Exchange Rate Volatility and the Credit Channel in Emerging Markets: A Vertical Perspective*

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Firms in emerging markets are exposed to severe financial frictions and credit constraints that are exacerbated by the sudden stop of capital inflows. Can monetary policy offset this external credit squeeze? We show that although this may be the case during moderate contractions (or in partial equilibrium), the expansionary effect of monetary policy vanishes during severe external crises. The exchange rate jumps to reduce the dollar value of domestic collateral until equilibrium in domestic financial markets is consistent with the external constraint. An expansionary monetary policy in this context raises the value of domestic collateral, but it exacerbates the exchange rate depreciation (beyond the standard interest parity effect) and has little effect on aggregate activity. However, there is a dynamic linkage between monetary policy and sudden stops. The anticipation of a dogged defense of the exchange rate worsens the consequences of sudden stops by distorting the private sector incentive to take precautions against these shocks. For similar general equilibrium reasons, dollarization

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of liabilities has limited impact during a sudden stop, but it has significant underinsurance consequences.
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Emerging markets can suffer severe contractions when capital inflows suddenly reverse ("sudden stops"). What is the right monetary policy response to this event? Answering this important question requires understanding the mechanisms through which monetary policy can affect sudden stops and their consequences. The main contribution of this paper is to rethink the workings of the credit channel in emerging market economies and to propose an alternative view that shifts the focus from credit channel and aggregate demand to insurance considerations.

Much of the recent literature on emerging markets crises highlights the limited financial development of these economies and the severe credit squeeze experienced by local firms during crises. From this structure, two opposing arguments are commonly made regarding optimal monetary policy. Extrapolating from developed economy credit channel analysis, some advocate an expansionary monetary policy to offset the effect of the credit squeeze during downturns. Others advocate a contractionary monetary policy and dogged defense of the exchange rate during crises. Proponents of the latter view do not disagree on the centrality of the credit channel mechanism, but argue that a depreciating exchange rate will have dramatic effects in the credit channel mechanism, through a deterioration in borrowers' balance sheets. The argument is that this effect is most likely to happen when the economy is dollarized and when inflation credibility is limited.[1]

The starting point of our analysis is the observation from Caballero and Krishnamurthy (2001) that credit constraints in emerging markets may exist both at the country level as well as the firm level. A firm may have limited collateral and therefore be constrained in borrowing from either domestic or foreign lenders. Or the country as a whole may have limited international collateral, and therefore domestic firms are constrained in borrowing from foreign

[1] For both sides of the argument see, e.g., Furman and Stiglitz (1998); Aghion, Bacchetta, and Banerjee (2000); Cespedes, Chang, and Velasco (2000); Gertler, Gilchrist, and Natalucci (2001); Christiano, Gust, and Roldos (2004); and Calvo and Reinhart (2003).

investors.[2] Extrapolation from developed economy analysis misses this distinction because in developed economies the credit constraint plausibly exists only at the firm level. The distinction is important for thinking through the effects of monetary policy because a sudden stop created by the reversal of capital inflows is predominantly about a binding international collateral constraint.

We argue that during mild crises, the distinction between domestic and international constraints is immaterial. Analysis of this case can be conducted in the standard credit channel framework. Much of the recent debate on monetary policy during crises implicitly assumes this to be the relevant scenario. As is stressed in the credit channel literature (e.g., Bernanke, Gertler, and Gilchrist 1999; Kiyotaki and Moore 1997), increasing the net worth of borrowers is the optimal response to a negative shock. Our analysis of this case reinforces the conclusions in the literature: there is some ambiguity regarding whether the optimal monetary policy is to raise or lower interest rates. It depends on the extent of liability dollarization and inflation credibility of the central bank.

The recipe of using monetary policy to increase the net worth of borrowers fails when the credit constraint exists at the country level. The reason is that monetary policy only regulates the borrowing of a domestic agent from a domestic lender. Thus, when the marginal lender is a foreign investor, monetary policy is ineffective because it does not alter the international collateral of the country.[3] We argue that this is the relevant case for emerging markets' crises.

Although monetary expansions have little effect on output during a severe crisis, they have important general equilibrium effects on asset prices. In *partial* equilibrium, it is still true that a monetary expansion raises firms' borrowing capacity by increasing their domestic liquidity. But in general equilibrium, the expansion just translates

[2]The importance of international collateral constraints for emerging markets was first identified in the sovereign debt literature (see, e.g., Eaton and Gersovitz 1981 or Bulow and Rogoff 1989).

[3]Though in very different terms, Dornbusch (2001) also expresses his uneasiness about the assumption that emerging economies with access to monetary policy can use it to boost activity. For example, in criticizing the standard view, he writes: "The loss of the lender of last resort [argument] is intriguing. This argument is based on the assumption that the central bank—rather than the treasury or the world capital market—is the appropriate lender..."

into a decline in the relative price of domestic liquidity vis-à-vis international liquidity, not in an expansion in international liquidity (i.e., it does not loosen the international constraint). We show that the fall in the price of domestic liquidity implies a *temporary* exchange rate depreciation during the crisis. In fact, the depreciation of the exchange rate is beyond the depreciation due to the standard interest parity mechanism. The depreciation does weaken balance sheets, as some have argued in the context of the credit channel. But it is not firm-level balance sheets that are to blame. The exchange rate depreciation is just the general equilibrium counterpart of the tight international constraint.

Our conclusions regarding the effects of monetary policy are independent of the dollarization of balance sheets. Monetary policy is impotent during crises whether or not dollarized balance sheets undo the beneficial effects of lowering interest rates. The reason, again, is that domestic dollarization just tightens constraints at the firm level; it does not alter the aggregate international collateral of the country.[4]

The second main theme of the paper concerns the insurance effects of monetary policy. Despite the apparent impotence of monetary policy during sudden stops, expectations regarding a particular monetary rule have important effects on the private sector's ex-ante decisions. The anticipation of monetary policy actions during crises affects agents' expectations of the relative price of domestic to international liquidity, which in turn affects the private sector's insurance decisions against sudden stops. If the private sector expects a dogged defense of the exchange rate, then it also expects a smaller decline of the value of domestic to international liquidity. Conversely, if it expects an expansionary monetary policy, then it expects a sharper decline in the relative price of domestic liquidity. The incentive to hoard international over domestic liquidity is more pronounced in the latter than in the former case. Importantly, hoarding more international liquidity is desirable when there are negative pecuniary externalities in the use of international liquidity, a feature that is

[4]Dollarization of *external* liabilities has some additional external insurance implications that we discuss later in this paper and, more thoroughly, in Caballero and Krishnamurthy (2003). This is not an issue for the analysis of this paper since we allow for state-contingent debt.

inherent to economies with underdeveloped financial markets (see Caballero and Krishnamurthy 2001).

From this perspective, our argument connects with the literature on the virtues of flexible versus fixed exchange rate systems.[5] In our model, a flexible exchange rate system coupled with a countercyclical monetary policy provides better *insurance* incentives to the private sector than a policy of defending the exchange rate during sudden stops.[6] More generally, monetary policy and its constraints have (unintended) consequences for the private sector's insurance decisions with respect to sudden stops. Policies that exacerbate the (partial equilibrium) domestic credit squeeze during sudden stops, or constraints that limit the central bank's ability to relax domestic financial constraints, lead to ex-ante imprudent private sector actions.

In section 1 we present a model of market segmentation in which we draw a distinction between domestic and international liquidity. Section 2 describes the consequences of monetary policy in the segmented financial market. In particular, we show the oversensitivity of the exchange rate to monetary policy and the role of the exchange rate in endogenously aligning the extent of domestic credit squeeze with the limited international liquidity. In Section 3 we turn to the ex-ante consequences of monetary policy and its private insurance implications. We show that the strategy of tightening monetary policy during crises lowers the private return to taking preventive measures.

In section 4 we revisit the dollarization of liabilities argument, but now in the context of our dual-liquidity model. We show that the balance-sheet effect typically emphasized in this literature has no aggregate consequences in general equilibrium during the crisis. However, and following our argument above, there is a dynamic cost. Dollarization lowers the expected return on hoarding international liquidity and hence reduces the private sector incentives to take adequate precautions against sudden stops. In section 5 we highlight that not having the credibility or willingness to conduct a

[5]See, e.g., Edwards and Levy-Yeyati (2003) for evidence supporting the advantages of a flexible exchange rate in absorbing external shocks.

[6]Our mechanism is distinct (or in addition to) the standard free insurance argument in the moral hazard perspective of crises (see, e.g., Dooley 1999). We return to this comparison after developing our model.

countercyclical monetary policy means that an insurance mechanism against crises is lost. Thus, one should look for alternative measures that induce the private sector to carry more international liquidity into crisis states. Examples of these measures include taxation of capital inflows, international liquidity requirements, and large sterilizations of capital inflows. While enacting these measures may be costly, they should be seen as yet another cost of having lost the ability to use monetary policy in an environment of recurrent external crises.

Section 6 shows that our main conclusions are robust to the relaxation of some of the main stylized assumptions of our model, such as the presence of a "diagonal" supply of funds or an alternative model of money. Section 7 concludes and is followed by a technical appendix.

1. A Model of External Crises

We study a three-date economy ($t = 0, 1, 2$) with a single (tradeable) good. Date 0 is a fully flexible planning period. Agents make investment and financing decisions at this date. At date 1 an external crisis may occur. We assume that there are two states of the world at date 1, $\omega \in \{b, g\}$, which occur with probabilities $\{\pi, 1 - \pi\}$. The crisis can occur only if the b-state realizes. At date 2 agents repay all debts and consume.

1.1 Private Sector

There is a unit measure of domestic firms. Each has access to a production technology. Building a plant of size k at date 0 requires a firm to invest $c(k)$—with $c(.) \geq 0$, $c' > 0$ and $c'' > 0$. The output from production depends on the shocks at date 1. There is a maximum of Ak output goods at date 2, but if negative shocks hit firms, then only ak ($a < A$) output goods may be produced. A more detailed description is given below.

Domestic firms have no resources at date 0. They must import capital goods and borrow from foreigners to finance their investment. Each firm is run by a domestic entrepreneur/manager who has risk-neutral preferences over date 2 consumption of the single good. Thus, financing and investment decisions are taken to maximize expected plant profits at date 2.

Domestic firms face significant financial constraints, and hence their financial net worth affects investment decisions. We assume that firms are endowed with w units of international collateral, in the form of receivables arriving at date 2. Our central assumption is that only these receivables have collateral value to foreigners (e.g., prime exports).

We disregard explicit equilibrium default and assume that all financing is done via fully collateralized debt contracts. Moreover, we assume that the debt contracts are made fully contingent on the state at date 1. We relax this in section 4 when discussing dollarized external debt, since the problem of dollar debt is essentially one of liabilities that are too inflexible.

At date 0, when firms sign debt contracts with foreigners, the contracted repayments of f^{ω} must not exceed w. Foreigners lend against this collateral at dates 0 and 1 at the rate i_0^* and i_1^* from period 0 to 1, and 1 to 2, respectively.

We also assume that domestic agents have some "domestic" assets that they can only trade to other domestic agents. First, we assume that the minimum date 2 output of ak can be pledged as collateral to other domestic agents. Second, we assume that agents are endowed with $\underline{M}$ units of domestic money (see below) that they can sell to other agents.

This modeling captures the distinction between domestic borrowing capacity and international borrowing capacity. We think of the domestic assets as "peso" assets, while the international collateral are "dollar" assets. Thus, changes in the exchange rate have an effect on the dollar value of domestic assets but not that of the international assets.

1.2 Credit Constraints During Crises

A crisis is a time when there is a shortage of resources available to finance investments. Formally, we model the external crisis by assuming that the demand for external resources rises in the b-state, while holding the international collateral fixed. An alternative (and more realistic) modeling of a shortage of external resources would be to assume that international collateral contracts during the crisis, while demand for external resources remains fixed. The implications of these two modeling strategies are similar for our purposes, but our approach reduces the number of assumptions and equations required. In particular, we do not need to add an assumption of incomplete international insurance markets.[7]

In the g-state there are no shocks and investment is unaffected. Let us now turn to defining the shock in the b-state and explaining how it affects investments.

The plants of one-half of the firms receive a shock at date 1 that lowers output per plant from A to a. The shock only arrives in the b-state, but is idiosyncratic in that each firm receives the shock with probability 1/2. The productivity decline can be offset by reinvesting θk ($\theta \leq 1$) goods, to give date 2 output of

$$\tilde{A}(\theta)k = (a + \theta\Delta)k \leq Ak \qquad \text{where} \qquad \Delta \equiv A - a,$$

so that $\tilde{A}(1) = A$. We assume that the return on reinvestment exceeds the international interest rate:

$$\Delta - 1 > i_1^*.$$

This means that firms will borrow as much as possible to finance reinvestment. A crisis occurs if firms are financially constrained at date 1, so that $\theta < 1$. We make parametric assumptions to ensure that this occurs in equilibrium only in the b-state (see the appendix).

A firm that receives a production shock is termed *distressed*. To cope with the shock, the firm first borrows directly from foreigners against its net international collateral of $w - f$. After this, it must turn for funds to the domestic firms that did not receive a shock (termed *intact*). As noted above, domestic agents accept the money held by distressed firms as payment. They also accept ak of the output from a firm's plants as collateral for any domestic debt. Thus the *domestic* (real) liquidity of firms entering date 1 (i.e., the date 2 goods that can be pledged to domestic agents) is

$$ak + \underline{M}/e_2 \tag{1}$$

[7]See Caballero and Krishnamurthy (2001) for the alternative approach. See Broner, Lorenzoni, and Schmukler (2003) for evidence that some of these international collateral shocks are due to shocks to specialist investors (in our framework, this is as if suddenly foreign lenders decide to reduce the share of w that is part of international collateral).

where e_2 is the date 2 nominal exchange rate (also the price level).

Intact firms have no output at date 1 either, so they must borrow from foreigners if they are to finance the distressed firms. At the interest rate of i_1^*, they can borrow up to $\frac{w-f}{1+i_1^*}$ from foreigners.

Since at date 1 firms, in aggregate, can borrow from foreigners up to

$$w^n \equiv \frac{w-f}{1+i_1^*}, \tag{2}$$

we refer to w^n as the *international* liquidity of the country during the crisis.

1.3 Central Bank

The central bank has $\underline{M}$ units of money outstanding at date 0. At date 1, it may choose to inject $(M - \underline{M})$ more money into firms. We assume that this money is distributed as "helicopter" drops to firms and redeemed at date 2 with taxes collected by the government.

We do not provide a detailed description of the government's tax powers and its tax base. Instead we assume that the government collects T goods via nondistortionary taxation, and that these taxes do not come from firms. We think of these taxes as resources from a consumer sector that has a date 2 endowment of $y^c \geq T$. When it is effective, expansionary monetary policy transfers resources from consumers to the corporate sector.[8]

We assume that the central bank is credible in maintaining the date 2 price level at one, so that money injections do not lead to inflation. We relax this assumption in section 5 when we discuss inflation credibility. Thus, for now, the date 2 exchange rate is $e_2 = 1$.

Our model of the monetary transmission mechanism involves no monetary frictions, because our qualitative conclusions do not depend on the presence of these frictions and ignoring them simplifies the exposition. The domestic "peso" interest rate is zero in our environment and is unaffected by monetary policy. Therefore the usual channel (through the interest parity condition) by which monetary policy affects the exchange rate is absent in our model. Despite this, we show that in our model, monetary policy still affects the exchange

[8]See, e.g., Woodford (1990) and Holmstrom and Tirole (1998) for a similar assumption.

rate. For this reason, we refer to the exchange rate movements induced by monetary policy as "overresponsive." Our results should be interpreted as *in addition* to those that arise from the movement in the peso rate and its effect through the interest parity condition. In section 6, we sketch a more standard model in which money provides a transaction service, thus confirming that our results are robust to this simplification.[9]

2. Monetary Policy, Exchange Rate Determination, and the Credit Channel

In this section we examine the equilibrium in the crisis state at date 1. Thus, for now, we take the date 0 investment decision of k and the financing decision of f as given. We study the case where credit constraints are binding in this crisis state, illustrating that the power of monetary policy to relax these constraints changes from mild (horizontal) to severe (vertical) crises.

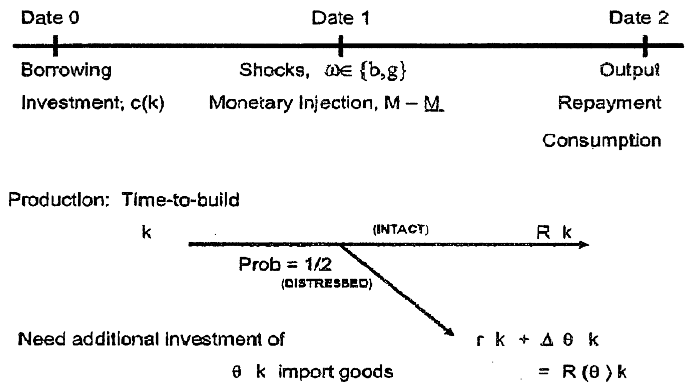
All of the discussion in this section takes place after the bad state has realized at date 1 and the central bank has injected $(M - \underline{M})$ pesos in response. Figure 1 illustrates the timing of shocks and agents' decisions.

2.1 Mild and Severe Crises (Date 1)

At date 1, distressed firms need to borrow in order to finance their production shock. Their total net worth, measured in dollars, is $\frac{ak+M}{e_1} + w^n$. Clearly, as M rises, so does net worth, at least for a given e_1. The key question is whether e_1 depreciates with an expansionary monetary policy and by how much. We argue that the answer to this question depends critically on the severity of the crisis. If the latter is severe, a monetary expansion is ineffective in raising output and leads to an exchange rate overreaction. This happens despite full inflation target credibility ($e_2 = 1$), as it reflects the fall in the real value of domestic collateral (i.e., not a monetary phenomenon).

[9] The discussion in section 6 also clarifies exchange rate determination in our setup. When the peso interest rate is zero, e_1, which we refer to as the date 1 exchange rate, can also be interpreted as the forward exchange rate standing at date 1 for exchange at date 2. In section 6 we show that when the peso interest rate is nonzero, this ambiguity disappears and e_1 is the date 1 exchange rate.

Figure 1. Timeline



Note: The figure presents the timing of investment, borrowing, and consumption decisions. Also pictured are the shocks affecting firms at date 1.

Let us consider equilibrium at date 1. Distressed firms can borrow w^n directly from foreign investors. Thereafter they must turn to other domestic agents to raise resources. Recall that intact firms can also borrow w^n from foreign investors. Moreover, since they are willing to accept domestic money as payment as well as purchase debt claims backed by ak of collateral, they can also finance the production shock of the distressed firms.

There are two regions of interest. If

$$\frac{1}{2}w^n > \frac{1}{2}\frac{ak + M}{1 + i_1^*}, \tag{3}$$

then intact firms have sufficient access to foreign funds to satisfy demand from all distressed firms. We refer to this case as the horizontal region, because the supply of funds from intact firms is elastic at the margin.

The other case is when

$$\frac{1}{2}w^n < \frac{1}{2}\frac{ak + M}{1 + i_1^*},$$

while $w^n < k/2$. That is, intact firms have insufficient resources to satisfy demand from distressed firms. We refer to this case as the vertical region, because the supply of funds is inelastic at the margin.

2.2 Horizontal Region (Mild Crises): The Standard Credit Channel

Intact firms have portfolios that include domestic loans, money, and international collateral. Indifference requires that i_1^* be the interest rate on the domestic loans as well. The exchange rate can also be determined from this indifference condition. Since the return on holding money must be equal to $1 + i_1^*$, the exchange rate is

$$e_1 = 1 + i_1^*. \tag{4}$$

This equation is the interest parity condition, given that $e_2 = 1$ and that money provides no special transaction service (so the peso interest rate is zero). Note that the exchange rate is unresponsive to monetary injections.

Total reinvestment is determined by the total resources of individual distressed firms,

$$\theta^H k = w^n + \frac{ak + M}{e_1} = \frac{w - f + ak + M}{1 + i_1^*} < 2w^n, \qquad \theta^H < 1, \tag{5}$$

where the superscript H denotes the horizontal equilibrium. The first inequality shows that the economy has not used all of its international liquidity, while $\theta^H < 1$ indicates that the economy is in a crisis: distressed firms are not able to meet their production shock fully because of their binding financial constraints.

As we mentioned above, we refer to this as the horizontal region, because the price of loans is not affected by their quantity. In principle, a distressed firm could continue borrowing at the given interest rate i_1^*, as long as its own financial constraint is relaxed.

We can see the effects of monetary injections from the preceding expressions. They operate though a credit channel à la Bernanke and Gertler (1995). From (5) we note that injecting money increases the resources of the distressed firms and increases their investment. From (4) we note that this policy has no effect on exchange rates in the horizontal region, so the monetary expansion is a powerful mechanism to raise the dollar value of distressed firms' collateral. It is possible that reintroducing the standard interest parity effect (which we have suppressed) will work against this conclusion. But as we show next, in the vertical region, we reach the unambiguous conclusion that the exchange rate effect will neutralize monetary expansions.

2.3 The Vertical Region (Severe Crises): Overresponsive Exchange Rate

In this region, the international supply of funds faced by emerging market economies during external crises is vertical (i.e., price inelastic). Since all investment at date 1 is eventually financed by foreigners, the stock of international liquidity is what determines investment in this region:

$$\theta^V k = 2w^n \tag{6}$$

where the superscript V stands for vertical equilibrium. Note that domestic collateral does not appear at all in this expression.

Consider the exchange rate next. Since intact firms borrow up to their maximum capacity from foreigners and hold portfolios only composed of domestic money and loans against domestic collateral, it must be that the return on holding domestic money exceeds i_1^*. That is,

$$e_1 > 1 + i_1^*,$$

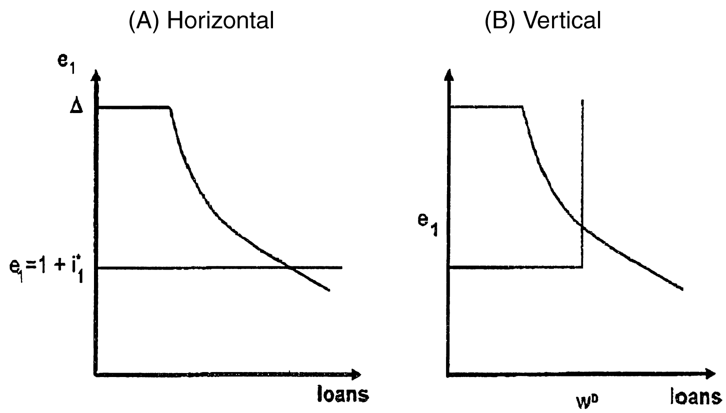
and the date 1 exchange rate is depreciated.

Indifference between holding money and domestic loans implies that the (dollar) interest rate on loans against domestic collateral also rises above i_1^*. In equilibrium, loans collateralized by w are made at rate i_1^*, while those collateralized by ak are made at a higher rate of i_1^d, where

$$i_1^d = e_1 - 1 > i_1^*.$$

Figure 2 represents the equilibrium determination of e_1. The vertical axis is the price, e_1, while the horizontal axis measures domestic reinvestment. For $e_1 = 1 + i_1^*$, intact firms elastically supply their international liquidity to distressed firms. However, at the point w^n, intact firms run out of international liquidity, and the supply curve turns vertical. On the other side of the domestic financial market, distressed firms demand as much international liquidity as they can obtain as long as the exchange rate is less than or equal to Δ. However, they are constrained in their domestic borrowing by their holdings of money and domestic collateral. The demand for international liquidity turns downward at some point, and effective demand is $\frac{M+ak}{e_1}$. Figure 2 represents two cases: one equilibrium in the horizontal region (panel A) and one in the vertical case (panel B).

Figure 2. Equilibrium Exchange Rate



Note: The figure illustrates the equilibrium determination of e_1 in both the horizontal and vertical regions of the supply of international liquidity.

This figure illustrates how e_1 rises above $1 + i_1^*$ in the vertical region when international liquidity is scarce. Note also that e_1 can never exceed Δ, the marginal product of reinvestment for distressed firms. However, there is a large interval for demand within which e_1 lies strictly between $1 + i_1^*$ and Δ. In this case,

$$e_1 = \frac{M + ak}{w^n} > 1 + i_1^*. \tag{7}$$

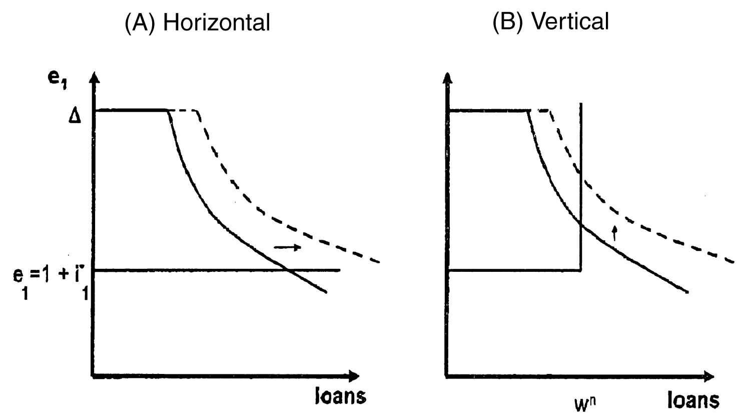
We can see that monetary injections have a very different effect in the vertical than in the horizontal region. From (6), we note that injecting money has no effect on date 1 reinvestment. This is because the economy has a shortage of international liquidity, and reallocating domestic liquidity has no real (aggregate) effect.

As before, the net worth of distressed firms is

$$w^n + \frac{ak + M}{e_1}.$$

That is, the credit channel is still active, and the net worth of distressed firms is what determines reinvestment at date 1. But the exchange rate now is *overresponsive* to monetary injections. Referring back to equation (7), we see that monetary injections are offset one-for-one by a depreciation in the exchange rate. Essentially, the

Figure 3. Domestic Liquidity Expansion



Note: The figure illustrates the effect of an expansion in domestic liquidity on the exchange rate, e_1, as well as the quantity of loans. The figure presents these effects in both the horizontal and vertical regions of the supply of international liquidity.

exchange rate depreciates to ensure that the dollar net worth remains at a level consistent with the availability of external funds. This role of the exchange rate, captured in (7), is what is behind the monetary ineffectiveness result.

2.4 Discussion: The Credit Channel in Emerging Markets

Panels A and B in figure 3 summarize the differences between the horizontal and vertical views. In their downward sloping segments, demands are equal to $(ak + M)/e_1$.

In the horizontal case, the increase in domestic net worth of distressed firms caused by expanding monetary policy raises date 1 investment, leaving e_1 unaffected. In the vertical region, the same increase has *no effect* on equilibrium investment and only raises e_1.

We view the horizontal region as relevant for developed economies; w is plentiful, and there is no distinction between domestic and international liquidity. It may also apply for emerging economies experiencing moderate contractions. The vertical region, on the other hand, seems to be a better description of the environment faced by emerging markets during severe external crises.

There are two points to emphasize from this analysis. First, it may be that other mechanisms overturn the result that injecting money is expansionary in the horizontal region (for example, debts may be dollarized, as we discuss shortly). But in the vertical region, we reach the unambiguous conclusion that injecting money is fully offset by the depreciation in the exchange rate.

This leads to a second point. A researcher looking at the net worth of credit-constrained firms during a crisis will always conclude that the reason for monetary policy ineffectiveness is the deterioration in net worth triggered by the exchange rate depreciation—in particular, the dollarization of liabilities (more on this below). But this is *not* the right conclusion in the vertical region. The main credit constraint behind the crisis is an *aggregate* constraint, not a microeconomic one; the exchange rate depreciation is simply the equilibrium response to such restriction.

3. Underinsurance and Monetary Policy

Of course, all our claims so far are from the perspective of date 1 in the b-state, when w^n is already given. But what is the impact of anticipated monetary policy in the event of a crisis on date 0 decisions? We turn to this discussion next.

We show that a central bank that is expected to contract money in the event of a vertical crisis at date 1 actually causes the private sector to alter date 0 decisions so as to arrive at date 1 with a smaller w^n. By supporting the date 1 currency, the central bank causes the private sector to overborrow at date 0 and underinsure against the crisis. Conversely, expansionary monetary policy gives the private sector incentives to insure against the crisis and reduce date 0 borrowing.

3.1 Private Sector Date 0 Decisions and e_1^b

At date 0, the private sector decides how much to borrow from foreign investors and how much real investment to undertake. The borrowing contracts specify an amount loaned to a domestic firm and a repayment at date 2, f^ω, contingent on the date 1 (aggregate) state $\omega \in \{b, g\}$. Since the funds raised from this loan are used in date 0 investment, and since foreign investors are risk neutral, the date 0 budget constraint is

$$c(k) \leq \frac{1}{(1+i_0^*)(1+i_1^*)}\left((1-\pi)f^g + \pi f^b\right). \tag{8}$$

In the g-state at date 1, all firms make profits of

$$Ak + (w - f^g) + \underline{M}.$$

In the b-state, one-half of the firms are distressed and they make profits of

$$\left(\frac{ak+M}{e_1^b} + \frac{w-f^b}{1+i_1^*}\right)\Delta,$$

while the other half are intact and make profits of

$$Ak + (w - f^b)\frac{e_1^b}{1+i_1^*} + M.$$

Combining these expressions leads to the following problem for a firm at date 0:

PRIV:

$$\begin{aligned} \max_{k,f^g,f^b} \quad & (1-\pi)(Ak + w - f^g + \underline{M}) \\ & +\pi\tfrac{1}{2}\left(\left(A + a\tfrac{\Delta}{e_1^b}\right)k + (\Delta + e_1^b)\tfrac{w-f^b}{1+i_1^*} + \left(1+\tfrac{\Delta}{e_1^b}\right)M\right) \\ s.t. \quad & f^g, f^b \leq w \\ & c(k) \leq \tfrac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b + (1-\pi)f^g). \end{aligned}$$

Our technical assumptions (see the appendix) guarantee that $f^g = w$ and $f^b < w$. The former holds as long as increasing investment in k at date 0 is more profitable than investment in international markets. And $f^b < w$ as long as saving some resources to absorb the production shocks at date 1 is more valuable than using all of those resources toward investment at date 0. It is apparent from the private program that e_1^b is the *only* equilibrium price that influences the date 0 decision. Let us study this connection more closely.

Since $f^g = w$, we simply need to consider the trade-off between increasing f^b and reducing k. At date 0, building a marginally larger plant increases (expected) date 2 profits by

$$(1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{e_1^b}\right). \tag{9}$$

Building this larger plant requires the firm to raise an additional $c'(k)$ at date 0. The probability of a crisis is π, so in order to raise an additional $c'(k)$ at date 0, f^b must rise by

$$\frac{c'(k)(1+i_0^*)(1+i_1^*)}{\pi}.$$

The cost to the firm of raising f^b is that there are fewer resources to absorb the date 1 production shock. The fall in expected profits due to having fewer resources is

$$\pi\left(\frac{\Delta + e_1^b}{2(1+i_1^*)}\right)\frac{c'(k)(1+i_0^*)(1+i_1^*)}{\pi},$$

which can be simplified to

$$c'(k)(1+i_0^*)\left(\frac{\Delta + e_1^b}{2}\right). \tag{10}$$

The optimal choice of k by the private sector equalizes (9) and (10). We note two comparative statics and the conclusion that follows from them: (1) The benefit of building a larger plant size is decreasing in e_1^b; (2) The marginal cost of investing is increasing in e_1^b. For both reasons, k is decreasing with respect to e_1^b.[10]

The investment/financing decision at date 0 is really to create a (real) "peso" plant at the cost of having fewer "dollar" assets in the b-state. The reason for this is that the output from k can only be used as domestic collateral and hence is affected by the value of the exchange rate. On the other hand, to build the plant, the firm has

[10]It is not e_1^b, per se, that matters in this trade-off, but $\frac{e_1^b}{e_2}$ (i.e., the expected future depreciation of the exchange rate) times one plus the i_1^p (the peso rate). Since we have set $e_2 = 1$ and $i_1^p = 0$, this point is obscured. We relax these assumptions later in the paper.

to raise f^b, meaning that there is less international liquidity in the b-state.

Intuitively, the reason why e_1^b matters is that it changes the terms of this investment/financing decision. A more depreciated e_1^b gives firms less incentive to increase k and more incentive to decrease f. This is the reason that k is decreasing with respect to e_1^b.

3.2 Consumption Maximizing e_1^b

We now ask what level of the exchange rate, e_1^b, is required in order for the date 0 decisions to maximize (expected) aggregate consumption. We show that for $e_1^b < \Delta$, the private sector generally overborrows and overinvests relative to this benchmark.

Consider first the date 0 decisions of the private sector, (k, f^g, f^b), that maximize aggregate consumption. To arrive at this program, we simply substitute out the exchange rate of e_1^b from **PRIV**. If we substitute the market clearing condition for e_1^b from (7) into **PRIV** we find that

AGG:

$$\max_{k,f^g,f^b} \quad (1-\pi)(Ak + w - f^g) + \pi\left(\tfrac{w-f^b}{1+i_1^*}\Delta + \tfrac{A+a}{2}k\right)$$

$$s.t. \quad f^g, f^b \leq w$$

$$c(k) \leq \tfrac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b + (1-\pi)f^g).$$

The trade-off between increasing k versus f^b is very different here than in **PRIV**. The benefit of increasing plant size is

$$(1-\pi)A + \pi\frac{1}{2}(A+a).$$

For $e_1^b < \Delta$, this benefit is strictly lower than the private sector's computation. On the cost side, borrowing more to build this plant costs

$$c'(k)(1+i_0^*)\Delta.$$

For $e_1^b < \Delta$, the cost lies strictly above the private sector's computation.

We conclude that, if $e_1^b < \Delta$, then the private sector's date 0 decisions involve overborrowing and overinvesting.

Intuitively, the cause of this date 0 overinvestment is that the private sector undervalues international liquidity in the b-state. At the aggregate level, resources in the b-state always generate a return of Δ from date 1 to date 2. On the other hand, firms see the cost of not having date 1 resources as proportional to e_1^b. As long as $e_1^b < \Delta$, the private sector's investment choices do not lead to maximization of date 2 expected aggregate consumption.

3.3 The Effect of Anticipated Monetary Policy

The previous result highlights a basic feature of the environment. Relative to the consumption-maximizing outcome, the private sector is always biased towards overborrowing and overinvesting. Thus we have a clear benchmark to evaluate policies that affect the exchange rate. In particular, the private sector's biases are exaggerated by a central bank that attempts to stabilize e_1^b. More generally, since the central bank can affect e_1^b with its choice of M, it can reduce this overborrowing problem through monetary policy. A straightforward argument establishes that if the private sector expects an increase in M if a crisis takes place at date 1, then k will be reduced at date 0 and expected date 2 consumption will rise.[11]

4. Dollarization of Liabilities

The credit channel literature in emerging markets has highlighted the role played by dollarization of domestic liabilities in magnifying the contraction. Indeed, even in our framework, a depreciated exchange rate deteriorates balance sheets by lowering the value of domestic assets relative to liabilities. But our framework qualifies the main conclusion from the literature: while dollarization may have the balance-sheet effect highlighted in that literature during mild crises (horizontal region), it does *not* during severe crises (vertical region).

At the firm level, it will seem that the problem is one of dollarized liabilities: firms are credit constrained, and the depreciated exchange rate will worsen balance sheets. But the relevant constraint

[11] The argument is by contradiction. Suppose that increasing M causes k to rise. Then from market clearing at date 1, it must also cause e_1^b to rise. However, since k is a decreasing function of e_1^b, k must fall. This is a contradiction. Therefore, k is decreasing in M, and aggregate consumption is increasing in M.

is a shortage of aggregate international liquidity, not a firm-level balance sheet problem. That is, in a vertical crisis, the country faces a macroeconomic constraint, not a microeconomic one.[12]

However, for the insurance reasons we discussed in the previous section, dollarization is not innocuous. It will generally lead to private sector underinsurance. Let us discuss these dates 1 and 0 issues in turn.

4.1 Dollarization During Severe Crises: A Fallacy of Aggregation

In order to discuss domestic dollarization, we introduce a set of domestic consumers who lend to firms at date 0. For the purpose of this subsection, it is sufficient to start the analysis at date 1, given some preexisting debt. Suppose that firms arrive at the date 1 crisis state with some dollar-denominated debt, b^d, with domestic consumers. Thus, a distressed firm's investment is given as

$$\theta k = w^n + \frac{ak + M - e_1 b^d}{e_1}. \tag{11}$$

The literature emphasizes the fact that from (11) a depreciation reduces the dollar value of local assets ak and M, while it leaves unchanged the value of dollarized liabilities $e_1 b^d$. Moreover, since a monetary expansion depreciates the exchange rate, it may worsen balance sheets and, perversely, turn contractionary.

But, as we argue in section 2, this analysis does not consider that under severe crisis the main binding constraint is the lack of aggregate international liquidity. Thus, all these considerations of the effect of M on e_1, and hence on the domestic credit squeeze, are important for distributional issues (from more to less dollarized firms and consumers) but not for the aggregate. The exchange rate reacts to monetary policy precisely to cause a credit squeeze that equilibrates investment demand with the limited external supply. At the aggregate level, distressed firms' investment is still

$$\theta k = 2w^n. \tag{12}$$

[12] There can be distributional effects—i.e., from those that don't receive M to those that do, or from those with more dollarized liabilities to those with fewer liabilities—but these are likely to be subordinate to the aggregate constraint.

Replacing (12) into (11) yields a new expression for the exchange rate as a function of M:

$$e_1^{b,d} = \frac{ak + M}{w^n + b^d}$$

where the $e_1^{b,d}$ stands for the equilibrium exchange rate with dollarized liabilities. This exchange rate expression needs to be contrasted with expression $e_1^{b,p}$ when domestic liabilities are denominated in pesos, b^p:

$$e_1^{b,p} = \frac{ak + M - b^p}{w^n}.$$

From these two expressions, we can consider the effect of monetary expansions on the exchange rate in economies with different degrees of dollarization:

$$0 < e_1^{b,d}(M)' = \frac{1}{w^n + b^d} < \frac{1}{w^n} = e_1^{b,p}(M)'. \tag{13}$$

The first implication of this expression is that expanding money always depreciates the exchange rate. A central bank that is concerned with the balance sheet position of firms (as in [11]) will be inclined to contract money and support the exchange rate. But since during a vertical crisis, the important constraint is that of (12), the central bank will be *protecting the wrong margin*.

The second implication of (13) is that during severe crises the exchange rate in a dollarized economy will be *less* responsive to a monetary expansion than that of the nondollarized economy. This is a sort of *market-based fear of floating*, as it results from equilibrium considerations for a given monetary policy, and not from any additional caution that the central bank may choose to adopt when liabilities are dollarized. The reason for this result is precisely that a depreciation is more contractionary in a dollarized economy and, therefore, can more easily generate the domestic credit squeeze needed to reduce investment demand to levels compatible with the limited availability of international liquidity.

4.2 Underinsurance Effect of Dollarization

There is a more subtle effect of dollarization in our framework. A central bank at date 1 that is concerned with preserving the balance sheets of firms may, in the vertical region, choose to support the exchange rate. But boosting e_1^b causes firms to undervalue insuring against the b-state and set f^b higher. This follows from the underinsurance results of the previous section. In this sense, the negative effect of central bank support of the exchange rate is that external liabilities will become less contingent. In a model with richer options on the denomination of liabilities, this effect will lead to excessive dollarization of liabilities (see Caballero and Krishnamurthy 2003).[13]

That is, while we challenge the standard view that dollarization of liabilities is a key factor *during* severe crises, we argue that it is an important factor behind crises due to the negative effects it has on private agents' external *insurance* decisions.

4.3 Dollarization of External Liabilities

Before concluding this section, we should point out that there is a related but distinct issue—the dollarization of *external* liabilities. This refers to the fact that most emerging market external debt is not denominated in the issuing country's currency. If debt is denominated in a country's own currency, then the debt will be effectively contingent on aggregate outcomes. In practice, of course, unlike our theoretical assumptions, there is very little contingent debt issued by emerging markets. Thus, if developing economies could or would borrow abroad in their own currency, they would effectively obtain insurance from foreigners against events that depreciate their currency, such as the tightening of external financial constraints. The "original sin" literature in, e.g., Hausmann, Panizza, and Stein (2001) highlights reluctance on the supply side of that market, while Caballero and Krishnamurthy (2003) describe demand side problems behind the lack of contingency of external debt. In our current analysis, external dollarization simply means that there is less contingency in liabilities, so that f^b is higher and closer to f^g. As a result, the country will have less international liquidity in the crisis state. It is also worth noting that the problem of external liability dollarization is

[13] This implication is supported by Bleakley and Cowan (2002), who find that in economies with fixed exchange rates, the match between the denomination of liabilities and that of revenues is weaker than in economies with flexible exchange rates.

reinforced by the underinsurance effects of dollarization of domestic liabilities as discussed above.

Adding external liability dollarization to our problem is conceptually straightforward and makes the supply of international funds at date 1 effectively diagonal, but nothing substantive changes in our analysis. We discuss this extension in section 6.

5. Policy Constraints and Policy Options

In many instances, a central bank faces constraints that force it to support the exchange rate. Dollarization of domestic liabilities is one such instance (whether the market or the central bank determines this is not important for our argument here). Inflation credibility problems are another one. We begin this section with a discussion of inflation credibility, and then turn to alternative policy instruments when monetary policy is constrained to be procyclical or less countercyclical than desirable. There is an important difference in the costs of losing monetary policy during severe crises vis-à-vis doing so in mild ones. In the latter, as in the standard Mundell-Fleming context, the cost is that the central bank loses a countercyclical instrument to smooth fluctuations. In the former, on the other hand, the cost is mainly an "insurance" one. The central bank loses a relatively cheap instrument to induce the private sector to take adequate precautions against crises. In the standard framework, the natural response to the loss of monetary policy is to search for another countercyclical policy instrument (e.g., fiscal policy). In the vertical crisis environment, the natural response is to search for an alternative insurance mechanism. We discuss such alternatives in the second part of this section.

5.1 Limited Inflation Credibility

Limited inflation credibility has two effects in our environment. First, a central bank with a history of high inflation cannot afford the inflationary consequences of an exchange rate depreciation during a crisis. This is a common explanation for the apparent "fear of floating" of central banks in emerging economies (see, e.g., Calvo and Reinhart 2003). However, for the reasons we have outlined above, the anticipation of a contractionary monetary policy during a vertical crisis will exacerbate the private sector's underinsurance problem and thereby worsen the crisis.

A second problem caused by limited inflation credibility is that a central bank that expands monetary policy in a crisis will have a limited effect on real balances. That is, in our environment, a central bank does better by increasing real money balances during a crisis. However, a central bank with limited inflation credibility will create inflation with little effect on real money balances and thereby on the expected return from hoarding international liquidity. In order to see this, note that in all our derivations up to now we have assumed there is long-run inflation (price level) credibility, so that e_2 remains at one regardless of the monetary policy adopted at date 1. But suppose that whenever there is a depreciation during a crisis, some of it is expected to pass through into e_2.

To be concrete, suppose that e_2 (i.e., the date 2 price level) is an increasing function of $\frac{M}{\underline{M}}$, with $e_2(1) = 1$. In a vertical crisis, a distressed firm sells M units of money and ak of domestic collateral to raise funds for salvaging production. The intact firms lend w^n against these assets. To an intact firm, the money is worth $1/e_2$, proportionately less than the ak of domestic collateral. Thus, let us define the return on lending international liquidity as

$$i_1^d = \frac{M/e_2 + ak}{w^n} - 1.$$

The return to an intact firm of purchasing money with international liquidity is just $\frac{e_1}{e_2} - 1$. Since this return must equal the return to lending against the domestic collateral of ak, we find that the interest parity condition is:

$$\frac{e_1}{e_2} - 1 = i_1^d.$$

For the case where $e_2 = 1$, we previously showed that the date 0 level of investment, k, is a decreasing function of e_1. We argued that supporting the currency at date 1 had the consequence of exacerbating the date 0 overinvestment problem of the private sector. Likewise, allowing e_1 to depreciate through an expansionary monetary policy reduced the overinvestment problem.

When e_2 is not fixed at one, a similar argument to that of section 3.1 establishes that k is a decreasing function of $\frac{e_1}{e_2}$. But since

$$\frac{e_1}{e_2} = \frac{M/e_2 + ak}{w^n},$$

the important term for policy purposes is the term involving real money balances (i.e., M/e_2). An expansionary monetary policy raises real balances only to

$$\frac{M}{e_2} < M.$$

Thus, a central bank with limited inflation credibility will have to resort to additional (and possibly very costly) mechanisms to induce adequate private sector insurance decisions. We turn to this discussion next.

5.2 Insurance Substitutes

The problem created by being unable to raise real balances is that the social-private spread, $\Delta - (1 + i_1^d)$, remains high. Thus, the return to hoarding international liquidity until date 1 remains undervalued, and private insurance decisions are distorted. As we argued in section 3, these considerations are unique to the vertical environment, because the insurance problem only arises if the aggregate international liquidity constraint binds.

There are two obvious ex-ante policy measures that can deal with the underinsurance problem: taxation of capital inflows during normal times (date 0) and international liquidity requirements at date 0. We now characterize the relationship between an ex-ante tax and i_1^d.

The first order condition in **AGG** is

$$c'(k^{AGG})(1 + i_0^*)\Delta = (1 - \pi)A + \pi\frac{1}{2}(A + a),$$

whereas for the private sector the condition sets (9) equal to (10) (with e_1 replaced by $1 + i_1^d$).

Aligning the date 0 private and consumption-maximizing incentives is a matter of choosing a tax/transfer policy. Suppose that the central bank levies a tax τ per unit of k, which is returned to firms in a lump sum fashion. Then the first order condition for the private sector becomes

$$c'(k)(1+i_0^*)\frac{\Delta+1+i_1^d}{2} = (1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1+i_1^d}\right) - \tau.$$

Choosing τ to align the private and central-bank incentives yields that for any equilibrium level of $i_{1,\tau}^d$, the optimal tax solves

$$\tau(i_{1,\tau}^d) = \frac{1}{2}\left(\frac{a\pi}{1+i_{1,\tau}^d} + c'(k^{AGG})(1+i_0^*)\right)(\Delta - (1+i_{1,\tau}^d)).$$

The tax is increasing in $\Delta - (1+i_{1,\tau}^d)$. Thus, economies where the central bank cannot follow countercyclical monetary policy, and therefore $\Delta - (1+i_1^d)$ remains high, may need to rely on capital controls to correct the underinsurance problem. Note that the same result could be achieved via a contingent liquidity requirement. The tax solution gives the private sector incentives to choose the efficient k, thus resulting in the efficient $w - f^b$. Alternatively, the central bank could mandate directly that each firm preserve international liquidity for the date 1 crisis state, so that the efficient level of $w - f^b$ is realized.

In practice, taxes come with their own sets of distortions: deadweight costs of taxation, costs of enforcement, evasion, etc. However, the important point to recognize is that, in the vertical environment, the cost of losing monetary policy is *not* being unable to manage aggregate demand or the extent of the domestic credit squeeze at date 1. Rather, the cost is the underinsurance by the private sector at date 0. In this sense, the cost of having to enforce capital controls may be seen as a direct cost of losing monetary policy.

6. Robustness: Peso Rates and Diagonal Supply

In this section, we show that our main conclusions are robust to modifications in two of the most stylized features of our model: the absence of a monetary friction and the absolute price inelasticity of the supply of funds during crises.

6.1 Peso Rates and Interest Parity Condition

Up to now we have simplified our analysis by removing all monetary frictions from the analysis, and therefore have set the domestic peso interest rate to zero. This simplifies exchange rate determination at date 1, but leaves us with an unusual model of money. Here we sketch a more standard model of money, in which money is special because it provides a transaction service.[14] Our substantive results remain unchanged, although now we recover the standard exchange rate effect via the interest parity condition in addition to the excess sensitivity result we discussed in the previous sections.

Let us return to the full inflation credibility case ($e_2 = 1$) and let us focus on the vertical region and the bad aggregate state.

At the end of date 1, the government has liabilities of B bonds and M units of money per capita. Each bond is redeemed at date 2 for one unit of money, and the government is credible in ensuring that the price level at date 2 is one. At date 1, money is the only domestically liquid asset. Neither claims against ak (corporate bonds) nor the government bonds are liquid. Thus, at date 1, distressed firms sell M units of money to the intact firms in exchange for w^n units of international liquidity, which means that

$$e_1^b = \frac{M}{w^n}.$$

It is instructive to go through the steps that take us to this equation in order to disentangle the mechanisms through which money affects the exchange rate during severe crises in this economy.

We introduce a date 1^- in order to study peso interest rates and the effects of open market operations. At date 1^- the aggregate state of the world has been realized, but the identity of agents receiving the shock (distressed or intact) has not. Because of the latter, agents are all identical at 1^-.

At date 1^-, both the bond market and the money market are open to all agents. Entering date 1^-, the government has outstanding $\underline{B}$ bonds and $\underline{M}$ money. The government does an open market operation to purchase $(\underline{B} - B)$ bonds for $(M - \underline{M})$ money.

Let us consider the relative asset returns on bonds, money, and international liquidity at date 1^-.

[14]See Diamond and Rajan (2001, 2003) and Lorenzoni (2001) for alternative models of money in liquidity-based frameworks.

One bond yields one unit of money at date 2 and costs $1/(1+i_1^p)$ units of money at date 1^-, where i_1^p is the peso interest rate. One unit of money can be sold at date 1 to finance the liquidity shock if the agent is distressed. Money is sold for international liquidity at a price of $1/e_{1^-}$. Each unit of international liquidity yields Δ at date 2. Thus the expected return on holding money from date 1^- to date 2 is $0.5\,(\Delta/e_{1^-}+1)$. As before, $\Delta \geq e_{1^-}$, which means that the net return is positive. It immediately follows that indifference between holding money and bonds requires that

$$1+i_1^p = \frac{1}{2}\left(\frac{\Delta}{e_{1^-}}+1\right). \tag{14}$$

One unit of money also can be converted in the foreign exchange market into one unit of international liquidity, at the price of e_{1^-}. One unit of international liquidity either can be used in production at date 1 or sold to a distressed firm at date 1. The expected benefit of the unit of international liquidity is $\frac{1}{2}(\Delta+e_{1^-})$. Thus, the interest parity condition is

$$(1+i_1^p)e_{1^-} = \frac{1}{2}(\Delta+e_{1^-}). \tag{15}$$

In the standard interest parity condition, the right-hand side of (15) is fixed, and a reduction in i_1^p must be offset by a depreciation in e_{1^-} to keep the left-hand side constant as well. But the depreciation in our vertical environment raises the return to the dollar-lender in the right-hand side of (15), which means that the left-hand side must rise, and this is achieved by a further depreciation in e_{1^-}. The latter is the excess sensitivity result we have discussed, and it results from the relaxation of the domestic credit squeeze caused by the monetary expansion.

Finally, combining (14) and (15), we can solve for the peso interest rate and the exchange rate as a function of monetary policy:

$$1+i_1^p = \frac{1}{2}\left(\frac{\Delta}{M}w^n+1\right)$$

$$e_{1^-} = \frac{M}{w^n}.$$

The latter is the expression we started this section with, and it summarizes the two channels through which money affects the exchange rate: interest parity and domestic credit squeeze.

Relative to our earlier model, it is the former (and standard) channel that is new. But neither channel can change the fact that international liquidity is fixed at date 1 and hence output cannot be affected by monetary policy:

$$C^V = \left(\frac{A+a}{2}\right) k + w^n \Delta + y^c.$$

And for date 0 decisions, it is only the *second* channel that matters, which is common to this and the model without monetary frictions.

6.2 "Diagonal" Supply

Let us now return to the model without monetary frictions, and continue to assume $e_2 = 1$. But rather than an inelastic supply of funds at date 1, let us consider instead a supply curve of the form

$$w^n s(e_1) \quad \text{where} \quad s(1) = 1, \quad s'(\cdot) > 0.$$

That is, the supply of international funds is "diagonal" as opposed to vertical.[15]

Equilibrium at date 1 is now

$$\frac{ak + M}{1 + i_1^d} = w^n s(e_1).$$

As in the pure vertical model, e_1 is increasing in M. However, consider the expression for total consumption at date 2. This is

$$C^V = \left(\frac{A+a}{2}\right) k + w^n s(e_1)\Delta + y^c,$$

[15]The diagonal supply also captures the idea that depreciating the exchange rate increases exports and, if the export sector is an important part of international collateral, thereby expands supply. Christiano, Gust, and Roldos (2004) offer a related perspective on diagonal supply. In their model, imperfect liquidity substitution stems from imperfect input-substitution and from the fact that different inputs are paid in different currencies. The "diagonal" aspect of their model arises from the (limited) possibility of substituting tradables and nontradables inputs.

which is now an increasing function of e_1 through the $s(\cdot)$ function. This implies that increasing M does have a contemporaneous effect on C^V.

Thus, from a date 1 perspective, the diagonal model has elements of both the horizontal model and the vertical model. As in the horizontal model, there is an aggregate demand channel/credit squeeze channel through which expanding money increases aggregate consumption. As in the vertical model, the money expansion depreciates the exchange rate beyond the standard interest parity effect.

Now, let us shift back to date 0. At this date, the firm contemplates borrowing some resources and increasing k, the size of the plant. As before, the shadow cost of the resources is increasing in e_1. A higher expected e_1 induces a firm to save some dollar resources until date 1, at which point these resources can always be lent to return $e_1 - 1$. Moreover, as long as $e_1 < \Delta$, the private sector's decisions will not be consumption maximizing. Thus, as in the vertical model, there is an insurance channel for monetary policy in the diagonal model. Expanding M at date 1 depreciates e_1. The anticipation of such depreciation makes the private sector reduce investment at date 0 and increase its insurance against the date 1 shock.

7. Final Remarks

The past decade has witnessed several episodes in which the sudden reversals of capital inflows triggers an emerging markets' crisis. These events have placed the risk of "sudden stops" as a central macroeconomic concern for emerging market economies. The main contribution of our paper is to illustrate how monetary policy affects financial constraints of firms during a sudden stop crisis and to highlight an *insurance* effect of monetary policy. Domestic monetary expansion relaxes individual financial constraints but is unable to relax the aggregate financial constraint faced by these economies during crises—it is the wrong kind of liquidity for such a purpose. However, while monetary policy is largely futile once the sudden stop has taken place, the anticipation of a particular reaction by the authority is important for private sector insurance decisions. A flexible exchange rate system, coupled with a countercyclical monetary policy, provides better *insurance* incentives to the private sector than a policy of defending the exchange rate during sudden stops.

Our insurance mechanism is distinct (or in addition to) the standard moral-hazard/free-insurance argument (see, e.g., Dooley 1999). In the latter argument, crises result from an implicit commitment by a local government or foreign institution to transfer resources to the imprudent borrower; a fixed exchange rate transfers reserves at submarket value (during crises) to the dollar-borrower or peso-investor. In our model, there is no direct transfer from the government. The monetary contraction implicit in the defense of the exchange rate lowers the domestic liquidity that borrowers can offer to dollar-lenders during the sudden stop, and in so doing, it lowers the effective return from *new* local dollar lending. By doing so, it affects the incentives to hoard international liquidity for crises.

More generally, monetary policy and its constraints have (unintended) consequences for the private sector's insurance decisions with respect to sudden stops. Policies that exacerbate the domestic credit squeeze during sudden stops, or constraints that limit the authorities' ability to relax domestic financial constraints, lead to socially imprudent private sector actions.

Our emphasis on dual liquidity and insurance has relevance for evaluation of other government policies. Proactively managing international reserves may result in benefits in our framework (see Caballero and Krishnamurthy 2004). Since international reserves are a form of international liquidity, and the private sector carries too little international liquidity into crises, the central bank has a role to play by carrying reserves in place of the private sector. Injecting reserves during a crisis relaxes the international financial constraint faced by the private sector and stabilizes the exchange rate. Relaxing the constraint is beneficial, but the effect on the private sector's own insurance incentives is not, for reasons akin to those we discussed in the context of monetary policy. Reserves management and monetary policy become complementary policy tools in this context. At the very least, the central bank ought to sterilize the forex intervention and possibly go beyond that in the monetary expansion in order to offset the perverse incentive effect of the reserves injection.

Of course, the insurance dimension we highlight in our analysis is not a substitute for conventional inflation credibility concerns. Quite the contrary, without inflation credibility, the central bank will be unable to let the exchange rate float and expand monetary policy during sudden stops, and may well be forced into tightening monetary policy. The anticipation of this behavior is very costly in our setting, precisely because it exacerbates the private sector's underinsurance problem. In other words, our insurance consideration *raises* the value of achieving medium-term inflation credibility.

Our stylized model is subject to many caveats. One worth mentioning in concluding is the lack of true dynamics. In reality, crises build up, going first through a horizontal phase in which domestic financial conditions tighten and external borrowing becomes gradually more expensive, then falling into a sharp vertical sudden-stop phase. A central question for policymakers in this context is how to conduct monetary policy at the early stages of the crisis, when supply is still horizontal but there is a concern that events may lead to a binding international liquidity constraint. At this stage, tightening monetary policy will destroy financially constrained projects but save international liquidity for the vertical event. We conjecture that this trade-off can be analyzed in terms similar to those we have used throughout: if the commitment to an aggressive countercyclical monetary policy in case of a vertical event is credible, then there is little need to tighten during the horizontal phase. But if the commitment is not credible or feasible, then the appropriate response is to tighten during the early phase in order to protect international liquidity, very much as taxing capital flows at date 0 was advisable in our simplified model when there were constraints on monetary policy during crises. In fact, the costs in terms of the additional financial distress imposed on the domestic private sector are, to a large extent, comparable to the costs of the ex-ante measures we already discussed.

Finally, while our analysis has focused on emerging markets, the underlying structure may be a starting point for other applications. Our model illustrates how a bottleneck may segment financial markets and create liquidity premia on assets. It shows how monetary policy affects and is affected by these bottlenecks. There are many other scenarios, such as liquidity traps and post-bubble-collapses, where similar ingredients appear worthy of consideration. We are currently exploring these applications.

Appendix

Financing Assumptions

The financial frictions of the model are embodied in the following two assumptions:

Assumption 1 ***(International Collateral)***
Foreigners lend to domestic firms only against the backing of w. Domestic agents lend against w, M, and ak.

Assumption 2 ***(Domestic Collateral)***
A domestic lender can only be sure that a firm will produce ak units of goods at date 2. Any excess production based on physical reinvestment at date 1 is neither observable nor verifiable.

One last assumption is required to rule out date 0 insurance arrangements that transfer resources from distressed firms to intact firms.

Assumption 3 ***(Nonobservability of Production Shock)***
The production shock at date 1 is idiosyncratic. The identity of firms receiving the shock is private information.

The mechanism design problem associated with these financing and informational constraints corresponds to the one in **AGG**. There is also a banking arrangement that, in principle, may get around the private information constraint, but this is very fragile.

Technical Assumptions

Consider next the technical assumptions on parameters that we have used. The program in **AGG** is

AGG:

$$\max_{k,f^g,f^b} \quad (1-\pi)(Ak+w-f^g)+\pi\left(\frac{w-f^b}{1+i_1^*}\Delta+\frac{A+a}{2}k\right)$$

$$s.t. \quad f^g, f^b \leq w$$

$$c(k) \leq \frac{1}{(1+i_0^*)(1+i_1^*)}(\pi f^b+(1-\pi)f^g).$$

First, we require that $w = f^g$ in this program, or that the return to investing domestically exceeds that of investing abroad.

Assumption 4 ***(High Investment Return)***

$$(1-\pi)A + \pi\frac{A+a}{2} \geq c'\left(\frac{w}{(1+i_0^*)(1+i_1^*)}\right)(1+i_0^*)(1+i_1^*).$$

Second, we require that the solution features some insurance against the b-state, so that $f^b < w$.

Assumption 5 ***(High Return to Insuring)***

$$c'\left(\frac{w}{(1+i_0^*)(1+i_1^*)}\right)(1+i_0^*)\Delta \geq (1-\pi)A + \pi\frac{A+a}{2}.$$

These last two assumptions can both be met by choosing a large enough value for Δ.

We require that equilibrium, with no central bank intervention, places us in the vertical region, or

$$1 + i_1^* < e_1 < \Delta.$$

The first-order condition for the program in **PRIV** is

$$c'(k)(1+i_0^*)\frac{\Delta + e_1}{2} = (1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{e_1}\right).$$

Denote the solution to this equation as $k(e_1)$. Then the largest value of k is attained when $e_1 = 1+i_1^*$, and the smallest value when $e_1 = \Delta$. Using this knowledge as well as the market clearing condition leads to:

Assumption 6 ***(Equilibrium in Vertical Region)***

$$\begin{aligned}\frac{\pi(\underline{M} + ak(i_1^*))}{w - (1+i_0^*)(1+i_1^*)c(k(i_1^*))} &< \frac{\Delta}{1+i_1*} \\ \frac{\pi(\underline{M}ak(\Delta - 1))}{w - (1+i_0^*)(1+i_1^*)c(k(\Delta-1))} &> 1\end{aligned}$$

Finally, we have implicitly assumed that the maximum reinvestment constraint does not bind in the vertical equilibrium:

$$\frac{k}{2} > \frac{w - f^b}{1 + i_1^*} = \frac{w - c(k)(1 + i_0^*)(1 + i_1^*)}{\pi(1 + i_1^*)}$$

This can be rewritten as

$$e_1 = \frac{\pi(\underline{M} + ak)}{w - (1 + i_0^*)(1 + i_1^*)c(k)} > 2a.$$

This leads to:

Assumption 7 ***(Reinvestment Constraint Does Not Bind in*** V***)***

$$a < \frac{1 + i_1^*}{2}$$

Dollarization of Domestic Liabilities

We sketch an extension to the model of section 6 in order to address dollarization of liabilities. As mentioned in section 5.2, this is one of the primary reasons that policymakers give for being unable to lower interest rates during a crisis.

Suppose that firms have debts of D dollars that have to be settled at date 1^-. These debts are owed to domestic consumers, so that they do not affect the international liquidity of the country. Then the total peso net worth of agents at date 1^-, before any open market operations, is

$$NW = \frac{\underline{B}}{1 + i_1^p} + \underline{M} + \frac{ak}{1 + i_1^p} - De_{1^-} \tag{A1}$$

Now suppose that the government does an open market operation where it purchases bonds with money. Since this transaction is done at market prices, the net worth remains as in (A1).

The open market operation has two effects. First, it lowers i_1^p and thereby raises $\frac{ak}{1+i_1^p}$. Second, it raises e_{1^-} and thereby increases the debt burden of domestic firms. For a large enough value of D, it is clear that the second effect can overwhelm the first, so that peso net worth *falls* rather than rises with the open market operation.

The interesting case for our model is when, after the open market operation, $NW < M$. That is, the peso net worth of the firms is less than the aggregate amount of money in the domestic economy. In this case, firms will not be able to sell their assets at date 1^- to acquire all of M. Thus, the market clearing condition at date 1 becomes

$$1 + i_1^d = \frac{NW}{w^n}.$$

In this case, expansionary open market operations lower i_1^d rather than raise it, but still have no effect on output. At date 1, since expansionary open market operations depreciate the exchange rate, the central bank will raise interest rates. The reaction in this case is ex-ante optimal, since raising interest rates causes i_1^d to rise and leads to better insurance decisions by the private sector. However, the fact that the central bank's time inconsistency problem is attenuated when domestic liabilities are dollarized does not mean that the underinsurance problem has been resolved. Quite the contrary, time inconsistency has been reduced because the country has *no* access to monetary policy.

References

Aghion, Philippe, Philippe Bacchetta, and Abhijit Banerjee. 2000. "Currency Crises and Monetary Policy with Credit Constraints." Mimeo, Harvard University.

Bernanke, Ben, and Mark Gertler. 1995. "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." *Journal of Economic Perspectives* 9 (Fall): 27–48.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics,* Vol. 1C, ed. John B. Taylor and Michael Woodford. Elsevier Science.

Bleakley, Hoyt, and Kevin Cowan. 2002. "Corporate Dollar Debt and Depreciations: Much Ado About Nothing?" Working Paper 02-05, Federal Reserve Bank of Boston.

Broner, Fernando, Guido Lorenzoni, and Sergio Schmukler. 2003. "Why do Emerging Markets Borrow Short Term?" Mimeo.

Bulow, Jeremy, and Kenneth Rogoff. 1989. "A Constant Recontracting Model of Sovereign Debt." *Journal of Political Economy* 97 (1): 155–78.

Caballero, Ricardo J., and Arvind Krishnamurthy. 2001. "International and Domestic Collateral Constraints in a Model of Emerging Market Crises." *Journal of Monetary Economics* 48:513–48.

Caballero, Ricardo J., and Arvind Krishnamurthy. 2003. "Excessive Dollar Debt: Underinsurance and Domestic Financial Underdevelopment." *Journal of Finance* 58 (2): 867–93.

Caballero, Ricardo J., and Arvind Krishnamurthy. 2005. "Inflation Targeting and Sudden Stops." In *The Inflation-Targeting Debate,* ed. Ben S. Bernanke and Michael Woodford. Chicago: University of Chicago Press.

Calvo, Guillermo A., and Carmen M. Reinhart. 2003. "Fear of Floating." *Quarterly Journal of Economics* 117 (2): 379–408.

Cespedes, Luis F., Robert Chang, and Andres Velasco. 2000. "Balance Sheets and Exchange Rate Policy." NBER Working Paper No. W7840 (August).

Christiano, Lawrence J., Christopher Gust, and Jorge Roldos. 2004. "Monetary Policy in a Financial Crisis." *Journal of Economic Theory* 119 (1): 64–103.

Diamond, Douglas W., and Raghuram G. Rajan. 2001. "Liquidity Shortages and Financial Crises." Mimeo, University of Chicago (June).

Diamond, Douglas W., and Raghuram G. Rajan. 2003. "Money in a Theory of Banking." NBER Working Paper No. 10070 (October).

Dooley, Michael. 1999. "Responses to Volatile Capital Flows: Controls, Asset-Liability Management and Architecture." World Bank Conference on Capital Flows, Financial Crises, and Policies (April).

Dornbusch, Rudiger. 1976. "Expectations and Exchange Rate Dynamics." *Journal of Political Economy* 84 (December).

Dornbusch, Rudiger. 2001. "Fewer Monies, Better Monies." NBER Working Paper No. 8324 (June).

Eaton, Jonathan, and Mark Gersovitz. 1981. "Debt with Potential Repudiation: Theory and Estimation." *Review of Economic Studies* 48:289–309.

Edwards, Sebastian, and Eduardo Levy-Yeyati. 2003. "Flexible Exchange Rates as Shock Absorbers." NBER Working Paper No. 9867 (June).

Furman, Jason, and Joseph E. Stiglitz. 1998. “Economic Crises: Evidence and Insights from East Asia.” *Brookings Papers of Economic Activity* 2.

Gertler, Mark, Simon Gilchrist, and Fabio M. Natalucci. 2001. “External Constraints on Monetary Policy and the Financial Accelerator.” New York University Working Paper (February).

Hausmann, Ricardo, Ugo Panizza, and Ernesto Stein. 2001. ”Why do countries float the way they float?” *Journal of Development Economics* 66 (2): 387–414.

Holmstrom, Bengt, and Jean Tirole. 1998. “Private and Public Supply of Liquidity.” *Journal of Political Economy* 106 (1): 1–40.

Kiyotaki, Nobuhiro, and John Moore. 1997. “Credit Cycles.” *Journal of Political Economy* 105 (2): 211–48.

Lorenzoni, Guido. 2001. “Interest Rate Stabilization and Monetary Control: A Reconciliation.” Mimeo, Princeton University.

Woodford, Michael. 1990. “Public Debt as Private Liquidity.” *American Economic Review, Papers and Proceedings* 80 (May): 382–88.