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ABSTRACT

Emerging economies are exposed to severe and sudden shortages of international financial resources. Yet domestic agents seem not to undertake enough precautions against these sudden stops. Following our previous work, we highlight in this paper the central role played by limited domestic development in ex-ante (insurance) and ex-post (spot) financial markets in generating this collective undervaluation of external resources and insurance. Within this structure, this paper studies several canonical policies to counteract the external underinsurance. We do this by first solving for the optimal mechanism given the constraints imposed by limited domestic financial development, and then considering the main - in terms of the model and practical relevance - implementations of this mechanism.

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1 Introduction

To a first order, an emerging economy external crisis can be described as an event in which a country's international financing needs significantly exceed its international financial resources. Given that these events are a "fact-of-life" in these economies, it is puzzling that domestic agents do not undertake measures to precaution against them. Indeed, quite the contrary, they often increase the likelihood of these events by over-borrowing during capital inflow booms, contracting dollar liabilities, and so on.

A common explanation for this behavior is that it is due to distortions created by anticipated official interventions, such as crony capitalism, fixed exchange rates, and IFI's bailouts.¹

We have argued elsewhere that the *external underinsurance problem* in these economies is more structural in nature than one concludes from just pointing at potentially misguided interventions. Underdeveloped financial markets, a basic feature of emerging economies, leads to a distorted valuation of international resources that in turn leads to external underinsurance. In this paper, we take this structure as given, and explore a series of canonical solutions to the underinsurance problem. Since the strategies we discuss are all used in varying form by governments in emerging markets, our main interest is in providing guidance on which strategies may work better under different constraints. We identify the strategies that work within our model and discuss some of the difficulties they may encounter in implementation.

In our framework, when a country's international financing needs exceed its international collateral (or liquidity), the domestic price of the latter rises vis-à-vis that of domestic collateral (or liquidity). A depreciation of the exchange rate, for example, is a manifestation of this phenomenon.²

However, when domestic financial markets are underdeveloped — in our terminology, when the domestic collateral value of projects is less than their expected revenues — agents' external insurance decisions are distorted. The reason is that domestic agents in need of external resources cannot transfer the full surplus generated by these resources to other participants in domestic financial markets that do have access to the scarce external funds. Thus, in equilibrium, the scarcity value of external resources is depressed, and private decisions are biased against hoarding international liquidity and thereby insuring against these events. The underinsurance with respect to external shocks takes many forms: excessive

¹See, for example, Krugman (1998), Burnside, Eichenbaum and Rebelo (2000), or Dooley (1999).

²See Caballero and Krishnamurthy (2001c).

external borrowing during booms, a maturity structure of private debt that is distorted toward the short term, dollarization of international liabilities, limited international credit lines, and so on.³

In this paper we study in a unified framework several of the main solutions to this underinsurance problem. Section 2 presents the environment that we have used in earlier work, and reproduces the result of collective external underinsurance in the competitive equilibrium with only spot loan markets. One difference in the current model is that we suppress all aggregate shocks. The reason is that our focus is on domestic arrangements to deal with the underinsurance problem. To keep matters simple, we do not discuss at all international credit lines and other valuable insurance mechanisms that involve foreigners.⁴ Alternatively, one can think of our discussion as net of these external insurances. A binding aggregate external constraint will be fully anticipated and still occur. External underinsurance, in its many forms, will simply collapse into excessive international borrowing during capital inflow booms.

While aggregate shocks have no role in the analysis, idiosyncratic ones are central since they generate the need for domestic financial transactions. Frictions in these transactions are at the root of the external underinsurance problem. In section 3, we show that if *domestic* agents are able to write complete insurance contracts with each other, the *external* underinsurance problem disappears. More domestic insurance increases the distressed firms' collateral ex-post, and hence their capacity to bid for the external resources held by other domestics. In equilibrium, this raises the relative price of international to domestic collateral, increasing the incentive to hoard international resources.

An important aspect of financial underdevelopment, however, is the absence of these private insurance markets. In section 4, we assume that idiosyncratic shocks are unobserved so they cannot be written into insurance arrangements. We solve the mechanism design problem associated with the private information constraint within our structure, and show that the social planner can in principle get around this informational constraint and achieve the competitive equilibrium with complete idiosyncratic insurance markets. We then turn to implementation of the social planner's mechanism. We begin by analyzing a solution whereby private agents form a conglomerate and extend credit lines to each other. While this arrangement is *individually* incentive compatible, it is not *coalition* incentive compatible and hence is not robust to the presence of spot markets, as in Jacklin (1987). Finally, we

³See Caballero and Krishnamurthy (2000a) and (2001a).

⁴See Caballero and Krishnamurthy (2000a) and (2001b) for discussions of insurance arrangements with foreigners.

explore two sets of solutions that require government intervention: Capital flows taxation or mandated international liquidity requirements, and sterilization of capital inflows. These solutions can also work, but they are subject to other forms of the coalition incentive compatibility problem as well.

2 A model of external underinsurance

We begin by laying out the model and describing the external underinsurance in the competitive equilibrium with only spot loan markets. In the next sections we shall discuss how this result is affected by better domestic insurance arrangements, or in their absence, by centralized arrangements to directly deal with the external underinsurance problem.

2.1 The environment

Consider a three date, $t = 0, 1, 2$, economy with a single consumption good. There are two classes of agents in the economy: a unit measure each of domestics and foreigners. Both take as objective to maximize date 2 expected consumption of the good,

$$U = E[c_2], \quad c_2 \geq 0.$$

Each domestic is an entrepreneur/manager who owns and operates a production technology within a firm. Investing $c(k)$ units of the good at date 0 results in capital of k units, where $c(k)$ is strictly increasing, positive, and strictly convex with $c(0) = 0, c'(0) = 0$.

As part of the normal ongoing restructuring of an economy, one-half of the firms (randomly chosen) need to re-inject resources into the firm at date 1 to achieve full output. Let $j \in \{i, d\}$ be the type of the firm at date 1. Firms that are not hit by this idiosyncratic shock are i-types (“intact”) and go on to produce date 2 output of Ak . Firms that receive the shock are d-types (“distressed”). Their output falls to ak , but by reinvesting $I \leq k$ units of good, the d-firm can obtain $I\Delta$ additional units of goods at date 2. We normalize $\Delta = A - a$, and assume that $\Delta > 1$. With full reinvestment, $I = k$, a distressed firm obtains the same output as an intact firm, Ak . In all cases of interest below, $I < k$, thus we henceforth drop this maximum reinvestment constraint from our discussion (while ensuring that it does not bind in our technical assumptions).

The domestic economy has no goods at either date 0 or date 1. All investment needs are met by importing goods from abroad, which are paid for with funds raised from loans. We assume that foreigners have large endowments of goods at all dates, and have access to storage with rate of return one.

Firms face significant financial constraints. Neither the plants nor their expected output are valued as collateral by foreigners. Instead, we assume that each domestic is endowed with w units of a good that arrives at date 2 and can be pledged as collateral to a foreign lender – i.e. domestics can take out loans against w that will be enforced by international courts. Tangibly, we might think of w as revenues from oil exports that reside in foreign bank accounts.

Assumption 1 (International collateral)

Domestics may take on loans at either date 0 or date 1 from foreign lenders against the international collateral of w , and must satisfy a full collateralization constraint:

$$d_{0,f} + d_{1,f} \leq w.$$

A domestic can also take on a loan from another domestic. Unlike foreigners, domestics do accept the plants as collateral. However we shall assume that these contracts are also imperfect in the sense that not all of the output of Ak is collateral.

Assumption 2 (Domestic debt and collateral)

We assume that domestic courts are additionally able to enforce domestic (local) debt contracts up to an amount of λak where $\lambda \leq 1$. Thus, the domestic lending constraint is:

$$d_{0,l} + d_{1,l} \leq \lambda ak + w - (d_{0,f} + d_{1,f})$$

Assumptions 1 and 2 are how we define an emerging economy. Thus, we think of the latter as an economy where pledgable assets are limited, *and* a large share of these assets are part of domestic but not international collateral.

We define an external crisis as a date 1 event in which the financing needs of the economy, $\frac{1}{2}k$, exceeds the international financial resources available to it, $(w - d_{0,f})$. Since they are not central to our concerns and results in this paper, we suppress all aggregate shocks. The external crisis happens despite being fully anticipated. This simplifies our discussion and means that external underinsurance will only take the form of overborrowing at date 0 (see below). With some abuse of terminology, we will continue referring to the latter as external underinsurance. The following assumptions on parameters guarantee that a crisis occurs at date 1 in all the equilibria we study throughout the paper, and that there is external underinsurance in the spot loan market equilibrium:

Technical Assumptions 1

$$\begin{aligned} (1) \quad & c'^{-1} \left(\frac{A+a}{2\Delta} \right) \lambda a > w - c \left(c'^{-1} \left(\frac{A+a}{2\Delta} \right) \right), \\ (2) \quad & c'^{-1} \left(\frac{A+a+\lambda a(\Delta-1)}{1+\Delta} \right) \lambda a < \left(w - c \left(c'^{-1} \left(\frac{A+a+\lambda a(\Delta-1)}{1+\Delta} \right) \right) \right) \Delta \\ (3) \quad & \lambda a \leq 1 \end{aligned}$$

2.2 Spot loan markets

Let us begin by studying the equilibrium in this economy when agents are restricted to borrowing via a sequence of spot loan contracts. Thus what we rule out for now are domestic insurance arrangements.

All of the investment needs of domestics (date 0 and date 1) have to be met by importing goods from foreigners. The goods are paid for by issuing date 2 debt claims. Suppose that each firm takes on foreign debt at date 0 of $d_{0,f}$ and invests all of these resources in building a plant of size k . Since firms are ex-ante identical, without loss of generality we can assume there is no domestic debt at time 0.

A firm at date 1 finds itself either distressed or intact. If distressed, it borrows up to its maximum international debt capacity in order to take advantage of the high return of rebuilding/restructuring the firm:

$$d_{1,f} = w - d_{0,f}.$$

These resources are then invested until date 2, yielding $d_{1,f}\Delta$.

After this, it must turn to intact domestic firms for funds. Intact firms have no output at date 1 either, so they must borrow from foreigners if they are to finance the distressed firms. This they can do up to their $w - d_{0,f}$ of financial slack. Unlike foreigners, domestics are willing to lend to other domestic against their projects. Since firms can use this collateral to borrow up to λak , we refer to this quantity as *domestic collateral*.

Denote the gross interest rate in this domestic loan market as L_1 . Then the firm takes out the maximum loan as long as $\Delta \geq L_1$:

$$d_{1,l} = \lambda ak.$$

As a result of domestic borrowing the firm raises $\frac{d_{1,l}}{L_1}$ for investment, to yield $\frac{\lambda ak}{L_1}\Delta$ at date 2.

Combining the above transactions, and taking into account that date 0 investment yielded ak at date 2, the profits accumulating to this firm at date 2 are,

$$V^d = (w - d_{0,f})\Delta + \frac{\lambda ak}{L_1}\Delta + (1 - \lambda)ak.$$

Intact firms, on the other hand, have the opportunity to lend to distressed firms at date 1. As long as $L_1 \geq 1$, the intact firm will borrow up to its maximum foreign debt capacity,

$$d_{1,f} = w - d_{0,f},$$

and invest these resources in the domestic loan market to yield L_1 . Denote x_1 as the face value of date 2 claims that the intact firm purchases. Then the intact firm makes date 2 profits of,

$$V^i = x_1 L_1 + Ak + (w - d_{0,f} - d_{1,f}) = (w - d_{0,f})L_1 + Ak.$$

Finally, at date 0, firms are equally likely to be distressed or intact. Thus they solve,

$$V^{spot} = \max_{k, d_{0,f}} \frac{1}{2}(w - d_{0,f})(L_1 + \Delta) + \frac{1}{2} \left(A + (1 - \lambda)a + \frac{\lambda a}{L_1} \Delta \right) k$$

$$s.t. \quad d_{0,f} \leq w$$

$$c(k) = d_{0,f}.$$

The only market clearing condition is that the loans issued by distressed firms must equal the loans purchased by intact ones:

$$\frac{1}{2}d_{1,l} = \frac{1}{2}x_1, \tag{1}$$

where the one half in front of each microeconomic decision reminds us that distressed and intact firms form equally sized groups.

Definition. *Equilibrium* in the economy with only sequential spot loan markets consists of decisions, $(k, d_{0,f}, d_{1,f}, d_{1,l}, x_1)$ and the domestic interest rate, L_1 . Decisions are optimal given L_1 , and given these decisions, the market clearing condition (1) holds.

Figure 1: Date 1 Market Clearing for Domestic Loans

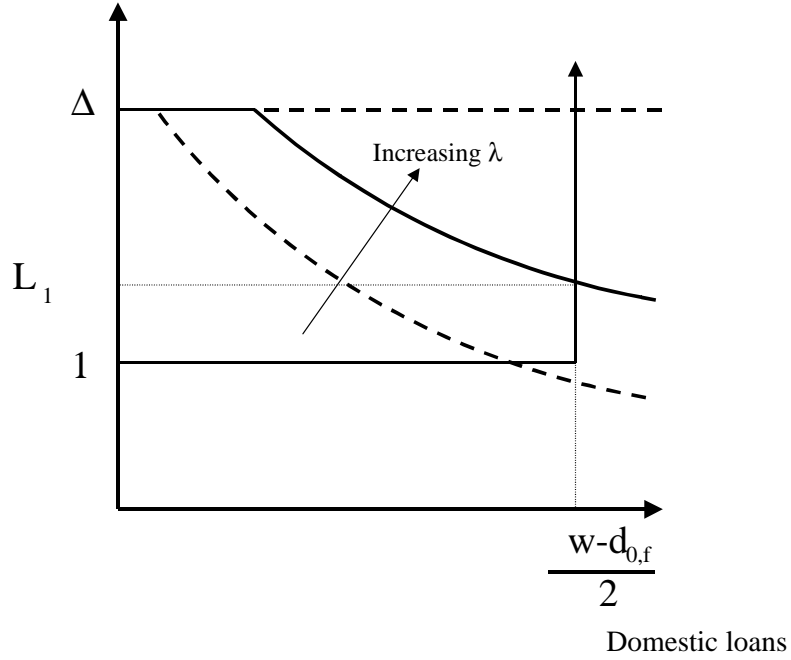


Figure 1 illustrates the market clearing. On the horizontal axis is the quantity of imported goods lent by intact firms/borrowed by distressed firms. The vertical axis is the price of loans L_1 . The supply is elastic at $L_1 = 1$ up to the point that the intact firms saturate their international collateral constraint of $d_{1,f} = w - d_{0,f}$, at which point it is completely inelastic. Demand for loans is given by the curve, $\frac{\lambda ak}{2L_1}$, which is downward sloping in L_1 .

It is easy to see from the figure that $\Delta \geq L_1 \geq 1$. The figure represents three alternatives for demand: The highest dashed line is the case where there is sufficient domestic collateral that $\Delta = 1$; the middle solid line is the case where L_1 lies strictly between one and Δ ; the lower dashed line is the case where λ is small and as a result demand is so collateral constrained that intact firms have excess supply of funds and the interest rate is one.

The parameter assumptions in Technical Assumption 1 ensure that equilibrium will have L_1 strictly between Δ and one – i.e. the solid line. In this case, substituting date 1 decisions into the market clearing condition gives,

$$L_1 = \frac{\lambda ak}{w - d_{0,f}}. \quad (2)$$

Note that L_1 lies above the international interest rate of one. The reason for this is the asymmetry between domestic and foreign agents embedded in assumptions 1 and 2. If foreigners were willing to hold claims against λak , then arbitrage between these and foreign assets would imply that $L_1 = 1$. Alternatively, if w were large so that on the margin some domestic investor was holding claims against both w and λak in their portfolio, then again it must be that $L_1 = 1$.

Given this price, the first order condition for the date 0 program can be written as:

$$c'(k) \frac{L_1 + \Delta}{2} = \frac{A + (1 - \lambda)a + \frac{\lambda a}{L_1} \Delta}{2} \quad (3)$$

where the left hand side represents the expected opportunity cost of the marginal units of international collateral spent on setting up a plant at date 0, while the right hand side is the expected marginal revenue associated to the marginal plant.

Proposition 1 *Consider two economies indexed by λ and λ' , where $\lambda > \lambda'$. Then,*

- $\Delta - L_1(\lambda) < \Delta - L_1(\lambda')$;
- *Welfare is increasing in λ , so that $V^{spot}(\lambda) > V^{spot}(\lambda')$;*
- *Date 0 investment and borrowing are decreasing in λ so that $k^{spot}(\lambda) < k^{spot}(\lambda')$.*

Proof: Follows after a few steps of algebra, from V^{spot} , (2), and (3).

The proposition highlights the role of λ on welfare, decisions, and prices. Fixing k , from the market clearing condition we can see that L_1 is increasing in λ . Thus as λ rises, L_1 rises toward the marginal product at date 1 of Δ . This has an important effect on date 0 decisions. A firm that decides to borrow less, is essentially “saving” these resources until date 1. At date 1, these resources are either used internally to yield Δ , or lent externally, in which case, despite the fact that the resources yield Δ to the borrower, the lender only internalizes L_1 of this return. Again, this occurs because the borrower is collateral constrained. As λ rises, the spread between Δ and L_1 falls causing firms to save more at date 0. This leads to greater investment at date 1 and welfare increases. Essentially, as λ rises prices are less distorted by the credit constraint and the intertemporal savings decision better reflects marginal products.

3 Public information of types and date 0 domestic insurance markets

Our aim in this section is to show that welfare can be improved through the use of a *domestic* insurance contract at date 0 that shuffles resources from intact to distressed firms at date 1.⁵ At first glance this may seem odd because at date 1 under our spot market equilibrium, *all* of the international resources find their way into the hands of the distressed firms. That is, intuition may suggest that the ex-post allocation cannot be enhanced by further reallocating domestic collateral to distressed firms since the scarcity is on international collateral, and this has already been fully transferred. However, in our setup, the welfare gain from domestic insurance comes entirely from affecting the ex-post price of international resources, L_1 , and bringing this closer to Δ so that ex-ante the borrowing/investment decision of k is less distorted. Moreover, reallocating ex-post wealth beyond what is needed to set $L_1 = \Delta$, affects $V^i - V^d$, but not decisions, equilibrium, or ex-ante welfare.

Assumption 3 (Public information)

The shock at date 1 is public information and insurance contracts can be written contingent on j .

Consider the following domestic insurance contract: All firms sign a grand insurance contract at date 0 with repayments in date 2 goods of $x_{0,l}(j)$, where $x_{0,l}(i) = -x_{0,l}$ and $x_{0,l}(d) = x_{0,l} > 0$. Since the types are observable, this contract can be made contingent on type- j . Repayments are enforceable as long as,

$$x_{0,l} \leq w - d_{0,f} + \lambda ak$$

Since there are an equal measure of each type, the insurance payments to distressed firms are exactly funded by the receipts from the intact firms.

At date 1, an intact firm sees the domestic interest rate of $L_1 \geq 1$ and has international collateral of $w - d_{0,f}$, and an insurance liability of $x_{0,l}$. Suppose that the firm lends all of its international collateral at L_1 , then its total resources are date 2 goods of,

$$(w - d_{0,f})L_1 + Ak$$

Against this it has the liability of $x_{0,l}$ giving date 2 profits of,

$$V^i = (w - d_{0,f})L_1 + Ak - x_{0,l}.$$

⁵Recall that our focus is not on the possibility of more or less insurance from foreigners, rather it is on domestic arrangements *given* the limited access to international financial markets.

The distressed firm borrows against its international collateral of $w - d_{0,f}$ and invests the proceeds in production to yield a date 2 return of Δ . As long $L_1 \leq \Delta$, it borrows $d_{1,l}$ in the domestic debt market, satisfying the constraint that,

$$d_{1,l} \leq \lambda ak + x_{0,l}. \quad (4)$$

Thus it makes date 2 profits of,

$$V^d = (w - d_{0,f})\Delta + (\Delta - L_1)\frac{d_{1,l}}{L_1} + \lambda ak + x_{0,l}.$$

Consider (4) a little more closely. We know that if $x_{0,l} = 0$, we are back in the situation we studied in the previous section and that $d_{1,l} = \lambda ak$. Since increasing $x_{0,l}$ from this point only loosens $d_{1,l}$, without loss of generality we can set,

$$d_{1,l} = \lambda ak + x_{0,l}.$$

That is, if the inequality in (4) was strict, then $x_{0,l}$ can be reduced until equality, while only loosening the insurance enforceability constraint and affecting the level of V^d and V^i , but not decisions or date 0 welfare (recall that agents are risk neutral). Given this, the date 0 problem is just,

$$\begin{aligned} V^{ins} = \max_{k, d_{0,f}, x_{0,l}} & \quad \frac{1}{2}(w - d_{0,f})(\Delta + L_1) + \frac{1}{2}(A + a)k + \frac{1}{2}(\Delta - L_1)\frac{\lambda ak + x_{0,l}}{L_1} \\ \text{s.t.} & \quad d_{0,f} \leq w \\ & \quad c(k) = d_{0,f} \\ & \quad x_{0,l} \leq w - d_{0,f} + \lambda ak \end{aligned}$$

Lemma 2 *In the insurance market equilibrium:*

$$L_1 = \Delta$$

Proof: We can see this in two steps. First, from the program, as long as $\Delta > L_1$, firms will increase $x_{0,l}$. Second, the only limit on $x_{0,l}$ is the enforceability constraint that $x_{0,l} \leq w - d_{0,f} + \lambda ak$. Suppose that $x_{0,l} = w - d_{0,f} + \lambda ak - \delta$, with $\delta > 0$. As $\delta \rightarrow 0$, the intact firms at date 1 have no international resources, and market clearing in the domestic loan market would require that $L_1 = \Delta$. As a comment, there is a large interval within which $x_{0,l}$ can fall for this to hold. ■

Substituting $L_1 = \Delta$ into the program gives the first order condition for investment,

$$c'(k)\Delta = \frac{A + a}{2}. \quad (5)$$

Contrasting this expression with the first order condition in the spot market equilibrium, (3), implies:

Proposition 3 *Let k^{ins} be the solution to (5) and k^{spot} be the solution to (3). Then:*

1. *If $\Delta - L_1^{spot} > 0$,*

$$k^{spot} > k^{ins} \quad \text{and} \quad V^{ins} > V^{spot}.$$

2. *If $\Delta - L_1^{spot} = 0$, the two first order conditions coincide and decisions as well as welfare are the same.*

By signing date 0 insurance contracts firms bid up the price of international collateral at date 1 until it reaches Δ . As a result, firms borrow less at date 0 and invest less, thus leading to a better allocation of external resources across date 0 and date 1. Note that the insurance solution leaves no role for λ . Indeed this is the point. Since the loan market at date 1 is affected by collateral frictions, the date 0 insurance market circumvents these frictions by loosening the domestic collateral constraint.

4 Private information of types and planning solutions

We shall henceforth set λ equal to one, as it plays a limited role in what follows. More importantly, from now onwards we shall acknowledge the many difficulties encountered by domestic insurance contracts in emerging economies and assume:

Assumption 4 (Private information)

The shock at date 1 is private information of the firm.

This assumption means that the insurance contracts of the previous section are not possible since, at face value, all firms will prefer to claim to be distressed and avoid payment. However the spot loan market is still feasible. We now investigate whether it is possible to still implement the full insurance solution.

4.1 Mechanism design problem

We take a standard mechanism design approach. The types at date 1 are private information and must be elicited by the mechanism. As usual, we appeal to the revelation principle to focus on direct revelation mechanisms.

Consider the following mechanism. At date 0, agents hand over w of international collateral to the planner. The mechanism is defined by,

$$m = (k, y_i, y_d, x_i, x_d).$$

At date 0, the planner hands resources to create capital of k to each firm. At date 1, agents send a message of their type, $j \in \{i, d\}$. They then receive an allocation of international collateral (or imported goods) of y_j and a claim on date 2 domestically produced goods of x_j .

Thus the planner solves the following problem:

$$\begin{aligned} V^m &= \max_m && \frac{1}{2}(Ak + y_i + x_i) + \frac{1}{2}(ak + y_d\Delta + x_d) \\ s.t. & \quad (RC0) && c(k) \leq w \\ & \quad (RC1) && \frac{1}{2}(y_i + y_d) + c(k) \leq w \\ & \quad (ICC) && y_i, y_d \geq 0 \\ & \quad (RCX) && x_i + x_d \leq 0 \\ & \quad (DCC) && x_i, x_d \geq -ak \\ & \quad (ICi) && Ak + y_i + x_i \geq Ak + y_d + x_d \\ & \quad (ICd) && ak + y_d\Delta + x_d \geq ak + y_i\Delta + x_i \end{aligned}$$

The constraints are as follows: RC0 and RC1 are date 0 and date 1 resource constraints on importing goods for investment. Since agents hand over all of their international collateral to the planner at date 0, the transfer to them, y_j , must be non-negative. The planner can shuffle claims on date 2 goods —i.e., domestic collateral— at date 1. RCX requires that this shuffling does not create new collateral in the aggregate. DCC states that the maximum the planner can shuffle away from any of the agents is given by their domestic collateral constraint, ak . The last two constraints impose incentive compatibility so that each type prefers the bundle intended for it.

The asymmetry between Assumptions 1 and 2 are embedded in RC0, RC1 and DCC. To import goods for investment, only international collateral can be used – hence RC0 and RC1. On the other hand, these goods can be shuffled around among domestics by transferring claims against domestic collateral – hence DCC. We think this asymmetry is a distinguishing feature of an emerging economy. In a developed economy most assets are both domestic and international collateral, in which case we could do away with DCC and rewrite the RC’s to include the domestic collateral of ak .

Given linearity in y ’s and x ’s, we will arrive at corner solutions in them. Since $c(k)$ is convex, we will have an interior solution in k . In order to see which corners determine the solution, rewrite the two incentive compatibility constraints as,

$$\begin{aligned} x_i + y_i &\geq x_d + y_d \\ x_d + y_d + (\Delta - 1)y_d &\geq x_i + y_i + (\Delta - 1)y_i. \end{aligned}$$

Note that $(x_i + y_i)$ appears as a sum everywhere in the program except in this last incentive compatibility constraint. If we were at an interior point on x_i and y_i then the incentive compatibility constraint can be slackened by lowering y_i and increasing x_i . Thus consider the solution of $y_i = 0$ and x_i at its highest value. Applying the same argument to $(x_d + y_d)$ dictates a solution of y_d to be at its highest value and x_d to be at its lowest. Thus, $y_d = 2(w - c(k))$, and $x_d = -ak$. Combining, gives us,

$$m = (k, y_i = 0, y_d = 2(w - c(k)), x_i = ak, x_d = -ak).$$

and rewriting the optimization problem gives,

$$V^m = \max_k \frac{1}{2}(A + a)k + \Delta(w - c(k)).$$

The first order condition to the planning problem is

$$c'(k)\Delta = \frac{A + a}{2}.$$

Let k^* be the solution. The last step is to verify that the solution satisfies the incentive compatibility constraints. That is,

$$\Delta(y_d - y_i) \geq x_i - x_d \geq y_d - y_i$$

or,

$$\Delta(w - c(k^*)) \geq ak^* \geq w - c(k^*)$$

which can be shown to hold under Technical Assumption 1.

Proposition 4 *The optimal mechanism under private information of types implements the full-insurance public information solution.*

This follows directly from comparing the first order conditions in this solution and the insurance solution of the previous section.

The mechanism works because it exploits the differential valuation of imported goods between distressed and intact firms. If a firm claims to be distressed rather than intact it receives $2(w - c(k^*))$ imported goods, but forgoes $2ak^*$ claims on date 2 goods. The interest rate implicit in this choice is,

$$L_1^* = \frac{ak^*}{w - c(k^*)},$$

where the technical assumption ensures that $\Delta > L_1^* > 1$.⁶ A distressed firm values the imported goods at Δ , while the intact firm values it at one. Thus distressed firms effectively borrow at L_1^* and intact ones lend at L_1^* . Both types' welfare is enhanced, and the full-insurance solution is achieved.

We now turn to the implementation of the planning solution and consider three sets of alternatives, noting that each requires the planner—which in some instances could be a private consortium—to act (and hence be able to monitor) on a different margin.

4.2 Domestic credit lines

The first solution we consider is a credit-line/banking arrangement akin to Diamond and Dybvig's (1983) deposit contracts in the context of consumption insurance.

Suppose that all firms hand over $w - c(k^*)$ to the bank at date 0. This leaves each firm with $c(k^*)$ for the purpose of building a plant. The bank then offers each firm the right to withdraw $w - c(k^*)$ at date 1 as well as a credit line to borrow an additional $w - c(k^*)$ at

⁶Also note that $L_1^* < L_1$ since $k^* < k$.

the interest rate of L_1^* . Funds not withdrawn at date 1 earn the interest rate of L_1^* until date 2.⁷

At date 1, distressed firms return to the bank and withdraw $w - c(k^*)$. In addition, they choose to take out a further loan against domestic collateral of ak^* at the rate of L_1^* . This gives them imported goods of exactly $2(w - c(k^*))$ which they invest until date 2 at the private return of Δ .

Since intact firms' alternative use of imported goods returns only one, intact firms choose not to withdraw their funds at date 1 and instead wait until date 2 providing them a total return of $L_1^*(w - c(k^*)) = ak^*$.

This structure clearly implements the planner's solution. However as was first pointed out by Jacklin (1985) it requires the fairly strong restriction that agents not be allowed to make any side trades. That is, all firms must be restricted to exclusively trade with the bank and be barred from trading in a market. If we drop this restriction, the banking arrangement is no longer *coalition* incentive compatible and the allocation reverts to the competitive equilibrium.⁸

In our context, Jacklin's critique can be formulated as follows. Suppose that one firm chooses to opt out of the banking arrangement, and privately makes an investment decision of k . At date 1, the firm is either distressed or intact. If distressed, suppose that it approaches a firm within the banking arrangement and offers to borrow at the interest rate of L_1^* against domestic collateral of ak . Since this return is as good as the return in the banking arrangement, the firm withdraws some of its international collateral and offers it to the rogue firm. The return to the rogue firm is,

$$V^d = \Delta(w - c(k)) + \frac{ak}{L_1^*}\Delta,$$

while the firm in the banking arrangement is unaffected. If the firm is intact, it instead offers to lend to a firm in the banking arrangement at the interest rate of L_1^* . Once again, the banking firm accepts, and the rogue firm's profits are,

$$V^i = L_1^*(w - c(k)) + Ak$$

Combining these last two expressions gives us the date 0 program of,

$$V^{rogue}(L_1^*) = \max_k \frac{1}{2}(w - c(k))(\Delta + L_1^*) + \frac{1}{2} \left(\Delta \frac{a}{L_1^*} + A \right) k.$$

⁷We do not impose a sequential service constraint as in Diamond and Dybvig (1983), which means that L_1 is left free to adjust in the out-of-equilibria event that more than half of the firms decide to withdraw. Thus there is no "bank-run" equilibrium.

⁸The result that competitive spot markets may undermine insurance arrangements arises in many settings. See for example, Rothschild and Stiglitz(1976), Atkeson and Lucas (1992), or Bisin and Rampini (2000).

The first order condition for this program is,

$$c'(k)(\Delta + L_1^*) = \frac{\Delta a}{L_1^*} + A.$$

Comparing this to the first order condition of the planning problem, we can see that for $L_1^* < \Delta$ the rogue firm makes a choice of $k > k^*$ and attains strictly higher utility than if it participated in the banking arrangement. Given this, the banking arrangement would unravel.

We can take this to its logical end by explicitly accounting for the possibility of side trades in the planning problem. This is done by adding a constraint that,

$$V^m \geq V^{rogue}(L_1^*)$$

Now the objective in the planning problem is,

$$V^m = (w - c(k^*))\Delta + \frac{1}{2}(a + A).$$

Substituting in $L_1^* = \frac{ak^*}{w-c(k^*)}$, this can be rewritten as,

$$V^m = \frac{1}{2}(w - c(k^*))(\Delta + L_1^*) + \frac{1}{2}\left(\Delta \frac{a}{L_1^*} + A\right)k^*.$$

Note that this is the same as the expression for V^{rogue} if evaluated at $k = k^*$. Since both objectives in V^m and in V^{rogue} are strictly concave, they each have a unique maximum, with the maximum in V^{rogue} weakly exceeding that of V^m . Given this, we can conclude that the best that the planner can do is to choose $k^* = k^{rogue}$ so that,

$$L_1^* = \frac{ak^{rogue}}{w - c(k^{rogue})}.$$

These are the same optimality and market clearing conditions that arose in the spot loan markets of section 2.2. In summary,

Proposition 5

(a) The credit-line arrangement implements the full-insurance solution as long as the planner can restrict agents from making side trades. (b) In the absence of this exclusivity restriction, the credit-line arrangement collapses to the competitive equilibrium with spot loan markets.

4.3 Capital inflow taxation/Liquidity requirement

Let us consider next a tax/transfer scheme based on date 0 borrowing (or investment of k). Since the primitive problem in the spot loan market equilibrium is that agents over-borrow/over-invest at date 0, a tax has the potential of achieving the optimal solution.

The planner taxes all date 0 external borrowing at the rate of τ and redistributes the proceeds (T) in a lumpsum fashion at date 0,

$$T = \tau d_{0,f} = \tau c(k^*)$$

The program for a firm is,

$$\max_k \quad \frac{1}{2}(w - c(k) - \tau c(k) + T)(L_1 + \Delta) + \frac{1}{2} \left(A + \Delta \frac{a}{L_1} \right) k.$$

This gives the first order condition,

$$c'(k)(1 + \tau)(L_1 + \Delta) = \left(A + \Delta \frac{a}{L_1} \right).$$

Thus,

$$1 + \tau = \frac{2\Delta}{\Delta + L_1} \frac{A + \frac{\Delta}{L_1} a}{A + a}$$

where,

$$L_1 = L_1^*.$$

It is straightforward to verify that for $L_1^* < \Delta$, the optimal tax will be positive.

An alternative, but similar in spirit, implementation of the borrowing tax is an international liquidity requirement. For example, suppose that the planner insisted that a fraction, $\frac{w - d_{0,f}^*}{d_{0,f}^*}$, of all foreign borrowings be retained as a liquidity requirement for one-period (i.e., until a crisis arises). Then, since firms choose to borrow $d_{0,f}^*$, this arrangement has them saving exactly the right amount until date 1.

While unlike the credit line arrangement each of these solutions can co-exist with the market for loans, they do require that the planner observe all external borrowings. If agents could evade the tax/return scheme or liquidity requirement, and trade in the loan market at date 1, they would prefer to. Moreover, this incentive rises as more firms fall under the planner's control since L_1 falls.

Finally, it is worth pointing out that this arrangement requires the planner to tax at date 0 and then remove the tax at date 1. If the tax is left active for both periods, the equilibrium would be exactly as in section 2.2, with the exception that the interest rate on international collateral would rise to $1 + \tau$. In general, this will lead to a worse outcome than the case of no-taxation.

Proposition 6 *If the planner can observe all external borrowings, a borrowing tax or liquidity requirement implements the full-insurance solution.*

4.4 Capital inflow sterilization

Consider a government that issues b face value of two period bonds at date 0 in return for international reserves of $\frac{b}{L_0}$. Thus the interest rate on these bonds is L_0 , and in order to purchase these bonds, firms increase their external borrowings by $\frac{b}{L_0}$.

At date 1, the government simply buys the bonds plus claims against domestic collateral using its international reserves of $\frac{b}{L_0}$. Finally, at date 2, the government raises lumpsum taxes of T in order to balance its budget. Since the investment of reserves at date 1 is done at the interest rate of L_1 , the budget constraint for the government is,

$$\frac{b}{L_0}L_1 + T = b,$$

where we note that if $L_0 = L_1$, budget balance is achieved without having to raise taxes.

There are two assumptions we make on the government. First, we assume that future tax liabilities are rationally anticipated and constitute a reduction in seizable endowments. Thus the collateral of each firm is reduced by T , so that, for example, the domestic loan capacity becomes,

$$d_{1,d} \leq w + ak - T$$

Second, we assume that the government bonds that are sold are only domestic collateral. That is they are like ak and hence foreigners do not purchase these bonds.⁹

In this context, suppose a firm purchases b bonds at date 0. Then its program can be written as,

$$\begin{aligned} \max_{k,b} \quad & \frac{1}{2}(w - c(k) - \frac{b}{L_0})(L_1 + \Delta) + \frac{1}{2} \left(Ak + b - T + \frac{\Delta}{L_1}(ak + b - T) \right) \\ \text{s.t.} \quad & c(k) + \frac{b}{L_0} \leq w \end{aligned}$$

Market clearing is,

$$L_1 = \frac{ak + b - T}{w - c(k) + \frac{b}{L_0}}$$

There are two cases to consider, depending on whether or not the international borrowing constraint is slack or not. Consider first the case that, $c(k) + \frac{b}{L_0} < w$. Since firms are at

⁹See the appendix in Caballero and Krishnamurthy (2000b) for a model justifying this assumption in terms of a risk of suspension of convertibility.

an interior in their purchase of bonds, it must be that $L_0 = L_1$, and therefore $T = 0$. Substituting this back into the market clearing condition:

$$\begin{aligned} L_1(w - c(k) + \frac{b}{L_1}) &= ak + b \\ L_1 &= \frac{ak}{w - c(k)}. \end{aligned}$$

In other words, intervention has no effect in this case.

The other case is where the international constraint binds. Suppose that the government sells enough bonds so that $c(k^*) + \frac{b}{L_0} = w$. The first order condition for the private sector is,

$$c'(k) \frac{L_0}{L_1} \frac{L_1 + \Delta}{2} = \frac{1}{2} (A + a \frac{\Delta}{L_1})$$

As always, the RHS is the return from an extra unit of k . The LHS is the opportunity cost of these resources. $c'(k)$ could otherwise be invested in the government bonds at L_0 , sold at L_1 at date 1, and the proceeds reinvested at either L_1 or Δ . Given the intervention, optimality for the private sector requires that the interest rate on these bonds be,

$$L_0 = \frac{A + \frac{\Delta}{L_1^*} a}{c'(k^*)(L_1^* + \Delta)} L_1^*.$$

Since $c'(k^*) = \frac{A+a}{2\Delta}$, we arrive to,

$$L_0 = \frac{A + \frac{\Delta}{L_1^*} a}{A + a} \frac{2\Delta}{\Delta + L_1^*} L_1^*.$$

For $L_1^* < \Delta$, we have that $L_0 > L_1^*$. Since after purchasing these bonds the private sector has exactly $c(k^*)$ left, firms invest the optimal amount of k^* , and the full-information solution is achieved.

Essentially, the implementation has the government “subsidizing” savings by offering a bond with an interest rate exceeding L_1 . It requires no knowledge of date 0 borrowing or investment. However, it does require that the government be able to tax and issue bonds.

On the one hand, since we have assumed that taxes come out of otherwise privately seizable endowments, this tax power is not any stronger than what we gave the private sector.¹⁰ On the other hand, it does come with a buried assumption. As in the banking arrangement we first discussed, if agents had the option to not pay taxes, not buy government bonds, but be allowed to trade with the firms who are paying taxes, they would prefer this option. As in the banking arrangement, the sterilization policy is not coalition incentive

¹⁰See Holmstrom and Tirole (1998) or Woodford (1990) for the converse case.

compatible. However, it seems reasonable to believe that coalition incentive compatibility with respect to taxes is easier to achieve than that of ruling out side trades in a private banking arrangement.

We label this policy as sterilization because, in practice, emerging markets that sterilize accumulate international reserves on the one hand, and issue government bonds on the other. However our bond policy is "real" and may seem closer to fiscal than to monetary policy. In Caballero and Krishnamurthy (2001b) we have argued that emphasizing this "real" side of a sterilization policy sheds light on observed outcomes that are puzzling when only the standard, purely monetary, side of it is considered.

Proposition 7 *Sterilizing capital inflows at date 0 by issuing two period government bonds, and consequently reversing the transaction at date 1, achieves the full-insurance solution as long as the planner has the power to tax endowments and bonds are not viewed as international collateral by foreign investors.*

5 Final Remarks

As in our previous papers, we have synthesized emerging markets' volatility in terms of two basic ingredients: weak links with international financial markets and underdeveloped domestic financial markets. The need for external insurance stems from the former insufficiency, while the latter is behind the external underinsurance problem.

The contribution of this paper is twofold: First, we have explicitly modeled the informational constraint on domestic insurance markets and have thereby been able to discuss the feasibility of contractual arrangements to solve the underinsurance problem. Second, we have explored in a unified setting several of the main international liquidity management strategies available to these countries.

If domestics can write complete insurance markets with each other, external underinsurance disappears. However the mechanism behind this result is not a standard insurance channel. The main problem of the economy during a sudden stop is not in the domestic allocation of its limited international collateral but on the aggregate amount of the latter. Domestic insurance improves efficiency by aligning the price of international collateral with its marginal product. In this sense, domestic insurance relates to our discussion in Caballero and Krishnamurthy (2001c) of the incentive —as opposed to the standard liquidity— virtues of a countercyclical monetary policy in economies subject to sudden stops. In fact, there we argue further that such policy could in some instances substitute for the absence of domestic insurance.

If domestic insurance is not possible – i.e when types are unobservable – we showed that it was possible to design mechanisms that could attain the same aggregate outcomes and welfare of the full information case. The common Achilles' heel of these solutions, however, is their failure to meet a coalition incentive compatibility constraint; which in practice means that they may not be robust to the existence of secondary markets or ways to opt out of the mechanism. Among the solutions of these type we studied, we argued that bond-policy is probably more robust than the others, but this policy can also have potentially large drawbacks if the intervention is not large enough and public bonds have illiquid secondary markets during crises (see Caballero and Krishnamurthy (2001b)).

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