Financial Fragility, Exchange-Rate Regimes, and Sudden Stops in a Small Open Economy[♦]

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Abstract

We model a typical Asian economy in crisis using a dynamic general equilibrium technique and establishing exchange rates from nontrivial fiat-currency demands. Sudden stops/bank panics are possible and are essential for evaluating the merits of alternative exchange-rate regimes. Strategic complementarities contribute to the severe indeterminacy of a continuum of equilibria. Social welfare and the scope of equilibria are also associated with the underlying policy regime and the built-in Sequential Checking Mechanism, including liquidity, solvency, and incentive-compatibility constraints in the model. Combining domestic and foreign reserve requirements promotes stability under a floating exchange-rate regime; however, this increases the scope for panic equilibria under both floating and fixed regimes. While backing the money supply reduces financial fragility under both systems, it only acts as a stabilizer in a fixed regime.

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1. Introduction

A financial crisis in emerging markets could arise out of a major reversal in the international capital markets, a panic initiating a bank-run scenario, or a sharp swing in exchange rates. The prevalent view in studies of the Asian crisis of the '90s includes: 1) increased risky lending behavior by banks leading to a boom in private borrowing; 2) lack of a sound financial structure in the process of financial and capital liberalization[1]; 3) borrowed money from foreign banks that enabled a significant portion of domestic banks' lending[2]; 4) the credit crunch among foreign creditors that directly impacted banks' solvency; and 5) fluctuation in foreign-exchange values that led to regime switching.

According to the accepted chronology, the floating of the Thai baht in July 1997 triggered the crisis. During the 1980s and the early 1990s, Indonesia, South Korea, Thailand, and Malaysia had managed floating arrangements. However, after the 1997 crisis, Indonesia, South Korea, and Thailand moved from intermediate pegs to free floating, while Malaysia turned to a very hard peg. See Table 1 for details.

Table 1. Exchange-Rate Regimes in the East Asian Countries Before the Crisis and After the Crisis

Country	Before/During the crisis	After the crisis
Japan	Free floating	Free floating
Philippines	Free floating	Free floating
China	Managed floating	Managed floating
Indonesia	Managed floating	Floating
Korea	Managed floating	Floating
Singapore	Managed floating	Managed floating
Thailand	Managed floating	Managed floating →floating
Malaysia	Managed floating	Fixed
Hong Kong	Fixed	Fixed

Source: Frankel et al. (2002)

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[1] The extensive literature on financial liberalization can go as far as Goodhart and Delargy (1998), Kaminsky and Reinhart (1999), Lindgren et al.(1999), Summers (2000), Boyd et al. (2000), Kishi and Okuda (2001), and Kaminsky (2003).

[2] The global capital-flow cycle was instrumental in the defaults of the financial intermediaries and in the severe financial turbulence in the emerging countries. See Calvo, Izquierdo, and Meija (2004), Calvo and Talvi (2005), Calvo, Izquierdo, and Talvi (2006), Bordo (2006), and Reinhart and Rogoff (2008).

Considering this information, our main goal was to develop a model to capture a stylized view that would deliver the stability to weather future financial crises through effective policy tools.

Building on the template of a small open economy, this paper is related to two broad areas of research on 1) the micro-foundations of banks and 2) monetary-policy rules. The former emphasizes depositors' preference shock, liquidity risk, and financial fragility. This framework, described by Diamond and Dybvig (D&D) in 1983, has been applied by Cooper and Ross (1998), Diamond and Rajan (2001), Peck and Shell (2003, 2010), Green and Lin (2003), and Ennis and Keister (2003, 2006, 2010). Chang and Velasco (C&V) (2000 (a), 2000 (b), and 2001) are of particular relevance. In discussing the effects of international capital inflows, multiple equilibria, external debts with various term structures and interest rates, and international reserves, C&V show how self-fulfilling prophecies of bank runs could bring on a crash following an asset price boom, and how coordination failure among foreign lenders may also contribute to a financial crisis.

This paper seeks to fill the gap left by the unsuitability of the Diamond-Dybvig (1983) framework for an overlapping generation model and builds on C&V. We build a Dynamic Stochastic General Equilibrium Model (DSGE) from the micro-foundation in order to replicate a small open economy (SOE) with a nontrivial banking system. Given the complexity of the interaction between policy parameters, this model is suitable for predicting volatility and stability along dynamic paths, the likelihood of cyclical fluctuations, and the endogenously-arising volatility (Wang and Hernandez, 2011). We distinguish this study from the literature in three ways. First, while C&V assume money in the utility function, we introduce non-trivial demands for multiple fiat currencies. Fiat money enters the model through domestic and foreign reserve requirements under which banks must hold a fraction of their deposits as unremunerated currency reserves. Second, we use a DSGE model with an infinite horizon to represent the Overlapping Generations. Thus, we are able to compare stability and volatility under each type of exchange-rate regime. Third, we provide an equilibrium selection process rather than a sunspot variable. Informational and institutional frictions may exacerbate credit rationing and endogenously arising volatility. In this respect, we reformulate the sequential checking algorithm and devise a re-optimization problem that can lead to different welfare-ranked equilibria.

In addition, our paper is related to the literature on monetary-policy rules, exchange-rate regimes, and the effect of a sudden stop in emerging countries' financial markets. Calvo and Reinhart (1999) show that fear of floating motivates many emerging markets to choose capital controls rather than dollariza-

tion, but the latter is a better market-oriented option for reducing the severity of sudden stops in capital inflows and the incidence of crises. Bordo and Meissner (2006) and Bordo (2006) review the effect of such sudden inflow stops on emerging markets and provide evidence that backing hard-currency debt with foreign reserves reduces the likelihood of currency and banking crises. On the other hand, Curdia (2008) examines the impact of monetary-policy responses to a sudden fall-off in foreign credits and finds that a currency peg is not the most desirable regime. A fixed exchange-rate regime performs better in an environment with low nominal rigidities or high elasticity of foreign demand. Devereux, Lane, and Xu (2006) study the effect of exchange-rate flexibility on monetary policy and find a clear trade-off between real stability and inflation stability under both fixed exchange rates and inflation-targeting rules. Braggion, Christiano, and Roldos (2009) study the optimal monetary response to a financial crisis similar to the Asian crisis of the '90s in a dynamic general equilibrium setup, but their focus is primarily on interest-rate policy and the consequence of a reverse monetary transmission mechanism.

Given the disagreement among the studies, the new results add to the literature a trade-off for policymakers for each exchange-rate regime when they seek to reconcile the goal of high welfare with the scope for non-panic equilibria. Uniting domestic and foreign reserve requirements promotes high welfare under a fixed exchange-rate regime but increases the scope for panic equilibria under both regimes. Alternatively, backing the domestic money supply decreases welfare under a floating regime but increases the scope for non-panic equilibria under both regimes.

The remainder of this paper is organized as follows. Sections 2 and 3 analyze the properties of equilibria under the alternative exchange-rate regimes, assuming that no crises are possible in equilibrium. Section 4 examines the possibility of crises by introducing extrinsic and intrinsic uncertainties. Section 5 is the conclusion.

2. Floating Exchange Rates

The model consists of an infinite sequence of two-period-lived, overlapping generations. Time is discrete and indexed by t=0, 1, 2, ….

2.1 The Model

There are four groups of players: households/depositors, domestic banks, foreign banks, and the domestic monetary authority. Foreign banks will lend to domestic banks inelastically up to an exogenous upper limit. The domestic

banks, a net debtor to the rest of the world, are subject to domestic and foreign reserve requirements. The timing of the event is described in Figure 1. Deposit Contracts announce a state-contingent consumption $\left(c_{1,t}, c_{2,t+1}\right)$ that maximizes the households' expected lifetime utility described in (1) and is subject to the truth-telling constraint (2), borrowing constraints (3)-(4), and resources and budget constraints (8)-(10). The state-contingent pair $\left(c_{1,t}, c_{2,t+1}\right)$ satisfies the condition $r \cdot \left(w + \tau_t\right) < c_{1,t} < c_{2,t+1} < R \cdot \left(w + \tau_t\right)$, which brings $c_{1,t}$ and $c_{2,t+1}$ closer together.

Figure 1. Sequence of Events
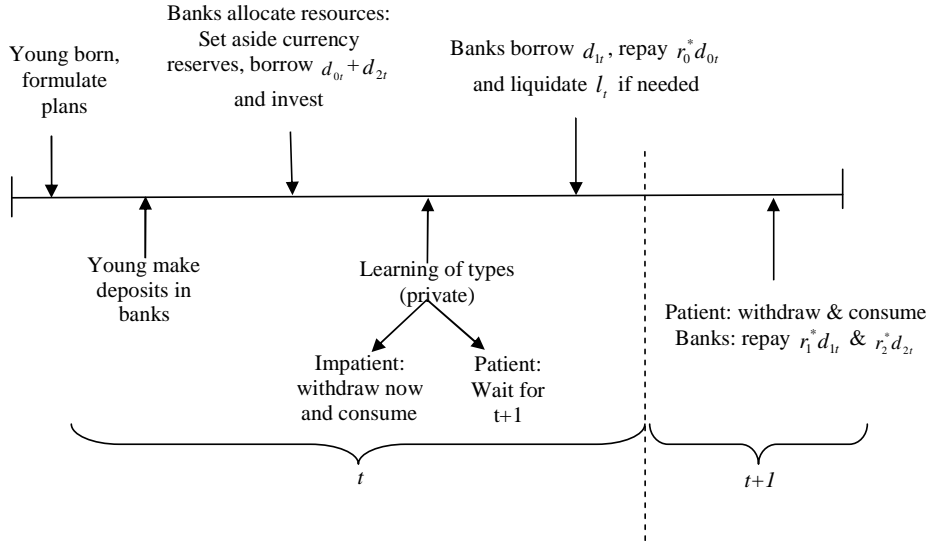
Households

A continuum of households with unit mass born at period t is young and is old at period $t+1$. As in the D&D framework, households within a generation are *ex ante* identical but experience a preference shock by the end of their youth. They can be impatient with probability $\lambda \in (0,1)$ or patient otherwise. Impatient households consume when young ($c_{1,t}$), while patient households consume only when old ($c_{2,t+1}$). A typical household's expected lifetime utility at the beginning of *t* is:

$$E_t\left[u\left(c_{1,t}, c_{2,t+1}\right)\right] = \lambda \cdot \ln\left(c_{1,t}\right) + (1-\lambda) \cdot \ln\left(c_{2,t+1}\right). \tag{1}$$

Early in the morning of youth, each household receives an endowment of w together with the monetary transfer τ_t from the monetary authority, regardless of types. At the same time, households deposit recourse with the banks that have access to a long-term investment technology that yields a return of $R > 1$ at the end of $t+1$. However, this investment will yield only the return $0 < r < 1$ in the case of early liquidation at t, where $R > r$. Households Patient consumers may credibly choose to misrepresent their types by withdrawing and reinvesting. To induce self-selection and truth-telling, the following condition must be met

$$c_{2,t+1} \geq r \cdot c_{1,t}.$$
(2)

Regarding the initial conditions for the dynamic, infinite-horizon economy, $(1-\lambda)$ patient initial old households at $t = 0$ wish to consume $c_{2,0}$ goods. This consumption is financed by distributing the initial money supplies $M_0 > 0$ and $Q_0 > 0$ equally among the patient initial old.

Financial Intermediation

The financial market provides liquidity at a variety of terms and/or dates of maturity, thus contributing to consumption smoothly. In this economy, only banks have access to the world credit markets by trading in several debt markets: early intra-period debt, $d_{0,t}$, late inter-period debt, $d_{1,t+1}$, and long-term debt, $d_{2,t+1}$. The first two are short-term debts; one is borrowed at the beginning of period t and repaid at the end of the same period; the other is borrowed at the end of period t and repaid at the beginning of the next period. In addition, to invest in the long-run domestic technology, the purpose of $d_{2,t+1}$ is to show that domestic banks have access to foreign capital markets. The gross real interest rates associated with these debt instruments are $\left(r_0^*, r_1^*, r_2^*\right) \gg 1$. As stated in Chang and Velasco (2000ab, 2001), the banks are constrained by an upper limit set by foreign banks.

$$0 < d_{0,t} + d_{2,t+1} \leq f_0,$$
(3)

$$0 < d_{1,t+1} + d_{2,t+1} \leq f_1.$$
(4)

$f_1 > f_0 > 0$ are exogenous and time-invariant structural parameters representing the maximum amount that foreign banks are willing to lend to domes-

tic banks. We focus on situations where foreign credit is rationed, which transpire when (3) and (4) are equal.

Monetary Authority

Two fiat national currencies circulate in the economy at any point in time. M_t and Q_t represent the outstanding nominal stock of domestic currency and foreign currency at t. The monetary authority sets the rate of money growth to be $\sigma > -1$, and the supply follows the rule

$$M_{t+1} = (1+\sigma) \cdot M_t, \quad \forall t > 0,$$

(5)

with $M_0 > 0$ given. The domestic monetary authority accomplishes all injections and/or withdrawals of domestic currency through the *ex ante* lump-sum transfers τ_t at the beginning of period t.

The monetary authority also backs the domestic money supply by holding B_t foreign currency, in the form of foreign-reserve assets that yield the world interest rate $\varepsilon > 1$ from t to $t+1$. These reserve holdings are set to follow the rule

$$B_t = \theta \cdot \left(\frac{M_t}{e_t} \right),$$

(6)

where $\theta \in [0,1]$ is the policy parameter that represents the fraction of the domestic money supply backed by the central bank, and e_t denotes the number of domestic-currency units exchanged for one foreign- currency unit. p_t and p_t^* are the associated prices. p_t / p_{t+1} is the gross real return realized by holding domestic currency, and $p_t^* / p_{t+1}^* = (1+\sigma^*)^{-1}$ represents the comparable gross real return on foreign currency, where $\sigma^* > -1$ is the exogenous net inflation rate in the rest of the world. The financial position of the government is summarized by the budget constraint

$$\tau_t = \frac{M_t - M_{t-1}}{p_t} - \frac{B_t - \varepsilon \cdot (1+\sigma^*) \cdot B_{t-1}}{p_t^*},$$

(7)

where the first term on the right-hand side of (7) indicates the change in the real-money balance and the second term accounts for variations in the foreign-reserve position backing the domestic money supply.

In addition, the central bank sets the reserve requirements as policy parameters. The parameters $\phi_f, \phi_d \in (0,1)$ designate the fraction of total deposits that banks must hold as currency reserves in the form of domestic and foreign currency, respectively. The situation $\phi_d + \phi_f < 1$ must be present.

Budget Constraints of Households

It is assumed that all transactions take place through banks. Young households receive $w + \tau_t$ goods when born, and banks receive these deposits and borrow $d_{0,t} + d_{2,t+1}$ goods from the rest of the world. At the same time, banks set aside the required currency reserves of $\phi_d \cdot (w + \tau_t)$ as domestic currency and $\phi_f \cdot (w + \tau_t)$ as foreign currency; these currency reserves are deposited in the banks' reserve accounts held within the monetary authority. The banks also invest in the long-term asset, k_{t+1} , which is financed by a combination of their resources and leads to the budget constraint

$$k_{t+1} \le d_{0,t} + d_{2,t+1} + (1 - \phi_d - \phi_f) \cdot (w + \tau_t) . \tag{8}$$

Household types are realized at the end of t. Under the truth-telling constraint, households behave as the true type. Accordingly, banks pay a total of $\lambda \cdot c_{1,t}$ goods to impatient depositors following a sequential-service constraint, on a first-come, first-served basis, and repay their early intra-period debt $r_0^* \cdot d_{0t}$ to foreign banks. At the end of t, banks can access a loan/bail-out inter-period debt, $d_{1,t+1}$. If more funds are required, banks liquidate prematurely the long-term investment by the amount l_t, but this is a last resort, since early liquidation is costly[3]. As mentioned in the Household's decision, long-term investment will yield only the return $0 < r < 1$ in the case of early liquidation at t, where $R > r$. The budget constraint that summarizes this state is given by

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[3] One could think of $d_{1,t+1}$ and l_t as substitute sources of liquidity for banks, but $d_{1,t+1}$ is cheaper, since $r_0^* < R$ is true at equilibrium. If the bank were to exhaust its resources before covering all liabilities, it would close, and any future payments contracted by that bank would be lost.

$$\lambda \cdot c_{1,t} + r_0^* \cdot d_{0,t} \leq r \cdot l_t + d_{1,t+1}. \tag{9}$$

There is no action until late in the end of *t+1*, when the patient households withdraw a total of $(1-\lambda) \cdot c_{2,t+1}$ from banks. By then, banks have repaid the amounts of the inter-period debt, $r_1^* \cdot d_{1,t+1}$, and the long-term debt, $r_2^* \cdot d_{2,t+1}$, to foreign creditors. With regard to the sources of income, banks receive the return of the long-term investment unliquidated, $R \cdot (k_{t+1} - l_t)$ and the gross real return on their currency reserves. Patient households take reserve requirements into account when forming their expectations, reducing the likelihood of their starting a bank run to a given set of circumstances. The resulting budget constraint is given by

$$(1-\lambda) \cdot c_{2,t+1} + r_2^* \cdot d_{2,t+1} + r_1^* \cdot d_{1,t+1} \leq R \cdot (k_{t+1} - l_t) + (w + \tau_t) \cdot \left[\phi_d \cdot \left(\frac{p_t}{p_{t+1}} \right) + \frac{\phi_f}{(1+\sigma^*)} \right]. \tag{10}$$

2.2 General Equilibrium with Floating Exchange Rates

We use the notation $\hat{x}_t$ to represent the value that the variable *x* takes at time *t* under floating exchange rates and report the result of the interior solution.

First, two conditions for international transactions are assumed: the purchasing power parity $\hat{e}_t \cdot p_t^* = \hat{p}_t$ and the no-arbitrage condition $R = r_2^* = r_0^* \cdot r_1^*$. Without restrictions on international capital flows, there is no arbitrage between the gross real domestic interest rate and the world-determined interest rate, after we control for the different length of the maturity periods. The cost of long-term debt is compensated for by the long-term domestic investment. Second, domestic and foreign real-money balances, $\hat{z}$ and $\hat{q}$, are dominated by the long-term investment in rate of return, which occurs only when both $p_t/p_{t+1} < R$ and $p_t^*/p_{t+1}^* < R$. Given that, the reserve requirements combine, and the demand for real-money balances is determinate. Third, the core dynamic reduced-form system is obtained, incorporating the five endogenous variables that are determinate in equilibrium, including the domestic and foreign real-money balances, $\hat{z}$ and $\hat{q}$, monetary transfers, $\hat{\tau}_t$, real balances of foreign-asset reserves, $\hat{b}_t$, and banks' long-term investment, $\hat{k}_{t+1}$. We establish the core dynamic system and solve the equilibrium in Appendix A.

Stationary Equilibria and Social Welfare

A stationary equilibrium for this economy is defined as the set of vectors $\left(\hat{z},\hat{\tau},\hat{q},\hat{b},\hat{k}\right) \in \mathbf{R}^5$, $\left(\hat{d}_0,\hat{d}_1,\hat{d}_2\right) \in \mathbf{R}_+^3$ and $\left(\hat{c}_1,\hat{c}_2\right) \in \mathbf{R}_{++}^2$, $\hat{l}=0$, and all conditions in the previous section are met. The stationary equilibrium values are determined uniquely by the real-money balance.

Proposition 1. Defining the set $\mathsf{P}=\left\{\sigma, r_0^*, r_1^*, r_2^*\right\} \in \mathbf{R}^4$ to be the space of bifurcation parameters under a floating exchange-rate regime, we observe multiple stationary equilibria in the model economy. The indeterminacy of equilibria is that for a given vector $\left(\hat{d}_0,\hat{d}_1,\hat{d}_2\right)$ there is a continuum of vectors $\left(r_0^*, r_1^*, r_2^*\right)$ consistent with equilibrium conditions.

Stationary allocations are characterized by a debt-structure vector of the form $\left(\hat{d}_0,\hat{d}_1,\hat{d}_2\right) = \left(f_0 - \hat{d}_2, f_1 - \hat{d}_2, \hat{d}_2\right) \gg 0$. An increase in the policy parameters $\left(\sigma, \phi_d, \theta\right)$ will increase the steady-state values $\left(\hat{z}, \hat{q}, \hat{b}^*\right)$ in the core. In a small open economy, monetary transfers are tied to the growth of the domestic real-money balance, and they depend on the variations in the foreign-reserve position backing the domestic money supply. The growth of the real-money balance affects domestic long-term investment in a positive way. $\hat{\tau}$ is nonlinear in both σ and ϕ_d but monotonically increasing in θ. $\hat{k}$ is increasing in σ but nonlinear in $\left(\phi_d, \phi_f\right)$. The steady-state consumption vector and the steady-state expected utility follow $\hat{U}=\lambda \cdot \ln\left(\hat{c}_1\right)+\left(1-\lambda\right) \cdot \ln\left(\hat{c}_2\right)$. Increasing both types of currency reserves, provided that $\phi_d=\phi_f$, and augmenting the backing of the domestic money supply, θ, reduce the expected utility[4]. The intuition is straightforward. A rise in ϕ_d, ϕ_f, θ will reduce the resources available for financial intermediaries to invest in the real economy. Since the decision to hold currency is dominated by the rate of return on long-term investment, in a model economy without shocks and without fears of a run on the banks, reserve savings generate dead-weight losses in the society.

3. Fixed Exchange Rates

In this section, we use $\overline{x}_t$ to denote the value that the endogenous variable x_t takes under a hard peg. This economy is identical to the one discussed in

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[4] The comparative statistics are available on request from the authors.

Section 3, except for the exchange-rate regime. We focus on a hard peg where the nominal exchange rate, e, remains constant over time. The monetary authority holds reserves in the form of interest-bearing, foreign-reserve assets. These reserve holdings aim to back the dollar value of the domestic money supply so that speculative attacks on the domestic currency can be avoided or minimized. At period t, the monetary authority sets both e and θ where $\theta \in [0,1]$[5].

$$B_t^* = \theta \cdot \left(\frac{M_t}{e} \right)$$

(11)

$$\tau_t = \frac{M_t - M_{t-1}}{p_t} - \frac{B_t^* - \tilde{r} \cdot \left(p_t^* / p_{t-1}^* \right) \cdot B_{t-1}^*}{p_t^*} = \phi_d \cdot \left(w + \tau_t \right) - \left(p_{t-1} / p_t \right) \cdot \phi_d \cdot \left(w + \tau_{t-1} \right) - \left(b_t^* - \tilde{r} \cdot b_{t-1}^* \right)$$

(12)

The first two terms on the right-hand side of equation (12) represent the amount of real money supply necessary to sustain the fixed nominal exchange rate. The third term indicates the effects of changes in the real foreign-reserve position of the government. The rate of return on the domestic real-money balance changes accordingly under a hard peg as

$$\left(\overline{p}_t / \overline{p}_{t+1} \right) = \left(p_t^* / p_{t+1}^* \right) = \left(1 + \sigma^* \right)^{-1}$$

(13)

Equation (13) reflects the lack of control of the domestic money supply. Under the hard peg, the dynamics of the system take place in monetary transfers τ_t instead of the domestic real-money balance z_t. The laws of motion regarding the dynamic system and the derivation of the steady-state equilibria under the fixed exchange-rate regime are available in Appendix B.

Stationary Equilibria and Social Welfare

Stationary equilibria under fixed exchange rates are defined by allocations such that $\left\{ \left(\overline{\tau}, \overline{z}, \overline{q}, b^*, \overline{k} \right), \left(\overline{d}_{0,j}, \overline{d}_{1,j}, \overline{d}_{2,j} \right), \left(\overline{c}_{1,j}, \overline{c}_{2,j} \right) \mid \overline{l} = 0 \right\} \in \mathbf{R}_{++}^5 \times \mathbf{R}_+^3 \times \mathbf{R}_{++}^2$, which satisfy all the conditions given above. We analyze the set of *separating* stationary equilibria, understanding that all households behave as the true type, and there are no panics or early liquidations. This second model economy, similar to the economy under the floating regime, violates two standard conditions of regularity. Regarding the number of equilibria, there is typically a

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[5] A currency-board arrangement exists when the monetary authority sets $\theta = 1$ once-and-for-all at $t = 0$.

continuum of equilibria in this economy, meaning that mapping the vectors of relative prices with the corresponding demand is not unique.

We find that consumption and expected utility are monotonically decreasing under inflation rate σ^*. When the world inflation rate is high, banks have no incentive to borrow long-term funds from abroad because inflation would undermine the real return on the currency reserves. On the other hand, increasing domestic- and foreign-currency reserves, provided that $\phi_d = \phi_f$, leads to higher utility when the world inflation rate, σ^*, is sufficiently low; however, this causes a reduction in utility when world inflation is high. The intuition is that under a very hard peg, the domestic country inherits the world's inflation rate, contributing to a relatively quick stabilization. When the rate of return on currency is relatively high, holding more of it is profitable and thus will improve welfare. Boosting the backing of the money supply (θ) raises welfare, but the magnitude of these changes is very small.

4. Potential for Crises and Vulnerability of Banks

This section analyzes the effect of an unanticipated shock that hits the economy immediately after depositors learn their type. The shock that triggers financial crises in this model takes one of two forms: a shock to the depositors' beliefs (i.e., a bad dream) or a sudden drying up of foreign capital. In some cases, given the strategic interdependence and coordination problems in this environment, individuals realize that their personal welfare depends not only on their actions, but on the actions of other individuals in the economy as well. As a result, a self-fulfilling prophecy of a bank run is possible. In other cases, banks re-optimize and deviate from their *ex ante* contingent plan. In this paper, we focus on the latter situation. In the remainder of this section, the notation $\tilde{x}$ indicates the re-optimized value of the variable x.

At the beginning of period t, domestic banks would have chosen the state-contingent consumption $(c_{1,t}, c_{2,t+1}) \gg 0$ and would have formulated a plan that involved $l_t = 0$, $(z_t, \tau_t, q_t, b_t^*, k_{t+1})$ and $(d_{0,t}, d_{1,t+1}, d_{2,t+1}) \geq 0$. The constraints on foreign credit $\{f_0, f_1\}$ are binding, and the *ex ante* choices of $d_{0,t}$ and $d_{2,t+1}$ are effective at this time. But the choices of $d_{1,t+1}$ and l_t are not. When a sudden stop hits the economy, it abruptly reduces resources available at the end of period t to f_1', where $0 < f_0 < f_1' < f_1$ is obtained. The borrowing constraint now becomes

$$d_{2,t+1} + \tilde{d}_{1,t+1} = f_1'$$

(14)

where $\tilde{d}_{1,t+1}$ denotes the re-optimized value of $d_{1,t+1}$ [6]. Both banks and depositors will need to re-optimize to account for the change, leading to the Sequential Checking Mechanism.

4.1 The Sequential Checking Mechanism

Figure 2 presents the Sequential Checking Mechanism. This algorithm consists of three steps. The first is to evaluate the liquidity position of banks. Next, we check the banks' solvency, followed by evaluating whether the resulting allocations are incentive-compatible or not.

Figure 2. The Sequential Checking Mechanism

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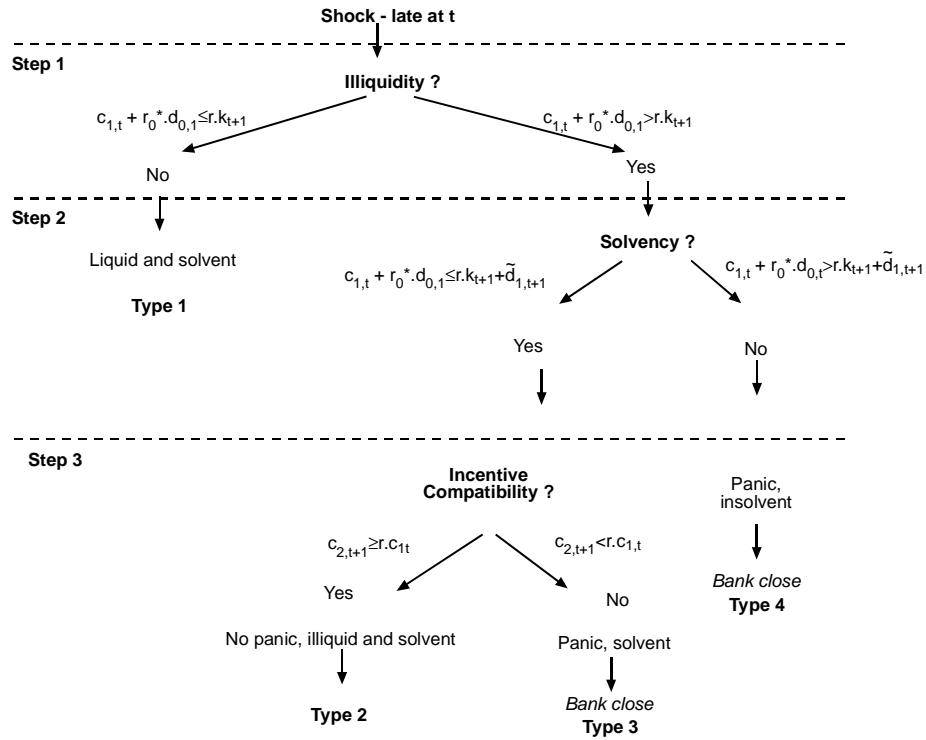
[6]   One could also argue that unanticipated reductions in foreign credit may trigger a shock to the preferences of depositors. If such a shock induces a crisis of a self-fulfilling nature, this may only exacerbate the existing problems in this economy. In this paper, for simplicity, we do not consider this possibility.

Checking Liquidity. Chang and Velasco (2000a, 2000b, and 2001) were among the first in the literature to evaluate the liquidity position of banks in the context of financial crises in emerging markets, and this study adopts the same approach. The representative bank may have an illiquid position when the real value of its short-term obligations at the end of period t, $c_{1,t} + r_0^* \cdot d_{0,t}$, exceeds the liquidation value of the long-term investment, $r \cdot \tilde{l}_t = r \cdot k_{t+1}$, or equivalently, when the following inequality applies:

$$c_{1,t} + r_0^* \cdot d_{0,t} > r \cdot k_{t+1}. \tag{15}$$

When the inequality in (15) does not apply, the bank has a liquid position. The left-hand side of equation (15) and the following equation (16) represent the case of a bank run, and thus, depositors of all types rush to withdraw their funds.

Checking Solvency. We must note that an illiquid position is a necessary condition for a bank-run equilibrium, but on its own it is not sufficient to set matters rolling. A bank's illiquidity may be temporary, caused by a shock that might be neutralized if foreign lenders were to provide provisional liquidity of $0 < \tilde{d}_{1,t+1} \leq f_1'$. The following inequality describes the condition for the insolvency:

$$c_{1,t} + r_0^* \cdot d_{0,t} > r \cdot k_{t+1} + \tilde{d}_{1,t+1} \tag{16}$$

The inequality in (16) means that if the real value of the new short-term foreign debt $\tilde{d}_{1,t+1}$ is not enough to alleviate the temporary liquidity problem, it would be in the best interest of foreign creditors to let the bank fold. In doing so, creditors may not recover the amount $d_{2,t+1}$ that they lent long-term to domestic banks at the beginning of period t. Foreign creditors tend to bail out solvent banks, but let insolvent ones go under. We summarize this idea with the following saying: *"Why throw good money after bad?"*

Checking Incentive Compatibility. In a situation where banks are illiquid but solvent, a fraction of the patient households may still have incentives to misrepresent their types and withdraw funds prematurely, leading to panics and closures. There is a coordination problem in which complementarity is present in the strategic interaction between individual depositors. We incorporate the incentive-compatibility constraint in (2).

4.2 Type of Equilibria and Equilibrium Selection Rules

After a shock hits our model economy, banks may need to formulate a new plan. In the case of extrinsic uncertainty, then $\left(\tilde{d}_{1,t+1},\tilde{l}_t\right)=\left(d_{1,t+1},l_t\right)$, since no fundamentals have changed. However, in the case of intrinsic uncertainty, $\left(\tilde{d}_{1,t+1},\tilde{l}_t\right)\neq\left(d_{1,t+1},l_t\right)$, and one would typically expect that $\tilde{d}_{1,t+1}<d_{1,t+1}$ and $\tilde{l}_t>l_t=0$. There are four different sets of equilibrium outcomes:

a) <u>Equilibria of Type 1</u>: This equilibrium is seen when (15) is not present. Liquidity implies solvency, and (2) must apply. Thus, banks have a liquid and solvent position, and the allocation is incentive-compatible. There are no panics in equilibrium and thus no need for a bail-out. This outcome is a *separating non-panic equilibrium with liquid banks*.

b) <u>Equilibria of Type 2</u>: This equilibrium occurs when (15) and (2) exist, but not (16). Banks have an illiquid position, but they are solvent and incentive-compatible. Foreign creditors choose to support domestic banks, and, subsequently, depositors choose not to engage in a run on banks. Thus, no panics occur. This outcome is a *separating non-panic equilibrium with illiquid banks*.

c) <u>Equilibria of Type 3</u>: This equilibrium emerges when (15) is satisfied, but (16) and (2) are not. Banks have an illiquid and solvent position, but their solvency is not incentive-compatible. Foreign creditors choose not to bail out such banks if they anticipate that depositors will institute a run on them, and the banks must then shut down. This equilibrium will display panics and is called a *pooling equilibrium with panics but solvent banks*.

d) <u>Equilibria of Type 4</u>: This outcome occurs when (15) and (16) are both valid, and (2) is not. Banks have an illiquid and insolvent position. Foreign creditors choose not to bail them out, and domestic depositors, finding their initial beliefs verified, choose to assemble for a run on the banks. This equilibrium will display panics, and it is a *pooling equilibrium with panics, illiquid and insolvent banks*.

The sequential checking mechanism re-evaluates (15), (16), and (2) given $\tilde{d}_{1,t+1}$, and determines the equilibria obtained accordingly. Banks maximize expected utility by choosing $\left(\tilde{d}_{1t+1},\tilde{l}_t\right)$, subject to a new budget constraint (14), the relevant budget constraints, and the exchange-rate regime. To proceed, we first set $\tilde{d}_1=f_1'-d_2<d_1$, and $\tilde{l}\neq0$, and solve for c_1 and c_2, respectively, as functions of $\tilde{l}$. Next, we impose equality in (2) and solve for $\tilde{l}$.

In summary, the equilibria of Types 1 and 2 are good separating ones where depositors behave according to their true type. Panics do not occur in good separating equilibria, since the allocations are incentive-compatible. However, the equilibria of Types 3 and 4 are pooling ones in which foreign creditors do not bail out the banks, and domestic depositors choose to misrepresent their types and tend to make runs on banks. Different levels of social welfare will be attached to each type of equilibria, and social welfare will be positively related to the amount of resources available to banks when shocks are realized.

4.3 The Role of Monetary Policy

This section examines how changes in monetary-policy parameters alter the ranges of existence for different equilibria. We calculate the comparative status of several policy parameters, σ, ϕ_d, ϕ_f and θ, among the results from banks' re-optimization (c_1, c_2, d_1, l). Then, we re-examine the sequential checking mechanism (15), (16), and (2) to find the scope for existence of each type of equilibria. The details are described in Appendix C. Table 2 summarizes the results.

Table 2. Policy Effects and Trade-Offs on the Scope for Existence of Equilibria after a Sudden Stop

				Scope for Existence	
Policy	Welfare	Type 1	Type 2	Type 3	Type 4
Floating					
$\uparrow \sigma$	Increase	n.a.	Narrow	Narrow	n.a.
$\uparrow \phi_d \uparrow \phi_f$	Decrease	n.a.	Widen	Widen	n.a.
$\uparrow \theta$	Decrease	n.a.	Widen	Narrow	n.a.
Fixed					
$\uparrow \sigma *$	Decrease	n.a.	Widen	Widen	n.a.
$\uparrow \phi_d \uparrow \phi_f$	Increase	n.a.	Narrow	Widen	n.a.
$\uparrow \theta$	Increase	n.a.	Widen	Narrow	n.a.

Note: Social welfare and the scope of equilibria are associated with the underlying policy regime and the built-in Sequential Checking Mechanism, including liquidity, solvency, and incentive-compatibility constraints in the model. Under illiquidity, the credit crunch among foreign creditors will directly impact banks' solvency. In solving for long-term debt, the vector $(d_{0,2}, \tilde{d}_{1,2}, d_{2,2}) = (f_0 - d_{2,2}, f_1' - d_{2,2}, d_{2,2})$ emerges. Banks must liquidate prematurely the amount of $\tilde{l} > 0$. In this particular subset of the pa-

rameter space, equilibria of Type 1 and Type 4 are not present, so the economy will not experience the best non-panic equilibria, but neither the worst panic equilibria.

Under floating exchange rates, we find that an increase in σ reduces the range of existence of Type 2 and Type 3 equilibria, while a jump in reserve requirements leads to a heightening of the scope for equilibria of Type 2 and 3. Hence, policymakers face tough decisions, since the range of non-panic equilibria will expand and shrink together with the magnitude of panic equilibria when σ, ϕ_d and ϕ_f move. An informative policy suggestion would be to augment θ so that the scope for non-panic Type 2 equilibria grows and the likelihood of panics in equilibrium subsides. The "magic bullet" (i.e., the ideal combination of policy parameters) that would maximize the likelihood of achieving equilibria of Type 2 and minimize that of panic equilibria under a floating regime is hard to identify—that is, beyond promoting a strong backing of the domestic money supply.

Under fixed exchange rates, one of the advantages of pegging the domestic currency to an international currency or currencies is that the economy inherits the world inflation rate, which is usually smaller than the domestic inflation rates for economies embarked on stabilization policies. We find that a rise in the world inflation rate, σ^*, increases the scope for non-panic Type 2 and panic Type 3 equilibria. Boosting the currency reserves, ϕ_d and ϕ_f, reduces the range of non-panic Type 2 equilibria but widens the possibility of panic Type 3 equilibria. On the other hand, Type 2 equilibria are more likely to occur when reinforcing θ, the backing of the domestic money supply. The combination of policy parameters that maximizes the likelihood of equilibria of Type 2 and minimizes that of panic equilibria under a hard peg is one with very low but positive reserve requirements and a high backing of the domestic money supply[7].

Discussion

In view of the high complexity of policy implementation, the monetary authority faces a clear trade-off between *ex ante* welfare and *ex post* financial fragility in alternative exchange-rate regimes. Pumping up the rate of domestic money growth under a floating regime is beneficial in terms of greater welfare and lesser scope for panic equilibria. If, instead, there is a hard peg in place, high world inflation rates create more stability and widen the scope for

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7 A low to medium world inflation rate would also be desirable, but this is beyond the control of the domestic monetary authority.

equilibria of Type 2, but at the cost of lowered welfare and higher scope for panic equilibria of Type 3.

Expanding the domestic money supply will result in more monetary transfer, long-term investment, and welfare improvement. Once a sudden stop hits the economy, however, a higher money-growth rate implies a lower rate of return on the domestic-currency reserves, which function as a backstop for patient depositors.

We also observe trade-offs regarding the effects of multiple reserve requirements. If the goal is to maximize the scope for non-panic equilibria and at the same time minimize panic equilibria, the monetary authority must choose relatively low values for reserve requirements under both exchange-rate regimes, although this policy forces down welfare under a hard peg. The function of multiple reserve requirements is to avoid unnecessary panics due to insufficient inter-period liquidity. Without financial crises, this mechanism cuts down on the resources that can be invested long-term and shows up as a fall in welfare. Once a sudden stop gets hold of the economy, the reverse in the movement of capital flows pushes up the cost of borrowing. The resulting contraction is followed by depreciation of the domestic currency. Foreign-currency reserves that hedge part of the foreign-exchange fluctuation risk ease the liquidity of financially stressed banks and lessen the possibility of panic withdrawals under a floating exchange-rate regime. However, under a fixed regime, more resources are needed to sustain the nominal exchange rate, and the mechanism to ensure non-panic equilibria fades away.

Finally, strengthening support for the domestic money supply maximizes the scope for non-panic equilibria and minimizes panic equilibria under both exchange-rate regimes. Under a floating regime, this comes with the down side of welfare reduction. Under a fixed-rate regime, backing the domestic money supply is an essential tool in managing the currency's value. As the crisis unfolds, the pressure of the currency's depreciation and its impact on the financial intermediaries can be kept to a minimum if there are sufficient resources in place. That explains why increases in the fraction of domestic currency that the central bank chooses to back can successfully widen the range of non-panic equilibria.

5. Conclusion

Regulatory agencies and creditors are still drawing the lessons of the mistake-laden recent past, so the production of sophisticated new macroeconomic policies and truly rigorous financial regulations is far from complete. Shifts in investors' expectations lead to the depreciation of currencies, bank runs, rapid

foreign capital outflows, and dramatic economic downturns. Private-sector over-expansion activates the investment boom-bust cycle. This study includes these variables in investigating the effect of monetary policy on a model economy.

At a methodological level, this paper adds to the literature and provides a framework for analyzing the interaction among key factors in forging monetary policy: fixed versus floating exchange-rate regimes, rates of domestic money growth, regulation of domestic- and foreign-reserve requirements, and the backing for the domestic money supply. We are fully aware that in the aftermath of a financial crisis, the policy considerations assume far greater importance than is standard, and the trade-offs being weighed become correspondingly more complex. We compare policies from the standpoint of steady-state welfare, stability, and the scope for existence of panic and non-panic equilibria. Accounting as it does for the complexity of the interactions among various policy proposals, the model is suitable for predicting volatility and stability along dynamic paths, the possibility of cyclical fluctuations, and the endogenously-arising volatility (Wang and Hernandez, 2011).

In conclusion, we observe a continuum of stationary equilibria. Local uniqueness and determinacy are lacking when no crises are present. We examine the potential for crises in the case of a sudden stop in a small open economy that is a net borrower. We show that the existence of equilibria of four types can be ranked based on the information constraints and on social welfare. The goals of the monetary authority are to maximize the likelihood of non-panic equilibria and to minimize that of panic equilibria. Under a floating regime, the policy combinations consistent with this goal display a high rate of domestic money growth, high reserve requirements, and a strong backing of the domestic money supply. Under a hard peg, this goal is accomplished by instituting low reserve requirements and a higher backing of the domestic money supply.

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Appendix A: The General Equilibrium System under a Floating Exchange Rate

The general equilibrium system is characterized by equilibrium variables. The domestic price level $\hat{p}_t$ clears the market for domestic real-money balances:

$$\hat{M}_t / \hat{p}_t = \hat{z}_t = \phi_d \left(w + \hat{\tau}_t \right).$$

(A.1.1)

It leads to the equilibrium return of domestic real-money balances

$$\hat{p}_t / \hat{p}_{t+1} = \left(1 + \sigma \right)^{-1} \left(\hat{z}_{t+1} / \hat{z}_t \right)$$

(A.1.2)

and, using also the government budget constraint in equation (5), to the equilibrium laws of motion of z_t and τ_t, respectively.

$$\hat{z}_t = a_0 \left(\sigma \right) + a_1 \left(\sigma \right) \cdot \hat{z}_{t-1},$$

(A.1.3)

$$\hat{\tau}_t = b_0 \left(\sigma \right) + b_1 \left(\sigma \right) \cdot \hat{z}_{t-1},$$

(A.1.4)

where the reduced-form coefficients are given by

$$a_0 \equiv \frac{\phi_d \cdot w \cdot \left(1 + \sigma \right)}{\left\{ 1 + \theta \cdot \phi_d + \sigma \cdot \left[1 - \phi_d \cdot \left(1 - \theta \right) \right] \right\}}, a_1 \equiv \frac{\theta \cdot \phi_d \cdot \varepsilon \cdot \left(1 + \sigma \right)}{\left\{ 1 + \theta \cdot \phi_d + \sigma \cdot \left[1 - \phi_d \cdot \left(1 - \theta \right) \right] \right\}},$$

$$b_0 \equiv \frac{a_0}{\phi_d} - w, b_1 \equiv \frac{a_1}{\phi_d}.$$

The representative bank's long-term investment in equilibrium follows

$$\hat{k}_{t+2} = k \left(\hat{z}_t \right) = c_0 + c_1 \cdot \hat{z}_t,$$

(A.1.5)

where $c_0 \equiv f_0 + \left(1 - \phi_d - \phi_f \right) \cdot \left(w + b_0 \right), c_1 \equiv \left(1 - \phi_d - \phi_f \right) \cdot b_1.$

The market for foreign currency also clears when $\hat{q}_t \equiv \left(e_t \cdot \hat{Q}_t / \hat{p}_t \right) = \phi_f \cdot \left(w + \hat{\tau}_t \right) = \phi_f \cdot \hat{z}_t / \phi_d$. In equilibrium, q_t and b_t^* are governed by the following two reduced-form equations

$$\hat{q}_t = q \left(\hat{z}_t \right) = d_0 + d_1 \cdot \hat{z}_{t-1},$$

(A.1.6)

$$\hat{b}_t = b\left(\hat{z}_t\right) = e_0 + e_1 \cdot \hat{z}_{t-1},$$
(A.1.7)

where $d_0 \equiv \phi_f \cdot \left(w + b_0\right), d_1 \equiv \phi_f \cdot b_1$ and $e_0 \equiv \theta \cdot a_0, e_1 \equiv \theta \cdot a_1$.

Moreover, the endogenous growth rate of the supply of foreign currency in the domestic economy is given by

$$\left(\hat{Q}_{t+1}/\hat{Q}_t\right) = \left[\left(1+\sigma^*\right) \cdot \hat{z}_{t+1}\right]/\hat{z}_t,$$
(A.1.8)

while the nominal exchange rate follows:

$$\left(e_{t+1}/e_t\right) = \left[\left(1+\sigma\right) \cdot \hat{z}_t\right]/\left[\left(1+\sigma^*\right) \cdot \hat{z}_{t+1}\right].$$
(A.1.9)

Finally, there are several conditions that characterize deposit contracts in equilibrium. One, the truth-telling condition in (2) applies. Two, the constraints on foreign credit must be combined, and thus

$$\hat{d}_{0,t} + \hat{d}_{2,t+1} = f_0 \text{ and } \hat{d}_{1,t+1} + \hat{d}_{2,t+1} = f_1.$$
(A.1.10)

A.1. Stationary Equilibrium

The core dynamic system is de-coupled, inheriting its dynamics from $\hat{z}_t$. The stationary values of core variables are:

$$\hat{z} = \left\langle \phi_d \cdot w \cdot (1+\sigma) \big/ \left(\sigma \cdot \left[1 - \phi_d \cdot (1 + \theta \cdot (\tilde{r}-1))\right] + 1 - \phi_d \cdot \theta \cdot (\tilde{r}-1)\right)\right\rangle$$

$$\hat{\tau} = \left\langle w \cdot \left\{\theta \cdot \phi_d \cdot (\tilde{r}-1) + \sigma \cdot \phi_d \cdot \left[\theta \cdot (\tilde{r}-1)+1\right]\right\} \big/ \left(\sigma \cdot \left[1 - \phi_d \cdot (1 + \theta \cdot (\tilde{r}-1))\right] + 1 - \phi_d \cdot \theta \cdot (\tilde{r}-1)\right)\right\rangle$$

$$\hat{q} = \left[\phi_f \cdot w \cdot (1+\sigma) \big/ \left(\sigma \cdot \left[1 - \phi_d \cdot (1 + \theta \cdot (\tilde{r}-1))\right] + 1 - \phi_d \cdot \theta \cdot (\tilde{r}-1)\right)\right]$$

$$\hat{b}^* = \left[\theta \cdot \phi_d \cdot w \cdot (1+\sigma) \big/ \left(\sigma \cdot \left[1 - \phi_d \cdot (1 + \theta \cdot (\tilde{r}-1))\right] + 1 - \phi_d \cdot \theta \cdot (\tilde{r}-1)\right)\right]$$

$$\hat{k} = \xi_1(\sigma) + \xi_2(\sigma) \cdot \hat{z}$$
(A.1.11)

where $\xi_1(\sigma) \equiv f_0 + \left[\left(1 - \phi_d - \phi_f\right) \cdot w \cdot \left\{2 + \theta \cdot \phi_d + \sigma \cdot \left[2 - \phi_d \cdot (1-\theta)\right]\right\}\right]\big/\left\{1 + \theta \cdot \phi_d + \sigma \cdot \left[1 - \phi_d \cdot (1-\theta)\right]\right\}$ and $\xi_2(\sigma) \equiv \left[\left(1 - \phi_d - \phi_f\right) \cdot \theta \cdot \tilde{r} \cdot (1+\sigma)\right]\big/\left\{1 + \theta \cdot \phi_d + \sigma \cdot \left[1 - \phi_d \cdot (1-\theta)\right]\right\}$. Notice that $\left(\hat{z}, \hat{q}, \hat{b}^*\right)$ are increasing in the policy parameters (σ, ϕ_d, θ) and that, as expected, $\hat{q}$ is increasing in ϕ_f. In addition, $\hat{\tau}$ is nonlinear in both σ and ϕ_d but monotonically increasing in θ. Finally, $\hat{k}$ is increasing in σ, but nonlinear in $\left(\phi_d, \phi_f\right)$. With respect to the steady-state gross returns on domestic and foreign real-money balances, the rise of the nominal exchange rate, and the

strengthening of the real exchange rate, they are all constant and equal to $(1+\sigma)^{-1}$, $(1+\sigma^*)$, $(1+\sigma)\cdot(1+\sigma^*)^{-1}$ and 1, respectively.

The steady-state consumption vector and the steady-state expected utility follow

$$\lambda\cdot\hat{c}_1 = f_1 - r_0^*\cdot f_0 + \left(r_0^*-1\right)\cdot\left[\Theta_0\left(\sigma\right)+\Theta_2\left(\sigma\right)\right]+\hat{z}\cdot\left[\Theta_1\left(\sigma\right)+\Theta_3\left(\sigma\right)+\Theta_4\left(\sigma\right)\right]$$

$$(1-\lambda)\cdot\hat{c}_2 = \text{Ж}_0\left(\sigma\right)-\left(R-r_1^*\right)\cdot\Theta_0\left(\sigma\right)+\Theta_2\left(\sigma\right)+\hat{z}\cdot\left[\Theta_1\left(\sigma\right)+\Theta_3\left(\sigma\right)+\Theta_4\left(\sigma\right)\right]$$

$$\hat{U} = \lambda\cdot\ln\left(\hat{c}_1\right)+(1-\lambda)\cdot\ln\left(\hat{c}_2\right)$$

(A.1.12)

where the intercept is $\text{Ж}_0(\sigma)\equiv\left[r_2^*\cdot\xi_1\left(\sigma\right)\cdot(1-\lambda)^{-1}+\phi_d\cdot w\cdot(1-\lambda)^{-1}\cdot\left(1+\sigma^*\right)^{-1}-r_1^*\cdot f_1\right]$. The reduced-form coefficients are given by $\Theta_1\left(\sigma\right)\equiv r_2^*\cdot\xi_2\left(\sigma\right)$, $\Theta_2\left(\sigma\right)\equiv\left[\phi_d\cdot w/\left(1+\sigma^*\right)\right]$, $\Theta_3\left(\sigma\right)\equiv(1+\sigma)^{-1}$ and $\Theta_4\left(\sigma\right)\equiv\phi_f\cdot\left[\phi_d\cdot\left(1+\sigma^*\right)\right]^{-1}$.

Focusing on the structure of foreign debt issued by domestic banks, we observed multiple stationary equilibria in this model economy with floating exchange rates. The general properties of the interior solution displayed by the stationary debt-structure in equilibrium depend on different values of the policy parameter σ. Thus, σ is a bifurcation parameter of the steady-state allocation given by $\left\{\left(\hat{z},\hat{\tau},\hat{q},\hat{b}^*,\hat{k}\right),\left(\hat{d}_0,\hat{d}_1,\hat{d}_2\right),\left(\hat{c}_1,\hat{c}_2\right)\big|\,\hat{l}=0\right\}$, and so is the structure of the interest rates $\left(r_0^*,r_1^*,r_2^*\right)\gg1$. Note that the core in the steady state $\left(\hat{z},\hat{\tau},\hat{q},\hat{b}^*,\hat{k}\right)$ is always unique and determinate, since it is not associated with the vector $\left(r_0^*,r_1^*,r_2^*=R\right)$. However, for a fixed point in the parameter space and for each stationary debt-structure vector $\left(\hat{d}_{0,j},\hat{d}_{1,j},\hat{d}_{2,j}\right)$, there is typically a continuum of vectors of interest rates satisfying the equilibrium conditions.

Appendix B: The General Equilibrium System under a Fixed Exchange Rate

The equilibrium laws of motion in equations (A.1.3) must be modified, and the following two equations come into play:

$$\overline{\tau}_t = \eta_1\left(\sigma^*\right) + \eta_2\left(\sigma^*\right) \cdot \overline{\tau}_{t-1},$$

(B.1.1)

$$\overline{z}_t = \rho_1\left(\sigma^*\right) + \rho_2\left(\sigma^*\right) \cdot \overline{\tau}_{t-1},$$

(B.1.2)

where the coefficients are $\eta_1\left(\sigma^*\right) = \left\langle \phi_d \cdot w \cdot \left\{ \left(1+\sigma^*\right) \cdot \left[\theta \cdot \left(\tilde{r}-1\right)+1\right]-1\right\} \middle/ \varkappa\left(\sigma^*\right)\right\rangle$, $\eta_2\left(\sigma^*\right) = \left\{ \phi_d \cdot \left[\theta \cdot \tilde{r} \cdot \left(1+\sigma^*\right)-1\right] \middle/ \varkappa\left(\sigma^*\right)\right\}$, $\rho_2\left(\sigma^*\right) \equiv \phi_d \cdot \eta_2\left(\sigma^*\right)$, $\rho_1\left(\sigma^*\right) \equiv \phi_d \cdot \left[w + \eta_1\left(\sigma^*\right)\right]$, and $\varkappa\left(\sigma^*\right) \equiv \left(1+\sigma^*\right) \cdot \left[1-\phi_d \cdot \left(1-\theta\right)\right]$. Notice that the equations above are first-order linear difference equations in τ_t. Under this hard peg, the dynamics of the system originate in τ_t instead of z_t, as was the case under floating exchange rates. We modify the equilibrium laws of motion to represent the hard peg and obtain:

$$\overline{q}_t = \chi_1\left(\sigma^*\right) + \chi_2\left(\sigma^*\right) \cdot \overline{\tau}_{t-1},$$

(B.1.3)

$$\overline{b}_t^* = \psi_1\left(\sigma^*\right) + \psi_2\left(\sigma^*\right) \cdot \overline{\tau}_{t-1},$$

(B.1.4)

where $\chi_1\left(\sigma^*\right) \equiv \phi_f \cdot \rho_1\left(\sigma^*\right) \middle/ \phi_d$, $\chi_2\left(\sigma^*\right) \equiv \phi_f \cdot \rho_2\left(\sigma^*\right) \middle/ \phi_d$, $\psi_1\left(\sigma^*\right) \equiv \theta \cdot \rho_1\left(\sigma^*\right)$ and $\psi_2\left(\sigma^*\right) \equiv \theta \cdot \rho_2\left(\sigma^*\right)$. Next, the nominal exchange rate becomes

$$\left(\overline{e}_{t+1} \middle/ \overline{e}_t\right) = \left(e \middle/ e\right) = 1.$$

(B.1.5)

The equilibrium conditions related to the deposit contract offered by banks are as follows. One, the truth-telling constraint in (2) applies. Two, the constraints on foreign credit in (6) and (7) continue in force. Three, the equilibrium law of motion for the long-term investment is now given by

$$\overline{k}_{t+1} = \varsigma_1\left(\sigma^*\right) + \varsigma_2\left(\sigma^*\right) \cdot \overline{\tau}_{t-1},$$

(B.1.6)

where $\varsigma_1\left(\sigma^*\right) \equiv f_0 + \left(1-\phi_d-\phi_f\right) \cdot \rho_1\left(\sigma^*\right) \middle/ \phi_d$ and $\varsigma_2\left(\sigma^*\right) \equiv \left(1-\phi_d-\phi_f\right) \cdot \rho_2\left(\sigma^*\right) \middle/ \phi_d$. Four, the total return on domestic- and foreign-currency reserves under this policy regime is given, respectively, by the following two equations:

$$\phi_d \cdot \left(\overline{p}_t / \overline{p}_{t+1} \right) \cdot \left(w + \overline{\tau}_t \right) = \mu_1 \left(\sigma^* \right) + \mu_2 \left(\sigma^* \right) \cdot \overline{\tau}_{t-1} \,, \tag{B.1.7}$$

$$\phi_f \cdot \left(p_t^* / p_{t+1}^* \right) \cdot \left(w + \overline{\tau}_t \right) = \upsilon_1 \left(\sigma^* \right) + \upsilon_2 \left(\sigma^* \right) \cdot \overline{\tau}_{t-1} \,, \tag{B.1.8}$$

where the coefficients are $\mu_1 \left(\sigma^* \right) \equiv \rho_1 \left(\sigma^* \right) / \left(1 + \sigma^* \right)$, $\mu_2 \left(\sigma^* \right) \equiv \rho_2 \left(\sigma^* \right) / \left(1 + \sigma^* \right)$, $\upsilon_1 \left(\sigma^* \right) \equiv \chi_1 \left(\sigma^* \right) / \left(1 + \sigma^* \right)$ and $\upsilon_2 \left(\sigma^* \right) \equiv \chi_2 \left(\sigma^* \right) / \left(1 + \sigma^* \right)$. Five, the space-contingent commodities are governed by

$$\lambda \cdot \overline{c}_{1,t,j} = f_1 - r_0^* \cdot f_0 + \left(r_0^* - 1 \right) \cdot \overline{d}_{2,t+1,j} \tag{B.1.9}$$

$$\left(1 - \lambda \right) \cdot \overline{c}_{2,t+1,j} = \omega_1 \left(\sigma^* \right) + \omega_2 \left(\sigma^* \right) \cdot \overline{\tau}_{t-1} - r_1^* \cdot f_1 - \left(r_2^* - r_1^* \right) \cdot \overline{d}_{2,t+1,j} \,, \tag{B.1.10}$$

where the parameters are $\omega_1 \left(\sigma^* \right) \equiv r_2^* \cdot \varsigma_1 \left(\sigma^* \right) + \mu_1 \left(\sigma^* \right) + \upsilon_1 \left(\sigma^* \right)$ and $\omega_2 \left(\sigma^* \right) \equiv r_2^* \cdot \varsigma_2 \left(\sigma^* \right) + \mu_2 \left(\sigma^* \right) + \upsilon_2 \left(\sigma^* \right)$.

B.1. Stationary Equilibria

The five variables that belong to the core, $\left(\overline{\tau}_t, \overline{z}_t, \overline{q}_t, \overline{b}_t^*, \overline{k}_{t+1} \right)$, are determinate under a fixed exchange-rate regime whenever an equilibrium exists, since they do not depend on the foreign interest rates $\left(r_0^*, r_1^*, r_2^* \right)$. We obtained the steady-state values for the variables in the core in the following five expressions:

$$\overline{\tau} = \eta_1 \left(\sigma^* \right) / \left[1 - \eta_2 \left(\sigma^* \right) \right] = \left\langle \phi_d \cdot w \cdot \left\{ \left(1 + \sigma^* \right) \cdot \left[1 + \theta \cdot \left(\tilde{r} - 1 \right) \right] - 1 \right\} / \text{\tiny M} \left(\sigma^* \right) \right\rangle$$

$$\overline{z} = \left[\phi_d \cdot w \cdot \left(1 + \sigma^* \right) / \text{\tiny M} \left(\sigma^* \right) \right]$$

$$\overline{q} = \left[\phi_f \cdot w \cdot \left(1 + \sigma^* \right) / \text{\tiny M} \left(\sigma^* \right) \right]$$

$$\overline{b}^* = \left[\theta \cdot \phi_d \cdot w \cdot \left(1 + \sigma^* \right) / \text{\tiny M} \left(\sigma^* \right) \right]$$

$$\overline{k} = f_0 + \left(1 - \phi_d - \phi_f \right) \cdot w + \left\langle \phi_d \cdot \left(1 - \phi_d - \phi_f \right) \cdot \left\{ \left(1 + \sigma^* \right) \cdot \left[\theta \cdot \left(\tilde{r} - 1 \right) + 1 \right] - 1 \right\} / \text{\tiny M} \left(\sigma^* \right) \right\rangle \tag{B.1.11}$$

Here, $\text{\tiny M} \left(\sigma^* \right) \equiv \left(1 + \sigma^* \right) - \phi_d \cdot \left\{ \left(1 + \sigma^* \right) \cdot \left[1 + \theta \cdot \left(\tilde{r} - 1 \right) \right] - 1 \right\}$, where $\left(1 + \sigma^* \right) \cdot \left[1 + \theta \cdot \left(\tilde{r} - 1 \right) \right] > 1$ is the case, $\forall \sigma^* > -1$. Given the latter, we found it reasonable to restrict our attention to allocations where $\left(1 + \sigma^* \right) > \phi_d \cdot \left\{ \left(1 + \sigma^* \right) \cdot \left[1 + \theta \cdot \left(\tilde{r} - 1 \right) \right] - 1 \right\} > 0$ is present, $\forall \sigma^* > -1$. It follows that $\overline{\tau} > 0$, and $\left(\partial \overline{\tau} / \partial \sigma^* \right) > 0$.

Stationary equilibria under fixed exchange rates are defined by allocations such that $\left\{\left(\overline{\tau},\overline{z},\overline{q},\overline{b}*,\overline{k}\right),(\overline{d}_0,\overline{d}_1,\overline{d}_2),(\overline{c}_1,\overline{c}_2)\middle|\overline{l}=0\right\}\in\mathbf{R}_{++}^5\times\mathbf{R}_+^3\times\mathbf{R}_{++}^2$, which satisfy all the conditions given above. Of course, the particular case of equilibrium that arises and its properties will depend on the composition of the vector $(\overline{d}_0,\overline{d}_1,\overline{d}_2)$ as we will see when checking for existence, uniqueness, and determinacy.

We observed the foreign-debt-structure vector $(\overline{d}_0,\overline{d}_1,\overline{d}_2)=(f_0-\overline{d}_2,f_1-\overline{d}_2,\overline{d}_2)\gg 0$. The foreign long-term debt in a stationary equilibrium with a hard peg is given by

$$\overline{d}_2=\Omega_0\left(\sigma^*\right)+\Omega_1\left(\sigma^*\right)\cdot\overline{\tau},\tag{B.1.12}$$

where $\Omega_0(\sigma^*)\equiv\left\{\lambda\cdot(1+\sigma^*)r_2^*\cdot\varsigma_1(\sigma^*)+\lambda\cdot(\phi_d+\phi_f)\left[\eta_1(\sigma^*)-w\right]-r_1^*\cdot(1+\sigma^*)\cdot(r_0^*-r_1^*)\right\}/\left[r_1^*\cdot(1+\sigma^*)\cdot(r_0^*-r_1^*)\right]$, and $\Omega_1(\sigma^*)\equiv\lambda\cdot\left[(1+\sigma^*)\cdot r_2^*\cdot\varsigma_2(\sigma^*)+(\phi_d+\phi_f)\cdot\eta_2(\sigma^*)\right]/\left[r_1^*\cdot(1+\sigma^*)\cdot(r_0^*-r_1^*)\right]$. The vector of state-contingent consumption and the expected utility are obtained from

$$\lambda\cdot\overline{c}_1=f_1-r_0^*\cdot f_0+\left(r_0^*-1\right)\cdot\Omega_0\left(\sigma^*\right)+\left(r_0^*-1\right)\cdot\Omega_1\left(\sigma^*\right)\cdot\overline{\tau},\tag{B.1.13}$$

$$(1-\lambda)\cdot\overline{c}_2=\Sigma_0\left(\sigma^*\right)-\left(R-r_1^*\right)\cdot\Omega_0\left(\sigma^*\right)+\left[\Sigma_1\left(\sigma^*\right)-\left(R-r_1^*\right)\cdot\Omega_1\left(\sigma^*\right)\right]\cdot\overline{\tau},\tag{B.1.14}$$

$$\overline{U}=\lambda\cdot\ln\left(\overline{c}_1\right)+(1-\lambda)\cdot\ln\left(\overline{c}_2\right)\tag{B.1.15}$$

Appendix C: Re-optimization

In this section, we describe new equilibria after re-optimization that resulted from the sequential checking process. The sequential checking mechanism re-evaluates (15), (16), and (2) given $\tilde{d}_{1,t+1}$, and determines the equilibria obtained accordingly. Banks maximize expected utility by choosing $(\tilde{d}_{1t+1}, \tilde{l}_t)$, subject to a new budget constraint (14), the relevant budget constraints, and the exchange-rate regime. To proceed, we first set $\tilde{d}_1 = f_1' - d_2 < d_1$, and $\tilde{l} \neq 0$ and solve for c_1 and c_2, respectively, as functions of $\tilde{l}$. Next, we impose equality in (2) and solve for $\tilde{l}$. Below, we present the results for early liquidation after a sudden stop, under floating and fixed exchange rates, respectively.

$$\hat{\tilde{l}}_j = \frac{\lambda \cdot (1-\lambda)\left[r \cdot \left(r_0^* - 1\right) \cdot f_0 - r_1^* \cdot f_1'\right]}{(1-\lambda) \cdot r^2 + \lambda R} + \left[\frac{\lambda}{(1-\lambda) \cdot r^2 + \lambda R}\right] \cdot \left\{R \cdot \hat{k} + (w + \hat{\tau})\left[\frac{\phi_d}{(1+\sigma)} + \frac{\phi_f}{(1+\sigma^*)}\right]\right\}$$
$$- \left[\frac{\lambda \cdot \left(R - r_0^*\right) + (1-\lambda) \cdot \left(r_0^* - 1\right)}{(1-\lambda) \cdot r^2 + \lambda R}\right] \cdot \hat{d}_{2,j}$$
, (C.1)

$$\overline{\tilde{l}}_j = \frac{\lambda \cdot (1-\lambda)\left[r \cdot \left(r_0^* - 1\right) \cdot f_0 - r_1^* \cdot f_1'\right]}{(1-\lambda) \cdot r^2 + \lambda R} + \left[\frac{\lambda}{(1-\lambda) \cdot r^2 + \lambda R}\right] \cdot \left\{R \cdot \hat{k} + \frac{(w + \hat{\tau}) \cdot (\phi_d + \phi_f)}{(1+\sigma^*)}\right\}$$
$$- \left[\frac{\lambda \cdot \left(R - r_0^*\right) + (1-\lambda) \cdot \left(r_0^* - 1\right)}{(1-\lambda) \cdot r^2 + \lambda R}\right] \cdot \overline{d}_{2,j}$$
. (C.2)

We must point out that $\tilde{l}$ is monotonically decreasing in f_1', which ensures a positive amount of early liquidation in equilibrium after the economy is hit by a sudden stop. Also, $\tilde{l}$ is a monotonically decreasing function of d_2, indicating that economies that borrow larger long-term amounts may experience smaller amounts of early liquidation of long-term investments.

When the sudden withdrawal of access to foreign credit appears on the scene, anxious domestic depositors and foreign creditors start checking a bank's capacity of operation. Under illiquidity, the credit crunch among foreign creditors will directly impact banks' solvency. In solving for long-term debt, the vector $(d_{0,2}, \tilde{d}_{1,2}, d_{2,2}) = (f_0 - d_{2,2}, f_1' - d_{2,2}, d_{2,2})$ becomes relevant. Banks must prematurely liquidate the amount of $\tilde{l} > 0$. In this particular subset of the parameter space, equilibria of Type 1 and Type 4 are not applicable, so the economy will not experience the best non-panic equilibria, but neither

the worst panic equilibria. Even though foreign lending could serve as a last resort for the illiquid bank, the depositors' beliefs may deteriorate and take the economy into a panic equilibrium. Thus, equilibria of Type 3 may exist, since incentive compatibility is violated for particular values of f_1, σ , and world interest rates. We observe that a change in borrowing constraints or in policy parameters illustrates a fragile and highly volatile environment faced by the financial system, which could lead to panics and generalized bankruptcies.