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Hot Money and Serial Financial Crises

Anton Korinek
University of Maryland

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Abstract

This paper develops a model of serial financial crises and optimal macro-prudential policy responses. When one country or sector in the world economy experiences a crisis, it becomes financially constrained. Global investors need to find other destinations for their investments, leading to flows of hot money to other unconstrained countries. However, larger capital inflows make the recipient countries more vulnerable to adverse shocks, creating the potential for serial financial crises. We analyze the role for macro-prudential policies to lean against the wind of such capital flows so as to offset the externalities that occur during financial crises.

JEL Codes: F34, E44, G38
Keywords: hot money, financial fragility, serial financial crises, macro-prudential regulation

1 Introduction

In recent decades, the world economy has experienced serial financial crises that seemed to be linked by a recurrent pattern: one country or sector in the world economy experiences a financial crisis; capital flows out in a panic; investors seek a more attractive destination for their money. In the next destination, capital inflows create a boom that is accompanied by rising indebtedness, rising asset prices and booming consumption – for a time. But all too often, these capital inflows are followed by another crisis. Some commentators describe these patterns of capital flows as "hot money" that flows from one sector or country to the next and leaves behind a trail of destruction.

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The goal of this paper is to develop a model that captures these phenomena and that analyzes optimal policy responses. In the model, financial relationships are inherently fragile because borrowers have a tendency to over-extend themselves and borrow so much that they experience binding financial constraints and crises in future periods. When some borrowers are financially constrained, lenders face a shortage of investment opportunities and bid the interest rate below its steady state level. This in turn provides an increased incentive to other, unconstrained borrowers to take on an excessive debt burden and expose themselves to the risk of future financial constraints and crises. This is the sense in which money becomes "hot" – each time one borrower faces a crisis, it flows to the next and increases that borrower's financial fragility, creating the potential for "serial financial crises."

From a social point of view, this is inefficient because individual borrowers do not internalize that their actions increase financial instability at an aggregate level. As a result, our paper suggests that countries should impose macro-prudential policy measures against capital inflows and leverage, especially when the inflows are "hot money."

1.1 Facts

Figure 1 documents the evolution of world interest rates as well as the pattern of the capital flows for a number of countries and regions that have experienced financial crises in which international capital flows were seen to have had an important role.

The top panel captures world interest rates by using US short-term rates and long-term 10-year Treasury yields deflated by the US consumer price index. We start the sample in the second half of the 1980s when most developed countries abolished their controls on international capital flows. Real interest rates over the period were on a steady downward trend. However, it can be seen that periods of financial distress or crisis were associated with stronger downward movements in interest rates. Examples are the aftermath of the recession of 1990/91, the East Asian and LTCM/Russia crisis in 1998 (reflected only in long-term yields), the dot.com bust and ensuing recession in 2001 as well as the most recent global financial crisis. Naturally, short-term dollar interest rates are under close control by US monetary authorities. However, the behavior of central bankers that follow e.g. a Taylor rule is consistent with our view that interest rates reflect the availability of investment opportunities for savers. Furthermore, the same pattern can be observed in long-term bond yields, which are determined largely by market forces.

The bottom panel depicts the current account as a fraction of GDP for a number of countries and regions that experienced financial crises over the past two decades. Current account deficits are a good proxy for capital inflows as the deficits need to be financed by capital from the outside world. Mexico's current account turned significantly negative after the 1990/91 recession and experienced a sharp reversal as a result of a financial crisis in 1994/5 as interest rates rose again. The current account of the "East Asia 5" (Indonesia, Korea,

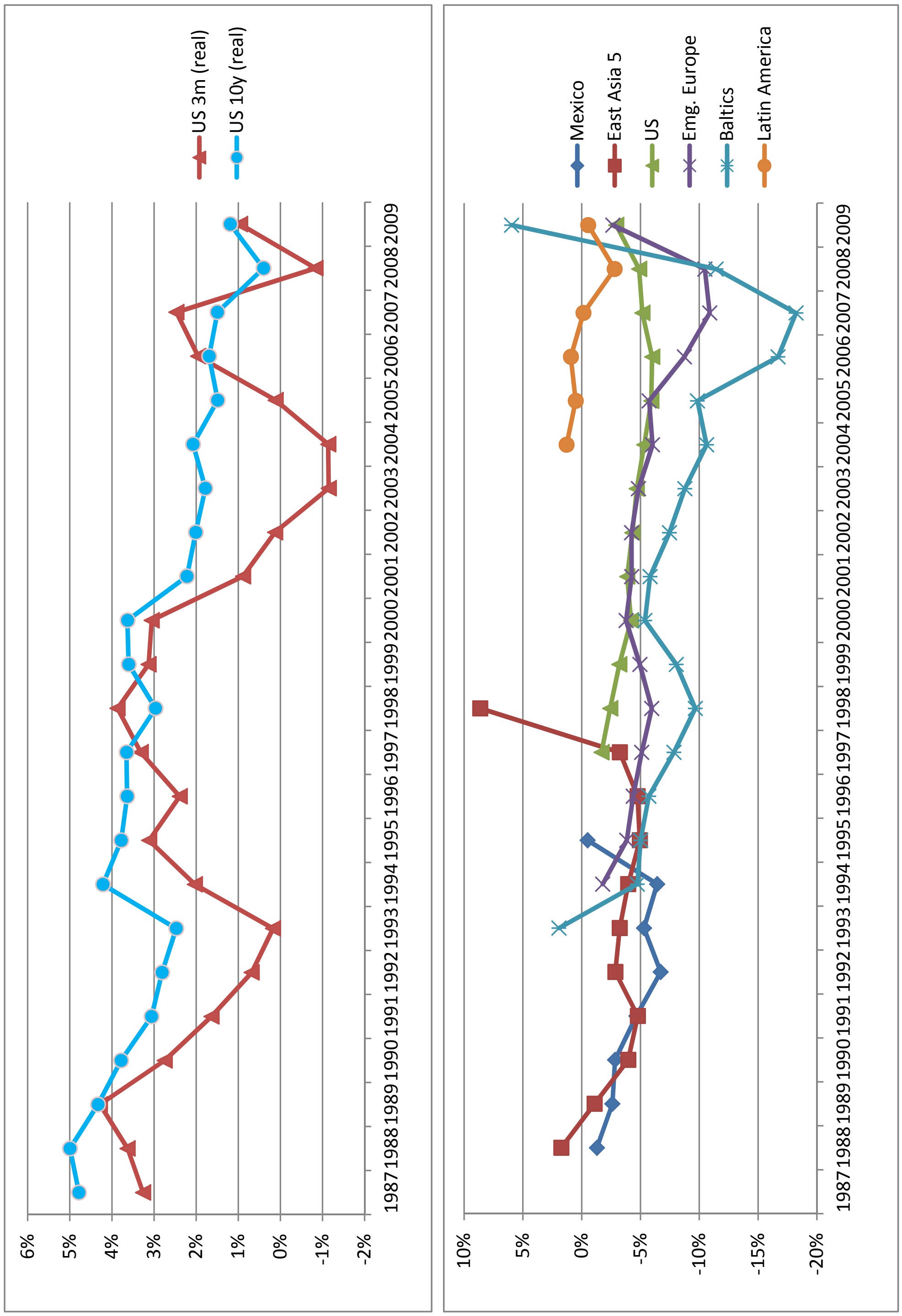

Figure 1: World interest rate and capital flows

Malaysia, Thailand, Philippines) turned negative around the same time, and experienced a reversal during the 1997/98 East Asian crisis. In the aftermath of this crisis, the US current account started to decline significantly, in part because many Asian countries embarked on a course of massive accumulation of US assets. This at first fueled the dot.com bubble that burst in 2000, which led to a minor slowdown in capital flows, but a sharp decline in interest rates that fed a massive housing bubble in the US and a number of other countries around the globe. Among the recipients of the associated capital flows was emerging Eastern Europe, in particular the Baltic countries, which experienced an increase in capital inflows each time that long term interest rates moved down. With the onset of the global financial crisis in 2008, they suffered massive reversals in their current account assoicated with steep financial crises. Among the next destinations pursued by international investors is Latin America (see e.g. IMF Global Financial Stability Report, 2010), where economies that have recently acquired an admirable degree of macroeconomic stability, helped by positive terms of trade shocks, represent an attractive target.

1.2 Literature

Our paper is closely related to the literature on financial amplification, such as Bernanke and Gertler (1989), Kiyotaki and Moore (1997), which has studied the positive aspects of financial amplification in a single sector. Aoki, Benigno and Kiyotaki (2008) apply this analysis to the case of an open economy. Recently Devereux and Yetman (2010) and Nguyen (2010) have analyzed potential spillover effects between multiple countries that are subject to financial amplificiation effects. These works assume that financial amplification effects are always at work in constrained countries. By contrast, Mendoza (2001, 2010) employs amplification effects in models of occasionally binding constraints to describe rare crises that occur relatively infrequently. Our work falls into this category, but instead of focusing on a single sector we analyze how a crisis (i.e. financial amplification) in one country may make another country more crisis prone in subsequent periods, capturing the phenomenon of "serial financial crises." This aspect of our work is related to Caballero, Farhi and Gourinchas (2008b) who capture the phenomenon of a "moving bubble," as one sector in the world economy becomes financially more constrained and capital flows into another less constrained sector. Martin and Ventura (2010) examine rational bubbles in an environment with financial amplification effects.

We also investigate the normative aspects of such financial amplification dynamics. This is related to a growing literature on financial amplification and externalities, as studied e.g. by Caballero and Krishnamurthy (2003), Lorenzoni (2008), Korinek (2009, 2010), Bianchi (2010) and Jeanne and Korinek (2010a). The insight in these papers is that in the presence of financial amplification effects, decentralized agents do not internalize that their privately optimal risk-taking decisions make the economy in aggregate more vulnerable to financial instability. In our paper, borrowers expose themselves to the risk of binding constraints when international investors offer them cheap credit, but they do so to an inefficient extent, creating a role for macroprudential regulation. Our contribution to this literature is to study how external factors such as crises in one part of the world economy lead to a greater supply of capital to other parts of the world economy ("hot money"). This magnifies the incentives for borrowers to take on larger debts and larger exposure to financial fragility, leading to higher externalities. It is in this sense that "hot money" increases the need for macroprudential regulation.

The sectoral structure of the our model is related to Korinek, Roitman and Vegh (2010) who capture the phenomenon of "decoupling" and "recoupling" during the 2008/09 financial crisis. They describe decoupling as a situation when one part of the world economy is financially constrained and can no longer demand capital or other inputs, which lowers factor prices and benefits the remaining unconstrained sectors. In a sense, the dynamics of "hot money" in this paper can be interpreted as an instance of "decoupling" in theirs. However, the current proposal extends this setup along two crucial dimensions: First, we focus on how the capital flows that constitute "decoupling" in one period create vulnerabilities that may lead to financial instability in the next period. Secondly, we assume that debt is collateralized by assets, which may lead to financial amplification when capital flows reverse and which creates a case for policy action.

2 Model Setup

We describe a model of the world economy in infinite discrete time $t = 0, 1, ...$ The world economy consists of two types of agents: (i) international investors who represent "hot money" and who hold savings that they move where return opportunities are greatest; (ii) different countries who borrow and who are subject to an endogenous collateral constraint. We describe each in detail.

2.1 International Investors

International investors come in overlapping generations: each period, a continuum of mass one of investors is born who live for two periods. We denote the variables of investors with the superscript h (as in "hot money" or "households"), and we add a generational specifier $h(t)$ in parentheses when it is necessary for clarity to distinguish the variables of different generations. Investors value consumption according to a neoclassical period utility function $v(c)$, with time discount factor β, resulting in a total level of utility

$$v\left(c_t^h\right) + \beta v\left(c_{t+1}^h\right)$$

In our applications below, we will focus on the special case $v(c) = \log(c)$ so as to obtain analytical solutions. Investors obtain the constant endowments e_1 and e_2 in the first and second period of their lives. In the first period, they choose how much to consume c_t^h and how much to save in zero coupon bonds at the gross world interest rate R_{t+1}, where $\frac{b_{t+1}^h}{R_{t+1}}$ denotes the amount saved. In the second period of their lives, they obtain the repayment b_{t+1}^h on their bond holdings, consume all their remaining wealth and perish. The optimization problem of generation t investors (in short notation) is

$$\max_{c_t^h, c_{t+1}^h, b_{t+1}^h} v\left(c_t^h\right) + \beta v\left(c_{t+1}^h\right) \quad \text{s.t.} \quad \begin{aligned} c_t^h + \frac{b_{t+1}^h}{R_{t+1}} &= e_1 \\ c_{t+1}^h &= e_2 + b_{t+1}^h \end{aligned}$$

which yields the standard Euler equation

$$v'\left(c_t^h\right) = \beta R v\left(c_{t+1}^h\right) \tag{1}$$

In general, the response of b_{t+1}^h to changes in the interest rate for arbitrary utility functions is

$$\frac{\partial b_{t+1}^h}{\partial R_{t+1}} = \frac{\frac{b_{t+1}^h}{R_{t+1}} v''\left(c_t^h\right) - v'\left(c_t^h\right)}{v''\left(c_t^h\right) + \beta R^2 v''\left(c_{t+1}^h\right)} > 0$$

as long as $b_{t+1}^h > 0$, i.e. the repayment of investors rises with the market interest rate.

Note that the decision problems of different generations of investors are not directly linked. This greatly simplifies our analysis – equation (1) defines a time-invariant supply of funds function $b^h(R)$ that satisfies $\partial b^h / \partial R > 0$.

In the case of log-utility, the Euler equation can be solved for an explicit supply of fund function. We obtain the following expressions for the amount of net saving and bond holdings

$$\frac{b^h(R)}{R} = \frac{\beta e_1 - e_2/R}{1+\beta}, \qquad b^h(R) = \frac{\beta R e_1 - e_2}{1+\beta} \tag{2}$$

Both expressions are increasing in R, i.e. investors save more and receive greater repayments when the interest rate is high. Furthermore, the supply of "hot money" is higher the larger the initial endowment e_1 compared to the second-period endowment e_2. The indirect demand function is

$$R\left(b^h\right) = \frac{(1+\beta) b^h + e_2}{\beta e_1}$$

2.2 Borrowers

There are $i = 1, ..., N$ symmetric entities of borrowers in the world economy, which we interpret as different countries or, alternatively, as different sectors of the world economy. Each country consists of a unit mass of identical borrowers. The basic setup of borrowers in a given country is an adapted version of the "insiders" in Jeanne and Korinek (2010a) who engage in collateralized borrowing. Borrowers are infinitely-lived and value consumption according to the period utility function $u(c)$ which is discounted at factor β. We denote the variables of a representative borrower in country i by the the superscript i. They maximize the expectation of their lifetime utility

$$E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} u\left(c_s^i\right) \right\} \tag{3}$$

A representative borrower in country i holds a_t^i units of a tree that yields a stochastic endowment income y_t^i every period, which is i.i.d. We assume that the total supply of the tree in each country is unity, and that the tree can only be owned by local agents in country i, otherwise it becomes worthless. This captures in a simplified manner that real assets typically cannot be transferred costlessly, because of e.g. technological reasons or incentive reasons.

Each period, the representative agent in country i chooses how much to consume c_t^i and how much to borrow in world capital markets, denoted by his bond holdings b_{t+1}^i, which will typically be negative to capture borrowing. The agent also chooses how much of the tree to buy or sell at the prevailing market price p_t^i and how much to carry into the next period a_{t+1}^i. The budget constraint of country i agents can be denoted as

$$c_t^i + \frac{b_{t+1}^i}{R_{t+1}} + a_{t+1}^i p_t^i = y_t^i + b_t^i + a_t^i p_t^i \tag{4}$$

Since the tree can only be held by domestic agents in country i, we will find that market clearing implies that $a_t^i \equiv 1$ in equilibrium.

One of the important assumptions about borrowers is that their access to finance is limited by an incentive problem. We assume that domestic agents have an opportunity to move their assets into a fraudulent scam after borrowing in period t, and that investors can dedect this and can take legal action, but only if they do so in the period that the fraud is committed. Because of imperfect legal enforcement, international investors can seize at most an amount ϕ of the asset holdings of borrowers, which they can re-sell to other agents on the domestic market in country i at the prevailing asset price p_t^i. This implies that abstaining from fraud is incentive-compatible for domestic agents in country i as long as[1]

$$\frac{b_{t+1}^i}{R_{t+1}} \geq -\phi p_t^i \tag{5}$$

This requirement imposes a collateral constraint that limits debt to a fraction ϕ of the current value of equity holdings of agents in country i. The optimization problem of a representative country i borrower can be expressed as maximizing (3) subject to (4) and (5). Assigning the shadow price λ_t^i to the collateral constraint, the first-order conditions to the problem are

$$u'\left(c_t^i\right) = \beta R_{t+1} E_t\left[u'\left(c_{t+1}^i\right)\right] + \lambda_t^i \tag{6}$$

$$p_t^i u'\left(c_t^i\right) = \beta E_t\left[u'\left(c_{t+1}^i\right)\left(y_{t+1}^i + p_{t+1}^i\right)\right] \tag{7}$$

[1] An alternative specification would be to assume that international investors can seize up to a fraction ϕ of the asset holdings of borrowers, which would entail the term $-\phi a_{t+1}^i p_t^i$ on the right hand side of the incentive-compatibility constraint. As discussed in Jeanne and Korinek (2010), the implications of the two setups are largely identical.

The second condition iterated forward yields the standard asset pricing equation

$$p_t^i = E_t \left[\sum_{s=t+1}^{\infty} \beta^{s-t+1} u'\left(c_s^i\right) y_s^i \right] \bigg/ u'\left(c_t^i\right)$$

3 Decentralized Equilibrium

The decentralized equilibrium in the economy is a set of allocations and prices that simultaneously solves the optimization problems of international investors and the N representative borrowers, subject to market clearing in international bond markets,

$$b_{t+1}^h + \sum_{i=1}^{N} b_{t+1}^i = 0 \qquad \forall t$$

3.1 Deterministic Single Country Case

For expositional purposes, we first focus on a simplified case that allows us to develop the intuition for the general case: in this subsection, we assume that there is single country $N = 1$. We drop the superscript "1" for variables that refer to this country and we assume that the country starts out with initial bond holdings of b_0.

By combining the optimality conditions of the single country and of international investors, we describe the decentralized equilibrium as recursive functions of the state variables (b, y),

$$\begin{aligned} c(b,y) &= \min\left\{ b + y + \phi p(b,y) ; (u')^{-1}\left(\beta R'(b') E\left[u'\left(c\left(b',y'\right)\right)\right]\right)\right\} \\ p(b,y) &= \frac{\beta E\left[u'\left(c\left(b',y'\right)\right) \cdot \left(y' + p\left(b',y'\right)\right)\right]}{u'\left(c(b,y)\right)} \\ R(b) &= \frac{e_2 - (1+\beta) b}{\beta e_1} \\ \text{and } b' &= R'(b) \cdot [b + y - c] \end{aligned}$$

These functions can be solved for in a manner similar to what is detailed in appendix B of Jeanne and Korinek (2010a).

3.1.1 Steady State

Assume first that the economy faces a constant stream of income $y_t = \bar{y}$. A deterministic steady state in this economy is characterized by a constant level of bond holdings $b = b_{SS}$ of the representative agent in the economy and of bonds holdings $b^h = -b_{SS}$ of international investors. The resulting steady state levels of consumption and of the asset price in the country are

$$c_{SS} = \bar{y} + \frac{R-1}{R} b_{SS} \qquad \text{and} \qquad p_{SS} = \frac{\bar{y}}{R-1}$$

Unconstrained Steady State If the steady state is strictly unconstrained, i.e. if $b_{SS} > -\phi R p_{SS}$, then the equilibrium interest rate in the world economy is $R_{SS} = 1/\beta$. This interest rate is consistent with the optimization problem of international investors if the amount borrowed lies on their supply schedule (2), implying

$$b^h = -b_{SS} = \frac{e_1 - e_2}{1+\beta} \tag{8}$$

This is the amount of saving that allows international investors to have a smooth consumption profile.

An unconstrained long-run steady state is indeed feasible if the fundamental parameters of the world economy satisfy

$$b_{SS} = b_{SS}^{unc} = \frac{e_2 - e_1}{1+\beta} \geq -\phi \frac{\bar{y}}{1-\beta} \tag{9}$$

Unconstrained Dynamics If this condition is satisfied, then the economy will converge to the unconstrained steady-state in the absence of shocks. Starting from an unconstrained initial debt level of the economy of b_0, we can employ the Euler equation of domestic agents in conjunction with the equilibrium interest rate relationship of investors (2) to describe the evolution of the economy as

$$u'(c_t) = \beta R(b_{t+1}) u'(c_{t+1})$$

The phase diagram of such an economy is depicted in figure **??**. If domestic agents have borrowed less than steady state, then $b_{t+1} > b_{SS}$ and the economy is located to the right of the dashed vertical line in the figure. Investors reduce the interest rate $R_{t+1} < R_{SS}$ to entice agents in the economy to borrow more. Given the price signal provided by the low interest rate, agents find that $\beta R_{t+1} < 1$ in their Euler equation and they find it optimal to choose a declining consumption path and accumulate more debt, as depicted by the zigzag line in the figure. Asymptotically, borrowers dissave until the interest rate satisfies $\beta R = 1$. As this situation is reached, both sets of agents have a perfectly smooth consumption profile. The opposite dynamics arise when the initial debt level is more than steady state $b_t < b_{SS}$.

The property that matters for our analysis of the full model in the next section is that the interest rate declines when unconstrained agents borrow less, and it gradually increases as the economy converges to its steady state.

Constrained Steady State If condition (9) is not satisfied, then the deterministic steady-state in the economy is constrained. In that case, the debt holdings of domestic agents are determined by the constraint, i.e. they borrow as much as possible without violating incentive compatibility,

$$\frac{b_{SS}}{R_{SS}} = -\frac{\phi\beta\bar{y}}{1-\beta}$$

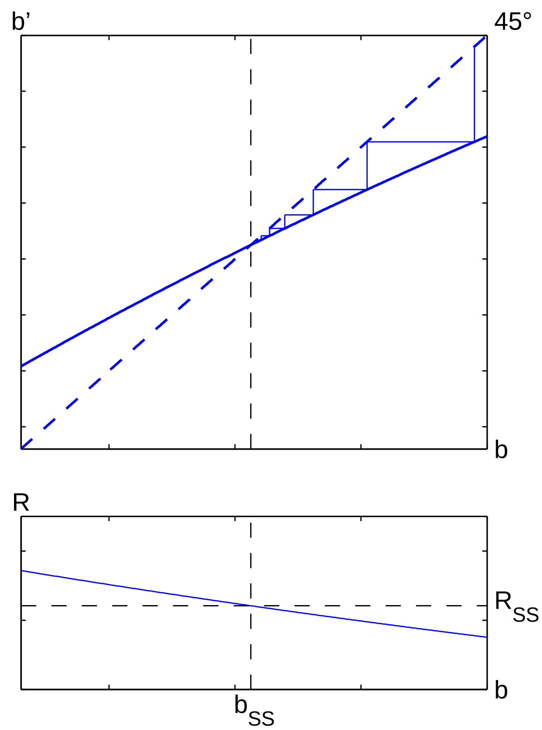

Figure 2: Unconstrained Dynamics

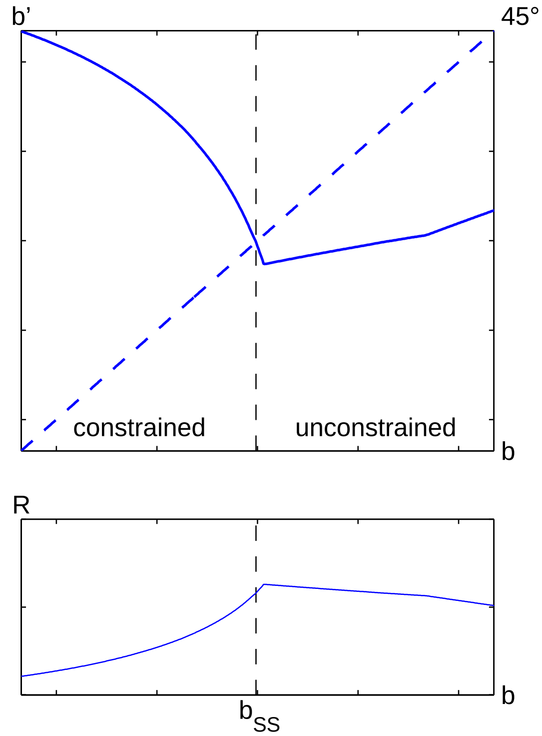

Figure 3: Constrained Dynamics

The equilibrium interest rate of investors at that debt level satisfies $\beta R_{SS} = \frac{e_2-(1+\beta)b_{SS}}{e_1} < 1$, i.e. borrowers in the economy permanently have incentives to dissave, but the constraint prevents them from doing so. We solve the two equations to obtain

$$b_{SS}^{con} = -\frac{\phi e_2 \bar{y}}{(1-\beta)\, e_1 - (1+\beta)\, \phi \bar{y}} < b_{SS}^{unc}$$

Note that in a given period, the economy will be unconstrained if its wealth level is $b \geq b_{SS}$ and constrained if $b < b_{SS}$.

3.1.2 Constrained Dynamics

Assume the wealth level b_t in the economy is below the threshold at which the borrowing constraint becomes binding. Then borrowing that period is determined by the level of the constraint

$$b_{t+1} = -\phi R_{t+1} p_t \tag{10}$$

Under a binding borrowing constraint, the asset price p_t falls below the value that would prevail in the absence of constraints because domestic agents are precluded from their optimal consumption smoothing and $u'(c_t)$ increases relative to $u'(c_{t+1})$. This reduces the borrowing limit and forces agents to cut back further on domestic consumption, leading to a feedback loop of falling borrowing, falling consumption, and falling asset prices. The lower the initial wealth level, the more severe the amplification effects and therefore the higher the wealth level with which the economy enters the ensuing period. As illustrated by figure 3, the next-period wealth function w' is therefore non-monotonic.

For a given supply of credit, the decline in the effective demand for credit by constrained borrowers reduces the interest rate R_{t+1}, as illustrated in the lower panel of the figure. The equilibrium market interest rate is therefore also a non-monotonic function of the wealth level of the economy.

3.2 Multiple Country Case

Having analyzed the single country case, the extension to multiple countries is straightforward. For the rest of our analysis, we focus on a world economy that consists of two regions, which we call "North" and "South," denoted by the superscripts N and S. Each of the two regions encompasses a continuum of small countries of mass 1, which experience endowment processes that are common within a region and that we denote as y_t^N and y_t^S respectively. Market clearing in the world economy (including the investor sector) can therefore be described as

$$b_t^h + b_t^N + b_t^S = 0$$

The variable that links all three sets of sectors is the world interest rate. If all borrowing countries are unconstrained, the intertemporal marginal rates of substitution of investors and of borrowers equal the market-clearing interest rate.

On the other hand, if one region experiences an adverse shock and becomes constrained, their collateral can no longer support the amount of debt that they desire, and their effective demand for debt declines, as we discussed above. By implication, the aggregate demand for borrowing in the world economy falls, which pushes down the world interest rate. The lower world interest rate makes it privately optimal for other borrowers to take on more debt. As a result, they become more vulnerable to the risk that future adverse shocks – or even mere increases in the world interest rate – lead to binding constraints and crisis. In short, a financial crisis in one part of the world economy leads to flows of "hot money" to other parts in the world economy and makes the recipients prone to serial financial crises.

4 Welfare Analysis

This section analyzes how a planner who internalizes the feedback effects that arise during financial amplification effects can improve welfare in an economy. In general, the decentralized allocations in an economy subject to amplification effects are not constrained efficient, as shown e.g. by Jeanne and Korinek (2010a).

The reason is that each borrower i takes the future value of collateral assets in his country as given, even though asset prices are driven by the joint behavior of all agents in economy. Since the level of asset prices determines the tightness of collateral constraints in the described class of economies, there exists an *externality* among borrowers in a given country: an individual borrower does not internalize that his borrowing decisions will affect the level of asset prices and by extension the tightness of collateral constraints of other borrowers when amplification effects arise. We will show below that a planner who internalizes this externality can offset the distortion by imposing a Pigouvian tax on capital inflows. Our analysis proceeds along the lines of Jeanne and Korinek (2010a).

Analytically, we describe the behavior of a policymaker located in a representative small country i that is w.l.o.g. part of the "South" region of the world economy. We assume that the policymaker takes equilibrium in international financial markets and therefore the world interest rate as given. However, in contrast to decentralized agents, the policymaker internalizes his actions on the equilibrium in the domestic economy, and in particular on the level of the asset price p_t^i. We assume that the planner determines the amount of borrowing b_t^i of domestic agents. Below we will analyze how to decentralize the actions of such a policymaker using a macro-prudential tax on borrowing. We note that the same policy could be implemented through a variety of other measures that are equivalent in the described setup, such as reserve requirements on capital inflows.

The objective of the planner is to choose b_t^i so as to maximize the welfare of borrowers in country i as given by equation (3) subject to (4) and (5), where the price p_t^i is determined by the optimality condition (7) of decentralized agents. In other words, the planner does not directly set asset prices in the economy, but he internalizes that his borrowing choices affect the net worth and the marginal utilities of private domestic agents, which in turn determines asset prices. A reason why the planner does not directly interfere in asset markets may be that private agents enjoy an information advantage in determining asset prices.

When the borrowing constraint on economy i is binding, the planner recognizes that the asset price in the economy can be expressed as a function of the beginning-of-period liquid net worth plus the exogenous interest rate

$$p_t^i = p\left(y_t^i + b_t^i; R_{t+1}\right)$$

since borrowing b_{t+1} is determined by the constraint. The planner's Euler equation is

$$u'(c_t^i) = \lambda_t^i + \beta R_{t+1} E_t \left[u'(c_{t+1}^i) + \lambda_{t+1}^i \phi p'(y_{t+1}^i + b_{t+1}^i; R_{t+1})\right] \qquad (11)$$

Compared to the decentralized Euler equation (6) there is an additional term, which reflects that by saving more today, the planner can increase the asset price by p' next period. Doing so relaxes the collateral constraint by $\phi p'$ units and increases utility if the constraint next period is binding so that $\lambda_{t+1}^i > 0$.

As we emphasized in the previous section, the incentive to borrow is particularly strong when other parts of the world economy have just suffered a crisis and world interest rates are low so that more capital flows to unconstrained countries. Under such circumstances, the tightness of constraints in case of a future crisis will be higher, as captured by λ^i_{t+1}, and macro-prudential regulations that lean against the wind of capital inflows are particularly desirable. On the other hand, if the economy is in a position where there is no risk of a crisis next period, then $E_t\left[\lambda^i_{t+1}\right]=0$ and the planner's Euler equation coincides with that of decentralized agents. In other words, if there is no risk of crisis next period, the planner will not intervene.

4.1 Implementation

Having established that the decentralized equilibrium differs from the constrained social optimum, the next question is how a benevolent policymaker can best improve the equilibrium. We assume that a policymaker can levy a state-contingent tax τ_t on collateralized borrowing from abroad by residents of the domestic economy and rebate the tax receipts in lump sum fashion. It can be shown (see Jeanne and Korinek, 2010) that the optimal tax that implements the constrained social optimum satisfies

$$\tau\left(b_t, y_t; R_t\right)=\frac{\phi\beta R_t E_t\left[\lambda_{t+1}\overline{p}'(y_{t+1}+b_{t+1};R_{t+1})\right]}{u'\left(c_t\right)}$$

This expression corresponds to the externality term from equation (11) above, normalized by the marginal utility of current consumption. Since we assumed the domestic economy is small, taxing borrowing does not affect the world interest rate and the allocations of international investors. The tax is fully borne by domestic agents. Since the tax alleviates an existing inefficiency, it improves welfare. Regarding the design of the tax, it should be noted that a tax that accrues over time creates fewer distortions than a tax that accrues upon entry of a capital flow, since it provides lower incentives to speculate on impending changes in the tax rate.

Naturally, there are a number of equivalent ways in which the same policy objective can be reached. An option that is frequently used in practice are unremunerated reserve requirements on capital inflows. Specifically, market participants who bring money into the domestic economy have to park a fraction of the amount in a reserve account with the central bank that does not accrue interest. The opportunity cost of holding money in an unremunerated account, i.e. the lost interest, can be seen as the equivalent of a tax. One potential danger of this approach is that the opportunity cost of holding reserves varies as market interest rates vary. In particular, if world interest rates are low, the opportunity cost of tying up capital in a reserve account is rather low, implying that a much higher reserve requirement has to be chosen to impose a tax of a given magnitude.

Quantity measures are equivalent to price measures in our simple model, but in practice it is more difficult to calibrate their correct magnitude, and they provide larger incentives for evasion when the quota on inflows is binding. See Korinek (2010a) for further discussion.

5 Quantitative Results

5.1 Calibration of Parameters

We choose the length of a time period as 12 quarters to capture the notion that one boom-bust cycle can play out within six years. Given this time frame, we choose a value of $\beta = \delta = 0.96^3$ to correspond to typical annual discount rates in the literature. The coefficient of relative risk aversion of borrowing agents in the N economies is taken as $\gamma = 2$. For international investors, we maintain a log-utility function. We assume that the output process in both economies is i.i.d. and follows a binominal distribution $y_t^i \in \{y_H, y_L\}$ describing booms and busts, with busts occuring with a probability of $\pi = .10$, i.e. on average every twenty periods. We normalize $y_H = 1$ and set $y_L = .97$ so as to obtain an average decline in external credit of 25% of GDP in the event of an adverse shock, which is in the medium range of the declines observed in figure 1. This value of y_L implies a cumulative loss of output of 9% of annual GDP.

Under the given parameter values, the steady-state asset price of borrowers is $p_{SS}^i = 7.68$. We set the collateralizability parameter $\phi = .05$ to allow for a maximum steady-state debt level of approximately $-b_{SS}^i = .38$, i.e. approximately 38% of GDP. We choose the endowment parameters of international investors such that there is a small shortage of investment opportunities in steady-state. Specifically, if the economies were marginally unconstrained in the steady state, then total savings of investors would be $b_{SS}^h = -2b_{SS}^i$ and they would enjoy a smooth consumption profile, implying $\beta R = 1$. This is optimal for investors if their endowments are set to $e_1 = \bar{c} + \theta b_{SS}^h$ and $e_2 = \bar{c} - \theta\beta b_{SS}^h$ with $\theta = 1$ and steady-state consumption $\bar{c}$. However, we set instead $\theta = 1.05$, which increases the supply of credit from investors and gives borrowers an extra incentive to take on debt. In the deterministic steady state of the economy, this implies an annualized real interest rate of 3.5% as opposed to the approximately 4% that would satisfy $\beta R = 1$. The parameter $\bar{c}$ determines the elasticity of the interest rate with respect to credit demand. We set $\bar{c} = 3$ to target a decline in the interest rate by 2% if one of the two regions is hit by a low endowment shock.

Our parameter values are summarized in table 1.

Table 1. Benchmark calibration

β	γ	ϕ	y_H	y_L	π	θ	e_1	e_2
0.885	2	0.05	1	0.97	10%	1.05	3.81	2.09

5.2 Simulation Results

Figure 4 illustrates the policy functions of the representative borrower in a country in region i as a function of finanical wealth b^i, while keeping output

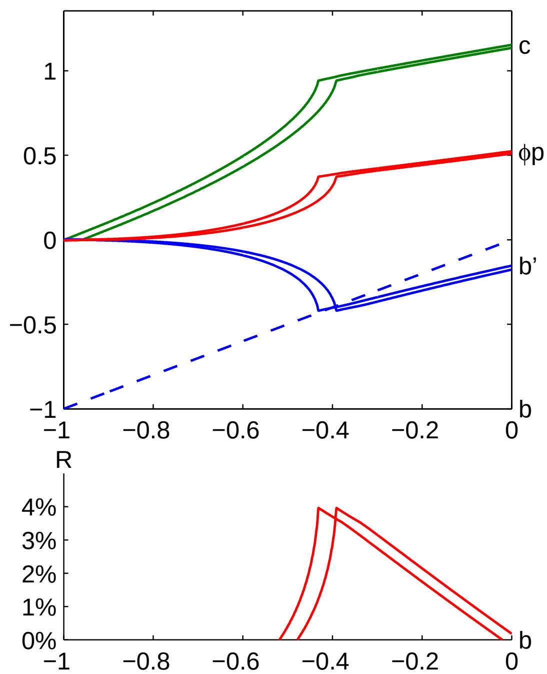

Figure 4: Policy functions c, p and b' and interest rate function

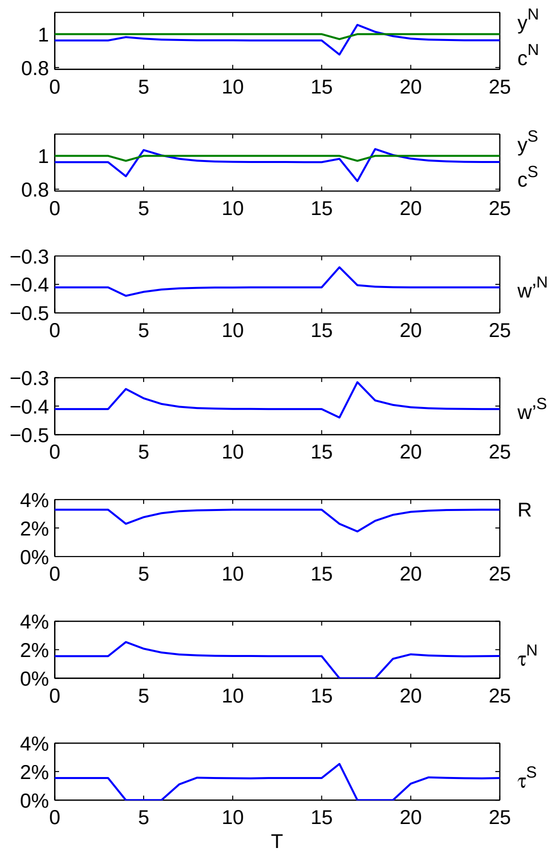

Figure 5: Sample path of world economy

in the other region j at its steady state value $b^j = b^j_{SS}$. Each policy function is represented by two lines that capture the optimal response under a high endowment shock and under a low shock, i.e. $c\left(b^i, y^H\right)$ and $c\left(b^i, y^L\right)$ and so forth. The bottom panel of the figure shows the annualized interest rate as a function of initial wealth b, again in high and low output states. Note that in the ergodic steady statef, the economy will always remain in the depicted region where the interest rate is positive.

Next we investigate how our model economy responds to shocks. Assume an economy that has experienced the positive shock y^H for a long time so that it has converged towards what we will henceforth call its "high steady state." If the economy suddenly experiences a low endowment shock, consumption, asset prices and debt fall by 11%, 23% and 25% respectively. Furthermore, the externality that borrowers impose on each other within the economy is an annualized 4.6% of the amount borrowed in the high steady state.

In figure 5 we depict a sample simulation of the world economy with two regions. The first panel shows output and consumption in the North, and the second panel depicts the two variables in the South. In the given simulation, there are three instances of negative endowment shocks and binding financial constraints. The North experienced a single crisis in period 16, whereas the South experienced crises in periods 4 and 17. In both regions, the reductions in output triggered amplified declines in consumption, as falling asset prices and falling borrowing capacity reinforced the effects.

The panels 3 and 4 we illustrate the amount of wealth carried into the future in the North and South, and panel 5 depicts the world interest rate. In response to the Southern crisis in period 4, the world interest rate declines since financial constraints reduce the effective demand for credit coming from the South. Taking advantage of the cheap credit, the North dissaves, i.e. takes on a larger amount of debt. After the Northern crisis in period 16, the South takes on greater debt, which makes it more vulnerable to shocks in ensuing periods. When the adverse endowment shock hits the South in period 17, it therefore experiences a crisis that is significantly larger than in period 4, leading to greater declines in consumption and borrowing than before.

A social planner would take precautionary actions against crisis risk. In the high steady state of the economy, he would impose a macroprudential policy measure that is equivalent to a 1.55% tax on foreign borrowing. If the other region gets afflicted by a crisis and more hot money flows into the domestic economy, he would adjust the tax upwards to 2.34% so as to lean against the wind of capital inflows. On the other hand, if the domestic economy suffers a crisis and becomes financially constrained, a planner could set the tax to zero, since equilibrium is determined by the binding constraint.

6 Discussion

This paper has developed a simple model of hot money and serial financial crises. Money is "hot" in the sense that countries that borrow and later experience binding constraints become subject to financial amplification effects that lead to a coordinated decline in consumption, borrowing, and asset prices. We showed that individual market participants do not internalize that they expose their country to such amplification effects when they make their privately optimal borrowing decisions. As a result, they create an externality on other borrowers. A policymaker can induce market participants to internalize these effects by imposing macroprudential policies such as prudential controls on capital inflows. Such measures reduce macroeconomic volatility and improve welfare in the domestic economy.

We also explored the risk of serial financial crises. If one part of the world economy becomes constrained in its access to international capital markets and suffers a crisis, the effective demand for borrowing declines and the world interest rate falls. This provides greater incentive for other countries to take on cheap debt and makes the affected economies more vulnerabe to future financial crises.

In the following we will discuss the implications of this view of the global financial system for a set of issues of current interest.

Neomercantilism In the preceding sections we took it as given that overlapping generations of international investors seek a place into which to channel their savings so as to smooth their consumption. However, in recent years, a number of countries have engaged in what has been called neo-mercantilist hoarding of international reserves (see e.g. Dooley et al., 2003; Rodrik, 2008; Korinek and Serven, 2010). This leads to an increase in the global supply of credit that is orthogonal to the factors that we have analyzed.

However, we may capture this effect by exogenously increasing the parameter e_1, which raises the incentive of investors in our model to provide credit. In equilibrium, this leads to a decline in the world interest rate R and greater indebtedness of the borrowing countries. In our model, increased reserve hoarding therefore makes the world economy riskier and increases the necessity of macroprudential policy measures.

We note that commodity price booms that lead commodity producers to increase their savings in sovereign wealth funds lead to similar effects, as they increase the amount of money that seeks a destination to invest in.

Real Exchange Rates In practice, booms and busts in credit flows are not only reflected in asset prices, but also in exchange rates. While we did not include this effect in our model, it is straightforward how to extend our framework in this direction. Korinek (2007, 2010) illustrates how capital inflows and outflows may lead to exchange rate appreciations and depreciations. In countries with foreign currency-denominated liabilities, there is a danger of financial amplification effects whereby depreciating exchange rates, adverse balance sheet effects and declining aggregate demand mutually reinforce each other. This gives rise to an externality that is similar to what we have analyzed above, reinforcing the need for macroprudential policies. In the context of emerging market economies, it is of particular importance that policy measures discourage the use of foreign currency-denominated debts, which play a crucial role in these feedback effects.

Strategic Complementarity of Macroprudential Regulation How does macroprudential regulation in one country affect the rest of the world economy? In our analytical model above, we assumed for simplicity that one small open economy in the "South" region imposed macroprudential policy measures on capital flows. Since the economy was small, the effect on world interest rates was negligible. On the other hand, if a large country, or a significant number of countries impose such measures, there will be a general equilibrium effect on the world economy.

Those countries that lean against the wind of international capital flows reduce the effective world demand for capital. For a given supply, the flood of capital flowing into other countries therefore increases, as will be reflected by lower interest rates and larger quantities of capital flows. For those economies that are not financially constrained, this will increase their indebtedness and make them more vulnerable to future crises. In economies that currently experience a crisis, the lower world interest rate will marginally relax their financial constraints and soften the crisis. Moreover, international investors will obtain a lower return and will therefore likely protest the policy measures.

Level of Financial Development There are two distinct ways in which an economy can become more financially developed in our model. First, it it may experience an increase in its borrowing capacity as captured by the leverage parameter ϕ. In a financially fragile world economy, higher ϕ leads to larger current account reversals when financial constraints occur, but also to greater precautionary saving. The overall effect on macroeconomic stability is generally ambiguous (see e.g. section 4.4 of Jeanne and Korinek, 2010a). However, if all countries in the world economy become more creditworthy and ϕ increases sufficiently so that the all countries become unconstrained, then the world will be characterized by stable dynamics as described above in section 3.1.1.

A second form of financial development is an increase in the set of claims that can be traded with international investors. In our model above, the world economy was restricted to trade only debt. If we allow e.g. for equity in the tree to be held by international investors in an economy where there is a shortage of investment opportunities so that $\beta R < 1$, then the shortage is mitigated, the world interest rate on bonds rises (as the supply of credit declines), asset prices rise (as the demand for assets goes up) and the world economy becomes more stable.

Investment and Growth While we analyzed the problem of hot money and serial financial crises in a model of an endowment economy, our results carry over into economies with investment and production. In such economies, private market participants expand the stock of capital during booms and the price of capital rises, enabling them to take on more credit.[2] During busts, the stock of capital becomes less valuable and the collateral to back up promises to repay declines. This may lead to a feedback spiral of declining borrowing capacity, falling asset prices, and fire sales. A policymaker who leans against the wind when credit flows into the economy may reduce excessive capital creation in booms, which mitigates the need for fire sales and the decline in asset prices plus the associated credit crunch in case of a bust, thereby increasing social welfare.

The problem is even further aggravated if investment has long-term effects on economic growth. Recent evidence (see e.g. IMF, 2009) suggests that credit crunches may have long-lasting detrimental effects on output because the investment lost during the crunch cannot be fully made up for during the ensuing recovery. Under such circumstances the welfare costs of financial crises are significantly greater than what we found in our numerical results because they

[2]Formally, this requires a form of q-theory of investment to hold, i.e. it that investors cannot costlessly transform consumption goods into investment goods and vice versa.

stretch over many periods. See Jeanne and Korinek (2010b) for a detailed investigation.

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A Numerical Solution Method

The numerical solution to the problem of international investors is straightforward – the function $b^h(R)$ can be solved explicitly.

To solve for the optimal behavior of borrowing countries, we employ a modified version of the endogenous gridpoint bifurcation method developed in Jeanne and Korinek (2010a), which derives the policy functions of borrowers for an exogenously given interest rate. We modify their solution method to account for the endogeneity of the interest rate by conjecturing initial policy functions and interest rates and by employing an iterative procedure. In each iteration step $k+1$, we update the policy functions of borrowers $\left\{c_{(k)}, p_{(k)}, \lambda_{(k)}, b'_{(k)}\right\}$ and the distribution of interest rates $\left\{R'_{(k)}\right\}$ in the following manner:

1. Given the policy functions $\left\{c_{(k)}, p_{(k)}, \lambda_{(k)}, b'_{(k)}\right\}$ for N borrowing countries, we determine the implied next-period distribution of aggregate lending $\left\{b^{h\prime}_{(k+1)}\right\}$ and the resulting distribution of interest rates $\left\{R'_{(k+1)}\right\}$.

2. Given this new distribution of interest rates, we employ the endogenous gridpoints bifurcation method of Jeanne and Korinek (2010) to solve for the optimal policy functions $\left\{c_{(k+1)}, p_{(k+1)}, \lambda_{(k+1)}, b'_{(k+1)}\right\}$.

We repeat the two steps until the procedure converges.