E\left[\mu_{t+1}^{\omega}\right]/E\left[\lambda_{t+1}^{\omega}\right]}$$

When there is no risk of binding constraints next period ($E\left[\mu_{t+1}^{\omega}\right] = 0$), this collapses to the standard optimality condition for capital accumulation. Otherwise, it accounts for the fact that each additional unit of output provides ϕ units of additional collateral.

The social planner's problem is modified along the same lines, and she arrives at the same optimality conditions for financing decisions as in our earlier setup:

Proposition 9 *The optimal tax on capital inflows in the model with capital investment is still given by equation (13).*

Proof. The optimality condition for financing decisions is unchanged from earlier. ■

This implies that our optimal tax formula for regulating capital flows and therefore our sufficient statistics approach are robust to introducing capital investment.

In addition to regulating capital flows, the planner may also find it optimal to impose a subsidy on investment, which diverts resources from current consumption but creates more collateral for future periods. A detailed analysis of the optimal investment subsidy to internalize these effects is provided in appendix B.1.

5.5 Time-Varying Leverage Ratio

This section extends our baseline model to the case in which the leverage parameter ϕ depends on the state of nature ω_t. It is frequently argued that an important driver of sudden stops are changes in the amount of funds that international investors are willing to provide for a given amount of collateral, i.e. changes in the leverage parameter ϕ. Geanakoplos (2009) and Brunnermeier and Pedersen (2009) document such pro-cyclical leverage ratios as a general feature of financial markets. They explain the phenomenon on the basis of changes in perceptions about risk of the marginal investor or about the likelihood that the collateral will lose value in the future.

If we introduce a state-contingent leverage ratio $\phi(\omega_t)$ into our baseline model of section 2, the optimality conditions of private agents (5) and (6) remain unchanged. However, the allocations in the economy change. A priori, it is difficult to establish whether a change in ϕ leads to greater or smaller externalities. On the one hand, the tightness of the constraint is a decreasing function of ϕ. For given wealth b_t, the financial constraint is looser when ϕ is high. On the other hand, when the financial constraint binds, the degree of amplification $\phi p' / (1 - \phi p')$ that we derived in Lemma 2 is an increasing function of ϕ.

The sufficient statistics of Section 3 to calibrate the externalities of capital flows are robust to time-varying leverage ratios. When we estimate the factor of amplification $\phi p' / (1 - \phi p')$ from the data, our estimate is conditional on a given sudden stop episode ω_t and our approach is consistent with $\phi(\omega_t)$ varying across different states of nature. Furthermore, it is irrelevant whether the amplification arises from a high coefficient ϕ or from a high p' – only the product $\phi p'$ matters, and this can be obtained directly from the data using equation (15).

5.6 Capital Flow Regulation under Over-Optimism

This section discusses how to regulate capital flows when domestic agents expose themselves to excessive crisis risk because of over-optimism. Many policymakers argue that this is an important reason why emerging market economies are so heavily exposed to crisis risk (see e.g. IMF, 2012). Formally, we capture this situation by assuming that private domestic agents form their expectations subject to a different probability measure than the domestic policymaker.

For simplicity of exposition, assume that the set Ω_t contains a finite number of elements for each t and denote the conditional probability of reaching state ω_{t+1} from state ω_t as perceived by private agents by $\pi^{P,\omega}_{t+1}$. Furthermore, we denote the conditional probability perceived by the social planner by $\pi^{S,\omega}_{t+1}$. Let us also assume that $\pi^{P,\omega}_{t+1} > 0, \pi^{S,\omega}_{t+1} > 0 \forall \omega_{t+1}, t$. We denote the expectations operator of private agents by $E_P[\cdot]$ and that of the social planner by $E_S[\cdot]$. Although our analysis is general and does not require that we take a stance on which of the probability measures is the "true" one, our results can be interpreted such that the expectations of private agents are biased towards excessive optimism and those of the planner correspond to objective probabilities.[18]

Paternalistic Benchmark As a benchmark, we first analyze a paternalistic planner who implements the financial market allocations that replicate his preferred equilibrium. (Detailed derivations are reported in appendix B.2.) A paternalistic planner's optimal capital controls satisfy

$$1 + \tau^{\omega}_{t+1} = \frac{\pi^{S,\omega}_{t+1}}{\pi^{P,\omega}_{t+1}} \left(1 + \frac{\phi \tilde{\mu}_{t+1} p'}{u^{\omega}_{T,t+1}} \right)$$

This expression is identical to (11) if there is no belief disagreement and $\pi^{S,\omega}_{t+1} = \pi^{P,\omega}_{t+1}$. However, when the planner and private agents disagree on their assessment of the probability of future states, it justifies enormous degrees of policy intervention even if there are no externalities so $\phi \tilde{\mu}^{\omega}_{t+1} p' = 0$. For example, if the planner perceives a state twice as likely as private agents, she would impose a tax $\tau^{\omega}_{t+1} = 100\%$ on security issuance conditional on that state.

This illustrates how problematic it is to justify policy intervention based on paternalism: if we assume that regulators know things better, then it is easy to justify any form of market intervention, leading down a slippery slope towards planned economies (Hayek, 1944).

Non-Paternalistic Planning Problem Instead, we now solve an optimal planning problem under the assumption that the policymaker does not

[18] We do not explicitly distinguish the expectations of domestic agents and international investors. We assume that both private domestic agents and the domestic planner take the state price density m^{ω}_{t+1} at which international investors trade contingent assets with the emerging economy as exogenous under the expectations operator $E_P[\cdot]$. Any discrepancies in expectations between domestic agents and international investors can be captured by adjusting the state price density m^{ω}_{t+1} accordingly.

act paternalistically, based on John Stuart Mill's notion of liberalism:[19] the policymaker allows each agent to solve their private maximization problem subject to their private expectations $E_P[\cdot]$, but she evaluates any externalities that the agent imposes on other agents in the economy according to the "social" expectations operator $E_S[\cdot]$. This preserves the individual freedom of private decision makers to manage their own affairs as long as they do not create externalities, but values any externalities based on the best possible quantification by policymakers, which naturally relies on the probability measure that policymakers believe in.

We set up the non-paternalistic optimal policy problem by maximizing the weighted sum of welfare of society. In order to account for the differences in beliefs, we ask how a policymaker would regulate the financial market allocations of a given mass ε of private agents who solve their private optimization problem (1), given their subjective probability measure and expectations operator $E_P[\cdot]$, while imposing externalities on the remaining mass $1-\varepsilon$ of agents, evaluated using the planner's expectations operator $E_S[\cdot]$. Taking the limit $\varepsilon \to 0$, the planner evaluates all of the general equilibrium effects and externalities in the economy according to the social probability measure but does not paternalistically impose her probability measure on regulated private agents, implementing Mill (1859)'s notion of liberalism. (See appendix B.2 for detailed derivations.) In short, the non-paternalistic planner corrects externalities but does not correct expectations.

The optimal tax wedge that derives from this setup is

$$\tau_{t+1}^{\omega} = \frac{\pi_{t+1}^{S,\omega}}{\pi_{t+1}^{P,\omega}} \cdot \frac{\phi \tilde{\mu}_{t+1} p'}{u_{T,t+1}^{\omega}}$$

We observe that this tax wedge also coincides with expression (11) if there is no belief disagreement $\pi_{t+1}^{S,\omega} = \pi_{t+1}^{P,\omega}$. When there is belief disagreement, the planner only intervenes in the financial decisions for states of nature in which the constraint will be binding the following period. The difference from our baseline setup is that the non-paternalistic planner scales up the tax that corrects the pecuniary externality in proportion to how much private agents undervalue the risk of future binding constraints compared to the planner, $\pi_{t+1}^{S,\omega}/\pi_{t+1}^{P,\omega}$. This ensures that private agents internalize the externality at the probability perceived by the planner.

[19] In his essay "On Liberalism," Mill (1859) writes that "the only purpose for which power can be rightfully exercised over any member of a civilized community, against his will, is to prevent harm to others" and that "over himself, [...] the individual is sovereign."

6 Conclusion

This paper shows that modern financial crises, which involve financial amplification effects via balance sheet channels, create an externality that induces decentralized agents to take on excessively risky forms of finance. We describe an optimal regulatory framework for capital flows to emerging markets that internalizes the externalities of international capital flows.

The key message of our paper is that it is critical for capital flow regulation to distinguish between different types of flows. Using both a sufficient statistics approach and simulation from a calibrated version of our model, we find that the externalities of different categories of flows differ by an order of magnitude: FDI imposes the smallest externalities, followed by portfolio equity investments, local currency debt, CPI-indexed local currency debt, GDP-linked dollar bonds, and regular dollar bonds, which impose the greatest externalities among the typical liabilities of emerging economies.

Methodologically, our paper introduces a sufficient statistics approach as in Chetty (2008, 2009) to quantify optimal policy measures in international finance. We show that a small set of statistics that can be obtained directly from the data is sufficient to quantify the externalities in a robust and transparent manner, and we validated the approach using simulations in a calibrated version of the model. We hope that our work will stimulate further research using sufficient statistics in international finance and macroeconomics.

There remain many avenues for future research. One important question concerns the international spillover effects of capital controls. In preliminary work (Korinek, 2014), we find that such spillover effects are generally benign, as long as three conditions are met: (i) the policymakers in individual countries refrain from exerting market power, (ii) policymakers possess sufficient instruments to implement their desired measures and (iii) the international market is sufficiently complete.

In another strand of work (Korinek and Sandri, 2014), we examine how to optimally regulate domestic versus foreign financial transactions. We find that financial amplification effects provide justification for both capital controls on foreign transactions and macroprudential regulation of domestic financial transactions. The latter follows a similar rationale as Lorenzoni (2008).

Finally, another important question is how to optimally implement capital controls to ensure their effectiveness. For example, is it more desirable in practice to use price or quantity controls? Ostry et al. (2011) analyze these questions in further detail.

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A Appendix

A.1 Microfoundations of Financial Constraint

Moral Hazard Problem After the domestic agent issues the bundle of payoffs $\{b_{t+1}^{\omega}\}$ in period t to raise $E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right]$ dollars of external finance, he has an opportunity to divert his future income and wealth from the reach of international investors, e.g. by investing in a scam. Investors can observe this action and take the agent to court. In that case, investors can seize up to a fraction ϕ of the total period t income of the agent where $\phi < 1$ reflects imperfections in legal enforcement. They sell the seized non-traded goods at the prevailing market price and convert them into traded goods so as to repatriate them, yielding $\phi\left[y_{T,t} + p_t y_{N,t}\right]$ units of traded goods in total. If the domestic agent does not take the opportunity to divert his future income at the time, there is no further diversion opportunity and the payment b_{t+1}^{ω} in period $t+1$ is enforced.

In recursive notation, the utility value V^R of an agent who plays by the rules is

$$V^R(b_t) = u(c_{T,t}, c_{N,t}) + \beta E\left[V^R\left(b_{t+1}^{\omega}\right)\right]$$

subject to the standard budget constraint (2). The utility value V^D and budget constraint of an agent who diverts his future wealth in period t are

$$\begin{aligned} V^D(b_t) &= u(c_{T,t}, c_{N,t}) + \beta E\left[V^R(0)\right] \\ \text{s.t.} \quad c_{T,t} + p_t c_{N,t} + E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] &= (1-\phi)\left[y_{T,t} + p_t y_{N,t}\right] + b_t \end{aligned} \tag{A.1}$$

The participation constraint of international investors requires that total security issuance is at most what the investors can seize,

$$-E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] \leq \phi\left[y_{T,t} + p_t y_{N,t}\right]$$

This is identical to the financial constraint (3). Given this constraint, observe that it is optimal for the domestic agent to abstain from the diversion scheme in equilibrium: by the constraint (3), the resources seized by investors are at least as large as the resources gained from reneging on his liabilities so that there is no wealth gain from diversion, as can be seen from the budget constraint (A.1); furthermore, for given wealth in period t, the agent is forced to carry a wealth level of $b_{t+1}^{\omega} = 0 \forall \omega$ into the following period, which is suboptimal by revealed preference.

A.2 Lagrangian of Domestic Optimization Problem

$$\mathcal{L} = E\sum_{t=0}^{\infty}\beta^t \left\{ u\left(c_{T,t}, c_{N,t}\right) - \lambda_t \left[c_{T,t} - y_{T,t} + \left(c_{N,t} - y_{N,t}\right) p_t + E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] - b_t\right] \right.$$
$$\left. + \mu_t \left[E\left[m_{t+1}^{\omega} b_{t+1}^{\omega}\right] + \phi\left(y_{T,t} + p_t y_{N,t}\right)\right]\right\}$$

A.3 Implementation of Constrained Efficient Allocation

Assume the Ramsey planner imposes a tax τ_{t+1}^{ω} on the issuance (i.e. subsidy on purchases) of state-contingent securities, which is rebated lump-sum so as to be wealth-neutral. The total amount spent on security purchases becomes $E\left[m_{t+1}^{\omega} b_{t+1}^{\omega} / \left(1 + \tau_{t+1}^{\omega}\right)\right]$ in the optimization problem of domestic agents. This modifies their budget constraint to

$$c_{T,t} + p_t c_{N,t} + E\left[\frac{m_{t+1}^{\omega} b_{t+1}^{\omega}}{1 + \tau_{t+1}^{\omega}}\right] = y_{T,t} + p_t y_{N,t} + b_t - T_t$$

and similarly for the financial constraint. The Euler equation of domestic agents becomes

$$u_{T,t} - \mu_t = \frac{\beta u_{T,t+1}^{\omega}\left(1 + \tau_{t+1}^{\omega}\right)}{m_{t+1}^{\omega}} \tag{A.2}$$

whereas the intertemporal optimality condition of the planner is

$$u_{T,t} - \tilde{\mu}_t\left(1 - \phi p'\right) = \frac{\beta\left(u_{T,t+1}^{\omega} + \phi\tilde{\mu}_{t+1} p'\right)}{m_{t+1}^{\omega}}$$

By setting $\tau_{t+1}^{\omega} = \phi\tilde{\mu}_{t+1} p' / u_{T,t+1}$, the planner ensures that the two optimality conditions coincide, i.e. that private agents allocate their wealth efficiently across the different states $\omega_{t+1} \in \Omega_{t+1}$ of the ensuing period. The planner's shadow price on binding constraints in period t then satisfies $\tilde{\mu}_t = \frac{\mu_t}{1-\phi p'}$, i.e. it equals that of decentralized agents times the factor of amplification $\frac{1}{1-\phi p'}$ because the planner internalizes the amplification effect.

Taxation of Capital Flow Bundles Next we consider how to price a security that consists of a bundle of state-contingent payoffs $\left\{X_{t+1}^{\omega}\right\}$. International lenders are willing to trade such a security at a price of $q_{X,t} = E\left[m_{t+1}^{\omega} X_{t+1}^{\omega}\right]$. To ensure no arbitrage with the individual Arrow securities that make up the bundle, it is necessary to impose a tax $t_{X,t}$ on the issuance of the security such that

$$t_{X,t} = E\left[\frac{\tau^{\omega}_{t+1} m^{\omega}_{t+1}}{1+\tau^{\omega}_{t+1}} \cdot X^{\omega}_{t+1}\right] = E\left[\eta^{\omega}_{t+1} X^{\omega}_{t+1}\right]$$

where $\eta^{\omega}_{t+1} = m^{\omega}_{t+1}\tau^{\omega}_{t+1}/\left(1+\tau^{\omega}_{t+1}\right)$ represents the externality pricing kernel of the economy.

B Extensions

B.1 Capital Investment

The model extended by capital investment is captured by the Lagrangian

$$\mathcal{L} = E\sum_{t=0}^{\infty}\beta^t\left\{u\left(c_{T,t}, c_{N,t}\right) + \mu_t\left\{E\left[m^{\omega}_{t+1}b^{\omega}_{t+1}\right] + \phi\left[f\left(k_t\right) + py_{N,t}\right]\right\}\right.$$
$$\left.-\lambda_t\left[c_{T,t} - f\left(k_t\right) + \left(c_{N,t} - y_{N,t}\right)p_t + E\left[m^{\omega}_{t+1}b^{\omega}_{t+1}\right] - b_t + k_{t+1} - (1-\delta)\,k_t\right]\right\}$$

The new optimality condition for capital k_{t+1} is

$$\lambda_t = \beta E\left[f'\left(k_{t+1}\right)\left(\lambda^{\omega}_{t+1} + \phi\mu^{\omega}_{t+1}\right) + (1-\delta)\,\lambda^{\omega}_{t+1}\right]$$

The social planner's problem is modified in the same way as in our baseline setup, and she arrives at an analogous condition for capital investment,

$$\tilde{\lambda}_t = \beta E\left[f'\left(k_{t+1}\right)\left(\tilde{\lambda}^{\omega}_{t+1} + \phi\tilde{\mu}^{\omega}_{t+1}\right) + (1-\delta)\,\tilde{\lambda}^{\omega}_{t+1}\right]$$

The only difference lies in the different shadow prices of private agents versus the planner. The planner can impose a subsidy s_t on new capital investment $i_t = k_{t+1} - (1-\delta)\,k_t$ to implement her preferred choice of investment. The subsidy ensures that the private optimality condition equals the social optimality condition,

$$1 - s_t = \frac{\tilde{\lambda}_t}{\lambda_t} \cdot \frac{E\left[f'\left(k_{t+1}\right)\cdot\left(\lambda^{\omega}_{t+1} + \phi\mu^{\omega}_{t+1}\right) + (1-\delta)\,\lambda^{\omega}_{t+1}\right]}{E\left[f'\left(k_{t+1}\right)\cdot\left(\tilde{\lambda}^{\omega}_{t+1} + \phi\tilde{\mu}^{\omega}_{t+1}\right) + (1-\delta)\,\tilde{\lambda}^{\omega}_{t+1}\right]} \qquad \text{(A.3)}$$

Recall that $\tilde{\lambda}_t = \lambda_t + \phi\tilde{\mu}_t p' \geq \lambda_t$ and $\tilde{\mu}_t = \mu_t/\left(1-\phi p'\right) \geq \mu_t$, i.e. the planner's valuations of wealth and of relaxing the constraint are identical to that of private agents if the constraint is loose but are higher if the constraint is binding.

The first multiplicative term $\tilde{\lambda}_t/\lambda_t$ is greater than one if the constraint is binding in period t. In that case, the planner would like to encourage consumption expenditure, which falls on both traded and non-traded goods, and therefore appreciates the real exchange rate. She will therefore tax investment, which absorbs solely traded goods and has no contemporaneous real exchange rate effect.

The second multiplicative term in equation (A.3) is less than one if the constraint is expected to bind in period $t+1$. In that case, the planner subsidizes investment, which creates more traded goods in period $t+1$ and therefore appreciates the exchange rate and relaxes the constraint.

B.2 Over-Optimism

Paternalistic Planner If the planner behaves paternalistically, she forms her own expectations $E_S[\cdot]$ of the discounted future flow of utility but recognizes that private investors price state-contingent securities using their own expectations operator $E_P\left[m^{\omega}_{t+1}b^{\omega}_{t+1}\right]$, which enters in the budget and borrowing constraint of private agents. This results in an optimization problem described by the Lagrangian

$$\mathcal{L} = E_S \sum_{t=0}^{\infty} \beta^t \Big\{ u\left(c_{T,t}, y_{N,t}\right) - \tilde{\lambda}_t \left[c_{T,t} - y_{T,t} + E_P\left[m^{\omega}_{t+1}b^{\omega}_{t+1}\right] - b_t\right]$$
$$+ \tilde{\mu}_t \left\{E_P\left[m^{\omega}_{t+1}b^{\omega}_{t+1}\right] + \phi\left[y_{T,t} + p\left(c_{T,t}/y_{N,t}\right)y_{N,t}\right]\right\}\Big\}$$

The resulting intertemporal optimality condition is

$$\pi^{P,\omega}_{t+1} m^{\omega}_{t+1}\left(\tilde{\lambda}_t - \tilde{\mu}_t\right) = \beta \pi^{S,\omega}_{t+1}\tilde{\lambda}^{\omega}_{t+1}$$

and the planner can implement the allocation by imposing a state-contingent tax/subsidy on security issuance of

$$1 + \tau^{\omega}_{t+1} = \frac{\pi^{S,\omega}_{t+1}}{\pi^{P,\omega}_{t+1}}\left(1 + \frac{\phi\tilde{\mu}_{t+1}p'}{u^{\omega}_{T,t+1}}\right)$$

as can be seen by simple comparison with the optimality condition of private agents under taxation (A.2).

Non-Paternalistic Planner A non-paternalistic planner respects the expectations of each individual agent and solves the optimization problem subject to these expectations but calculates the general equilibrium and the resulting externalities subject to her own expectations. Analytically, we set up our non-paternalistic planning problem using an $\varepsilon/1-\varepsilon$-approach. The planner maximizes the sum of welfare of all agents and asks how to regulate the behavior of a given mass ε of agents who employ the private expectations operator $E_P[\cdot]$ while internalizing that their behavior leads to general equilibrium effects and externalities that affect the welfare of the remaining mass $1-\varepsilon$ of agents, which is evaluated using the planner's expectations operator $E_S[\cdot]$. The optimal level of regulation for the mass ε agents is imposed on all agents. In the limit as $\varepsilon \to 0$, this implements a symmetric planning allocation in which each agent maximizes her utility following her own subjective probability measure but the level of regulation corresponds to the externalities evaluated under the planner's probability measure.

We denote the allocations associated with the mass ε of domestic agents by lower-case letters and the variables of the remaining mass $1-\varepsilon$ agents by upper-case letters, which the planner takes as given (in equilibrium, they are identical to the lower-case letters). The real exchange rate in this setup is given by the expression

$$p_t = p\left(\left[\varepsilon c_{T,t} + (1-\varepsilon)\, C_{T,t}\right]/y_{N,t}\right)$$

The planner maximizes the sum of welfare of all agents, captured by the Lagrangian

$$\begin{aligned}
\mathcal{L} = \varepsilon E_P \sum_{t=0}^{\infty} \beta^t \Big\{ & u\left(c_{T,t}, y_{N,t}\right) - \hat{\lambda}_t \left[c_{T,t} - y_{T,t} + E_P\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] - b_t\right] \\
& + \hat{\mu}_t \left\{ E_P\left[m^{\omega}_{t+1} b^{\omega}_{t+1}\right] + \phi\left[y_{T,t} + p\left(\left[\varepsilon c_{T,t} + (1-\varepsilon)\, C_{T,t}\right]/y_{N,t}\right) y_{N,t}\right]\right\}\Big\} \\
+ (1-\varepsilon)\, E_S \sum_{t=0}^{\infty} \beta^t \Big\{ & u\left(C_{T,t}, y_{N,t}\right) - \tilde{\lambda}_t \left[C_{T,t} - y_{T,t} + E_P\left[m^{\omega}_{t+1} B^{\omega}_{t+1}\right] - B_t\right] \\
& + \tilde{\mu}_t \left\{ E_P\left[m^{\omega}_{t+1} B^{\omega}_{t+1}\right] + \phi\left[y_{T,t} + p\left(\left[\varepsilon c_{T,t} + (1-\varepsilon)\, C_{T,t}\right]/y_{N,t}\right) y_{N,t}\right]\right\}\Big\}
\end{aligned}$$

The optimality conditions for the variables of the mass ε agent are

$$\begin{aligned}
\pi^{P,\omega}_t \varepsilon \left(u_{T,t} - \hat{\lambda}_t + \varepsilon \hat{\mu}_t \phi p'\right) + \pi^{S,\omega}_t (1-\varepsilon)\, \varepsilon \tilde{\mu}_t \phi p' &= 0 \\
m^{\omega}_{t+1}\left(\hat{\lambda}_t - \hat{\mu}_t\right) &= \beta \hat{\lambda}^{\omega}_{t+1}
\end{aligned}$$

In the limit of $\varepsilon \to 0$, we can combine these to

$$\begin{aligned} \hat{\lambda}_t &= u_{T,t} + \frac{\pi_t^{S,\omega}}{\pi_t^{P,\omega}} \tilde{\mu}_t \phi p' \\ u_{T,t} + \frac{\pi_t^{S,\omega}}{\pi_t^{P,\omega}} \tilde{\mu}_t \phi p' - \hat{\mu}_t &= \frac{\beta \left(u_{T,t+1}^{\omega} + \pi_{t+1}^{S,\omega} / \pi_{t+1}^{P,\omega} \cdot \tilde{\mu}_{t+1} \phi p' \right)}{m_{t+1}^{\omega}} \end{aligned}$$

As described in Corollary 4, the latter equation, capturing the optimal intertemporal tradeoff, can be replicated by imposing a tax on individual agents that satisfies

$$\tau_{t+1}^{\omega} = \frac{\pi_{t+1}^{S,\omega}}{\pi_{t+1}^{P,\omega}} \cdot \frac{\phi \tilde{\mu}_{t+1} p'}{u_{T,t+1}^{\omega}}$$

B.3 Impulse Responses

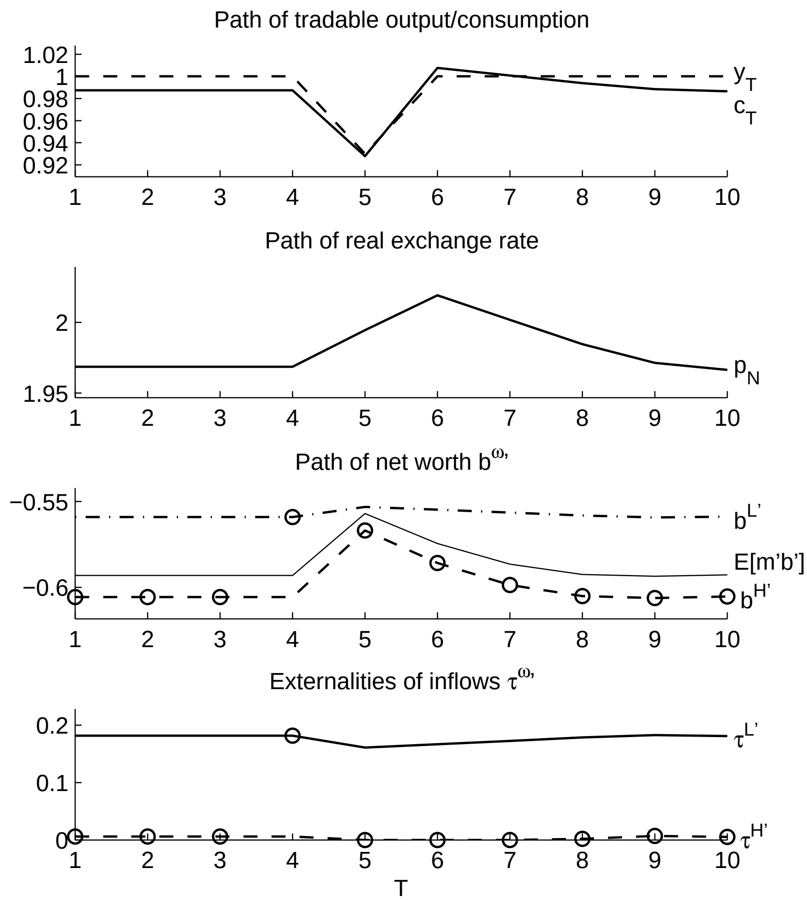

Figure 4: Impulse Response to Sudden Stop Shock in Planner's Allocation

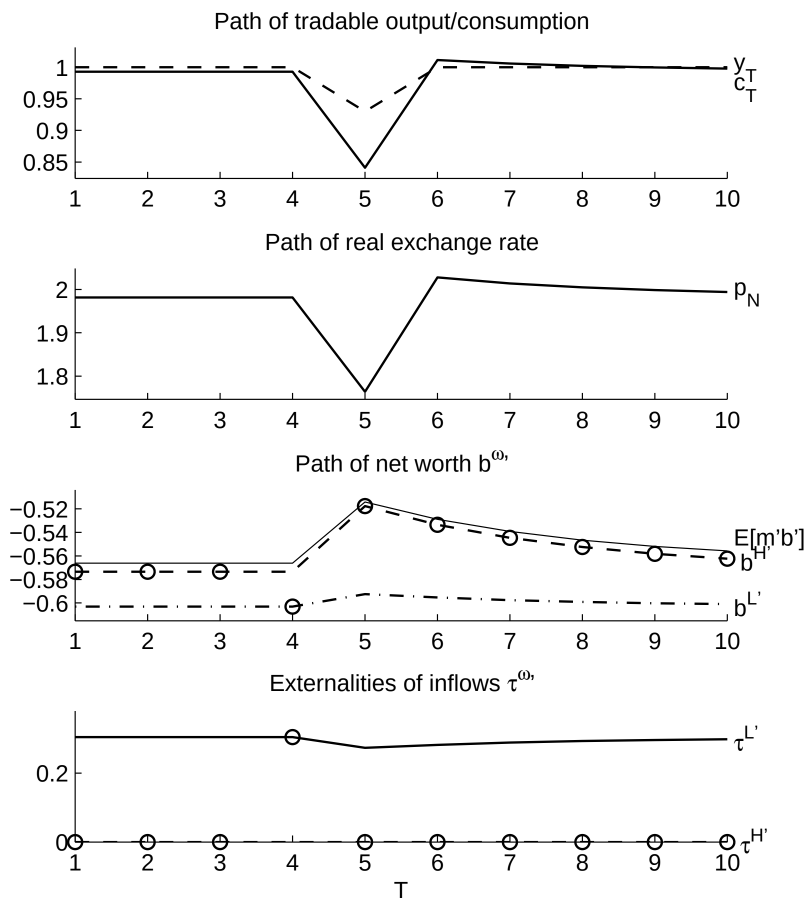

Figure 5: Impulse Response to Sudden Stop Shock in Restricted Planner's Equilibrium where $\tau_t^\omega = \bar{\tau}_t \forall \omega$