A "Vertical" Analysis of Monetary Policy in Emerging Markets

Ricardo J. Caballero Arvind Krishnamurthy*

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Abstract

During emerging market crises, domestic agents might have sufficient collateral to borrow from other domestic agents, but they are unable to borrow from foreigners because the country, as a whole, lacks international collateral. In this setting, we show that an (ex-post) optimizing central bank's response to an external crisis is to tighten monetary policy to support the exchange rate. Although this response can be rationalized ex-post, it has negative consequences ex-ante when domestic financial markets are underdeveloped: It reduces the already insufficient private sector incentives to insure against external crises. If a central bank could commit, it should expand monetary policy instead. Indeed, there are important drawbacks to lacking the willingness, credibility, or feasibility to implement an expansionary monetary policy during crises. It means that the central bank must resort to other, potentially more costly instruments to address the underinsurance problem, including capital controls and international liquidity requirements.

JEL Codes: E0, E4, E5, F0, F3, F4, G1

Keywords: External shocks, domestic and international liquidity, monetary policy, interest parity departures, exchange rate overshooting, fear of floating, commitment, credibility, underinsurance.

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Abstract

During emerging market crises, domestic agents might have sufficient collateral to borrow from other domestic agents, but they are unable to borrow from foreigners because the country, as a whole, lacks international collateral. In this setting, we show that an (ex-post) optimizing central bank's response to an external crisis is to tighten monetary policy to support the exchange rate. Although this response can be rationalized ex-post, it has negative consequences ex-ante when domestic financial markets are underdeveloped: It reduces the already insufficient private sector incentives to insure against external crises. If a central bank could commit, it should expand monetary policy instead. Indeed, there are important drawbacks to lacking the willingness, credibility, or feasibility to implement an expansionary monetary policy during crises. It means that the central bank must resort to other, potentially more costly instruments to address the underinsurance problem, including capital controls and international liquidity requirements.

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1 Introduction

This paper investigates central bank policy in an emerging economy that experiences shocks to its external supply of funds. A negative shock can lead to a crisis in which output and asset prices fall. What should the central bank do in such scenario?

In a small open economy model, the standard answer to this question is to let the currency depreciate and lower interest rates. The standard counterargument to this recommendation is that emerging economies have serious inflation-credibility problems, and failing to defend the currency during the crisis may trigger a costly inflationary spiral. This counterargument is reinforced when, due to a history of chronic inflation, there is extensive dollarization of domestic liabilities.[1]

However there are a growing number of emerging economies for which inflationary concerns are no worse than for developed economies. These countries currently include Chile, Mexico, Poland and many of the Asian economies. Will the debate soon be of historical value only, with little relevance for the new prototypical emerging economy? In other words, should the emerging economies that have controlled inflation simply follow the same monetary policies as developed economies? And, will central banks be inclined to behave similarly in both type of economies?

To answer these questions, one needs to examine the central differences in the structure of these economies (developed and emerging), and how they relate to their respective monetary transmission channels. We isolate one factor in particular: the different nature of financial constraints faced by these economies.

We distinguish between developed and emerging economies by modelling the presence of two distinct financial constraints. If agents can borrow from either domestic or foreign lenders, then there are two types of financial frictions to consider: An agent may have limited collateral, and therefore be constrained in his borrowing from either domestic or foreign lenders. Or, the country as a whole may have limited international collateral; thus domestic agents are constrained in borrowing from foreign investors. We argue that the second type of constraint is much more prominent in emerging markets than in developed economies, and is the distinguishing feature of emerging markets' crises.[2]

When the only financial constraint faced by agents is at the microeconomic level, then the optimal central bank policy is to expand the money supply, thus relaxing the financial

[1] For both sides of the argument, see, e.g., Furman and Stiglitz (1998), Fischer (1999), Aghion et al (2000), Cespedes et al (2000), Gertler et al (2001), Christiano et al. (2003), and Calvo and Reinhart (2003).

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

constraint and increasing output. This is the recipe for a developed economy. Our model of this case corresponds closely to the standard model of microeconomic financial constraints emphasized in most of the macroeconomics literature on credit constraints (e.g., Bernanke, Gertler, and Gilchrist, 1989, and Kiyotaki and Moore, 1997). As is widely communicated in that literature, increasing the net worth of borrowers enables them to receive additional credit from either domestic or foreign lenders and thereby increases aggregate output. In our model, expanding the money supply accomplishes this task.

When the financial constraint exists at the country level, this logic fails, because monetary policy only regulates the borrowing of a domestic agent from a domestic lender. As long as the marginal lender is another domestic agent, monetary injections increase output. However, when the marginal lender is a foreign investor, monetary policy is ineffective because it does not alter the international collateral of the country.[3]

This distinction between domestic borrowing capacity and international borrowing capacity is the central theme in our analysis. In an emerging market crisis the international borrowing capacity of the country is limited relative to its investment needs. The supply of international funds is fixed and price-inelastic ("vertical"). In Section 2 we develop a model in which a shock may lead to a binding vertical constraint. We show that asset prices, the exchange rate, and output fall during such an event. We also contrast that model with one in which there is no distinction between domestic and international borrowing capacity.

Section 3 describes the objectives of the central bank and derives central bank policy during a crisis. Although in our model monetary expansions have no output effects, they have large effects on the exchange rate. Since the quantity of international funds is inelastic, their price —the exchange rate— is very responsive to monetary policy. A central bank that is balancing output against an inflation target will see little benefit by expanding, and significant inflation-target benefits by contracting. Thus the central bank will exhibit "fear of floating," even if no inflation-credibility problems are present.[4]

In Section 4 we turn to ex-ante optimal (preventive) policies. That is, we shift our attention to the time prior to the crisis, when private sector and central bank actions could lessen the extent of the coming crisis. As in Kydland and Prescott's (1977) and, Barro and

[3]While 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..."

[4]See Calvo and Reinhart (2003) and Hausmann et al (2001) for extensive documentation of "fear-of-floating" among emerging economies with flexible exchange rate regimes.

Gordon's (1983) analysis, we find that the interplay between private sector expectations and central bank actions creates a need for commitment. However, the concern in our model is with the private sector's preventive measures rather than with its inflation expectations.[5] In our model of emerging markets, the private sector underinsures against crisis events. Importantly, the extent of the underinsurance depends on the expectations of central bank actions during a crisis. We show that the strategy of raising interest rates during crises lowers the private return to taking preventive measures and hence discourages it. As a result, it is optimal for the central bank to commit to a counter-cyclical monetary policy. That is, the ex-post optimal response of the central bank of supporting the currency by raising interest rates, in fact is sub-optimal ex-ante.

In our model monetary policy works through an "insurance" channel rather than the usual aggregate demand channel. We recommend that the central bank expand monetary policy during crises because this improves the private sector's ex-ante incentives to insure against crises. On the other hand, in a developed economy the central bank lowers interest rates during a recession in order to stimulate aggregate demand.

This distinction in the role played by monetary policy in emerging markets vis-a-vis developed ones offers an insight into alternative policy instruments, in cases where monetary policy cannot be used: for example, as is the case in our model, if the central bank cannot commit not to supporting the exchange rate. This, as well as standard problems with inflation-credibility and dollarization of domestic liabilities (which we discuss in sections 5 and an appendix, respectively), will constrain the use of monetary policy as a counter-cyclical instrument. The important observation in our context is that the cost of losing monetary policy is not that an instrument for managing aggregate demand is lost; rather, it is that an insurance mechanism against crises is lost. Thus, rather than looking to fiscal policy as a substitute for monetary policy, one should look for an alternative insurance mechanism. Section 5 discusses 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.

Finally, Section 6 shows that our main conclusions are robust to the relaxation of some

[5] See Part V in Persson and Tabellini (2000) for a thorough review of the inflation-credibility literature. Also, see Chapter 9 in Obstfeld and Rogoff (1996) for an emphasis on open economy implications of inflation-credibility considerations.

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 the appendix.

2 The Private Sector and Crises

This section lays out the underlying structure of the economy. It provides a stylized model of the private sector and financial crises.[6] Firms hold buffer stocks of assets in order to meet financial needs that may arise before their projects are completed. These buffer stocks may be held either as domestic or international assets. In the vertical view of this paper, the distinction between these two types of assets is central for aggregate outcomes. We contrast this view with a horizontal view in which the distinction is immaterial for outcomes.

2.1 Setup

We study an economy exposed to an external financial crisis. The crisis occurs at date 1, and is followed by a final date 2 when firms repay their outstanding debts. We start time with a date 0, which is a fully flexible period when agents make investment and financing decisions. The periods are indexed by $t = 0, 1, 2$, and there is a single (tradeable) good.[7]

There is a unit measure of domestic firms, such that each has access to a production technology. Building a plant of size k at date 0 requires them to invest $c(k)$ — with $c(.) \geq 0$, $c' > 0$ and $c'' > 0$ — which yields date 2 output proportional to the size of the plant (see below). Domestic firms have no resources at date 0. They must import capital goods and borrow from foreigners to finance their investment. The financing and investment decisions maximize expected plant profits at date 2. Each firm is run by a domestic entrepreneur/manager who has risk-neutral preferences for date 2 consumption of the single good.

Domestic firms face significant financial constraints. Each firm is endowed with w units of collateral, in the form of receivables arriving at date 2. Only claims against these date 2

[6] The underlying structure is similar to that described in Caballero and Krishnamurthy (2001) but the model itself is substantially simpler and better suited for the substantive analysis of monetary policy that follows.

[7] See Caballero and Krishnamurthy (2003a) for a model which builds on the distinction between nontradable and tradable goods. While this distinction is realistic and makes some of our results a bit less stark, it is qualitatively unimportant for the issues we discuss here. See Section 6 in this paper for a “diagonal” model with implications similar to those of a model with nontradable goods.

goods 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. At date 0, when firms sign debt contracts with foreigners, the contracted repayments of f 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.

2.2 Date 1 Financing Needs and Crises

For the remainder of this and the next section, let us take as given all date 0 investment and financing decisions and focus on the crisis period. In a crisis, the financial constraints bind for firms.

There are two (aggregate) states of the world at date 1, $\omega \in \{b, g\}$, which occur with probabilities $\{\pi, 1-\pi\}$. In the b-state, firms may receive a production shock for which they need resources. Financial constraints will prevent them from fully absorbing the production shock. The b-state is the crisis state. In contrast, in the g-state there are no shocks and financial constraints do not bind. Let us now turn to defining the shock in the b-state, and explaining how financial constraints may come to bind.

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 0.5.[8]

The productivity decline can be offset by reinvesting θk ($\theta \leq 1$) goods, to give date 2 output of,

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

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 curtailed in their date 1 reinvestment, $\theta < 1$, despite the fact that $\Delta - 1 > i_1^*$. In this case firms are financially constrained at date 1. Parameter assumptions ensure that this occurs in equilibrium only in the b-state (see the appendix).

[8] More realistically, we can introduce the aggregate shock as a contraction of international collateral (e.g., due to a decline in terms of trade) or through a rise in the international interest rate faced by the country's prime borrowers. In this case, for the crisis to occur only in the b-state we would have to add an incomplete international insurance markets assumption (as opposed to the technological assumption of liquidity shocks that we made). Our conclusions would be similar.

A firm that receives a liquidity 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**). 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. But why would intact firms lend to distressed firms any more than foreigners would? That is, why is the domestic financial market different from the international financial market? Because we assume that domestic agents accept the output from a firm's plants as collateral.

However, since a perfectly functioning domestic financial market is hardly a good description of an emerging economy, and because this departure has central implications for our analysis, we assume that only a fraction of the output from the plants can be pledged to other domestic agents. We make this fraction equal to the minimum output, ak. Since firms can use this collateral to borrow in the domestic financial market, we refer to ak as **domestic** collateral.

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

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

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

2.3 The Horizontal View

In the horizontal view, distressed firms are constrained in meeting their financing needs only to the extent that they have limited collateral. The total collateral of a firm is $ak + w - f$. This quantity is insufficient to meet the production shock.

Translated into our context, the horizontal view implicitly assumes that the country as a whole, at the margin, has an international liquidity slack. A foreigner would be willing to extend another loan at i_1^* to some domestic firm. But the worthy firm is not distressed. The shortfall is in the total collateral of distressed firms, rather than in the country's international liquidity.

In our model, because intact firms borrow up to w^n from foreigners in order to lend to distressed firms against ak, there is excess international liquidity if,

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

In other words, intact firms have sufficient access to foreign funds to satisfy loan demand from all distressed firms. Since intact firms then have portfolios that include both domestic loans and international collateral, indifference requires that i_1^* be the interest rate on the domestic loans as well.

Total reinvestment is determined by the individual distressed firms' collateral constraint:

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

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.

We refer to this as the horizontal view, 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 financial constraint is relaxed.

2.4 The Vertical View

In this view, the international supply of funds faced by emerging economies during external crises is vertical. The main problem for the country is not insufficient collateral of distressed firms, but rather a shortage of country-wide international liquidity. Inequality (1) is reversed:

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

so that distressed firms have enough domestic collateral and, at the interest rate of i_1^*, their loan demand exceeds the international liquidity of the intact firms. However, international liquidity is scarce relative to the production needs:

$$w^n < \frac{1}{2} k.$$

Since all investment at date 1 is eventually financed by foreigners, the stock of international liquidity is what determines investment in this region:

$$\theta^V k = 2w^n, \tag{3}$$

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

In the vertical modelling of crises, the interest rate on loans against domestic collateral departs from i_1^*. Since intact firms are borrowing up to their maximum capacity from foreigners and lending to distressed firms against domestic collateral, the domestic price of a dollar-loan, i_1^d, rises above i_1^*:

$$i_1^d > i_1^*.$$

In equilibrium, loans collateralized by w are made at rate i_1^*, while those collateralized by ak are made at the higher rate of i_1^d. The rise in i_1^d also means that the date 1 value of domestic collateral $\left(\frac{ak}{1+i_1^d}\right)$ falls.

Figure 1 represents the equilibrium determination of i_1^d. The vertical axis is the price, i_1^d, while the horizontal axis measures domestic loans or domestic reinvestment. For $i_1^d = i_1^*$, 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, the demand for funds by distressed firms turns downward when the domestic collateral discounted at $\Delta - 1$ is insufficient, and hence effective loan demand is: $ak/(1+i_1^d)$. Figure 1 represents two cases: one equilibrium in the horizontal region (panel a) and one in the vertical case (panel b).

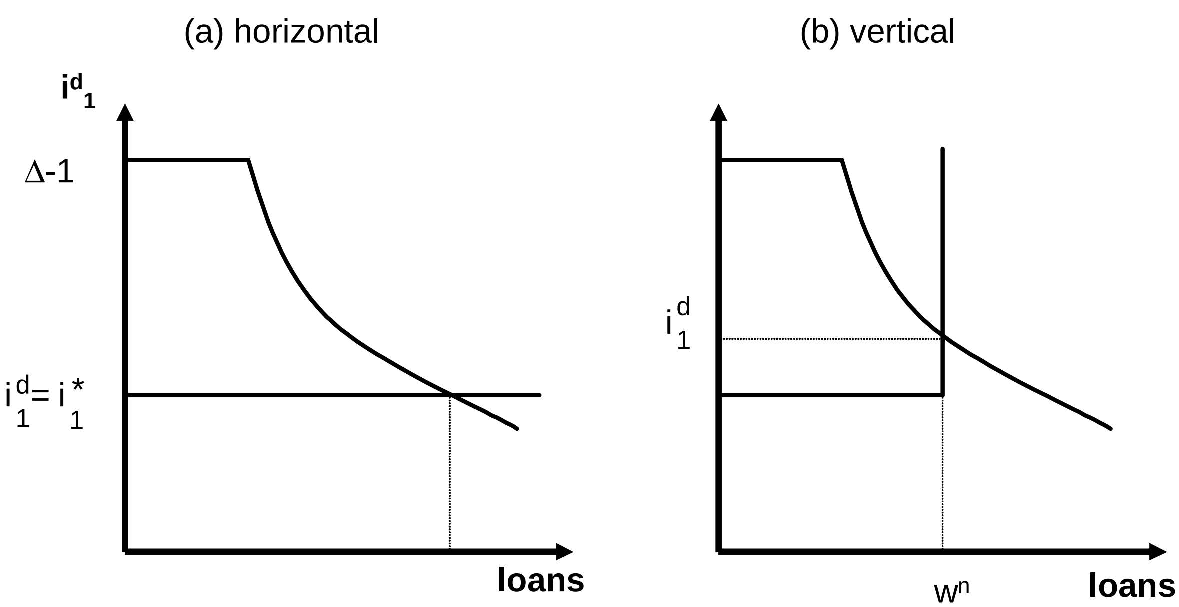

Figure 1: Equilibrium in the domestic loans market

This figure illustrates how i_1^d rises above i_1^* in the vertical region when international liquidity is scarce. Note also that i_1^d can never exceed $\Delta - 1$. This is because the marginal product of reinvestment for distressed firms is $\Delta - 1$, and as a result distressed firms never pay more than $\Delta - 1$ for funds.

However, there is a large interval for demand within which i_1^d lies strictly between i_1^* and $\Delta - 1$. In this case,

$$i_1^d = \frac{ak}{w^n} - 1 > i_1^*. \tag{4}$$

While a change in domestic collateral has no effect on output in equilibrium, it does have a direct effect on i_1^d. A shortage of international liquidity implies that $i_1^d > i_1^*$, and a shortage of domestic collateral implies that i_1^d will generally be less than the marginal product of investment at date 1, $i_1^d < \Delta - 1$.

The only equilibrium price in our model is i_1^d. This is the interest rate at date 1 on a risk free one-period loan against a unit of domestic collateral, and is both the dollar cost of capital for firms in need of funds and the expected return on loans for domestic lenders.

3 Discretionary Monetary Policy during Crises

The central bank affects the economy through monetary injections at date 1. 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 non-distortionary 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.

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. 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. We also have chosen our model for money because it will make clear that the government has other instruments that can achieve the same outcomes as monetary policy. We discuss this issue in Section 5. However, our goal in this section is to show what money *can do* as opposed to the uniqueness of money as a policy instrument.

As in Woodford (1990) and Holmstrom and Tirole (1998), we propose a mechanism that gives the government a special power —beyond that of the private sector— to create liquidity. However, in our setup this does not immediately translate into a government tool for increasing output. We assume that taxation used to fund a monetary expansion does not alter the international collateral of the country. Foreign investors continue to lend only against w, and the extent of a crisis is still determined only by w^n. Thus, the goods that back the money supply are not international collateral, and monetary injections during crises only increase the domestic liquidity of firms.

3.1 The Central Bank and the Domestic Interest Parity Condition

At the beginning of date 1, the central bank has $\underline{M}$ outstanding and held by firms. If the bad state is realized, then the central bank injects $(M - \underline{M})$ more money into firms. 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. For now, we assume that the central bank is able to support a commitment to set $e_2 = 1$.

Let us consider the g-state first. In this state, there are no production shocks and the central bank does not inject any money into the economy. The price of money is determined in the asset market:

$$e_1^g = 1 + i_1^*. \tag{5}$$

This equation is the interest parity condition given that $e_2 = 1$ and that money provides no special transaction service.

In the b-state, the central bank does inject money. The money injections affect e_1^b and date 2 output.

Post-injection, a distressed firm has total domestic net worth (collateral value of ak plus liquid monetary asset, measured in terms of date 2 goods):

$$ak + E\left[\frac{M}{e_2}\right] = ak + M.$$

In equilibrium, $ak + M$ is exchanged for:

$$\frac{ak + M}{1 + i_1^d} \tag{6}$$

units of international liquidity.

In order for an intact firm to be induced to exchange a unit of international liquidity for a unit of money, it must expect a return on purchasing money equal to the domestic dollar rate, i_1^d. Thus, the expected appreciation of the currency is equal to i_1^d, which is reflected in the *domestic* interest parity condition:[9]

$$e_1^b = 1 + i_1^d. \tag{7}$$

For a fixed value of e_2, a rise in i_1^d leads to depreciation of the date 1 exchange rate. We assume that the central bank dislikes the depreciation. As is conventional, we assume that the central bank takes as its objective the maximization of aggregate consumption minus an inflation cost. In our context, the cost term is a quadratic loss function of the exchange rate as it depreciates from e_1^g:

$$\Pi^{cost}(e_1) = \frac{\alpha}{2}\left(\frac{e_1}{e_1^g} - 1\right)^2 \qquad \alpha > 0. \tag{8}$$

3.2 Horizontal View

Distressed firms borrow w^n directly from foreigners and

$$\frac{ak + M}{1 + i_1^*}$$

from intact firms. The gross output per unit of this investment is Δ. Adding this output to the output generated by date 0 investments and the consumers' endowment yields an aggregate consumption by domestic agents in the horizontal region of:

$$C^H = \left(\frac{A + a}{2}\right)k + \frac{w^n}{2}(\Delta + 1 + i_1^*) + \frac{ak + M}{2}\left(\frac{\Delta}{1 + i_1^*} - 1\right) + y^c. \tag{9}$$

It follows that output is increasing with respect to M. Moreover, in this region $e_1^b = 1 + i_1^*$ and is not affected by M, so the central bank obviously will *expand* as much as it needs to relax the financial constraint (or until it hits the vertical constraint).

3.3 Vertical View

With the horizontal case as a reference, we now turn to the vertical view of crises. Using the investment expression (3), we can construct aggregate consumption in the vertical region:

$$C^V = \left(\frac{A + a}{2}\right)k + w^n\Delta + y^c. \tag{10}$$

¿From this expression, we reach a conclusion that contrasts starkly with the horizontal case: Expansionary monetary policy has *no* effect on aggregate consumption. This is

[9] The condition differs from the usual interest parity condition in that there is no domestic interest rate (or equivalently, the domestic interest rate is zero). In Section 6 we introduce a transaction role for money. This leads to a money demand function, a positive money interest rate, and a more standard interest parity condition.

because the economy has a shortage of international liquidity, and reallocating domestic liquidity has no real effect.

Given this lack of effectiveness, the central bank turns its attention to its inflation target. The exchange rate depreciates in the b-state and the central bank takes this to be costly. Thus its optimal response is to contract the money supply and support the exchange rate.

To see this, note that the objective of the central bank in the vertical region boils down to,

$$\max_{M} -\frac{\alpha}{2}\left(\frac{e_1^b(M)}{1+i_1^*}-1\right)^2. \tag{11}$$

In response to a shock that may raise $e_1^b > 1+i_1^*$, the central bank will choose monetary policy to maintain the exchange rate at $1+i_1^*$. Now recall that:

$$e_1^b = 1+i_1^d. \tag{12}$$

Market clearing at date 1 results in the domestic dollar rate of,

$$1+i_1^d = \left(\frac{ak+M}{w^n}\right) > 1+i_1^*. \tag{13}$$

Equations (12) and (13) yield an expression for e_1^b which is increasing with respect to M:

$$e_1^b = \left(\frac{ak+M}{w^n}\right).$$

These results can be summarized as follows. Let M^{nc} be the solution to (11). Then,

Proposition 1 *In the vertical region, the central bank chooses to tighten domestic liquidity ($M^{nc} < \underline{M}$). This restricts demand for international liquidity, causing i_1^d to fall towards i_1^*, and defends the date 1 exchange rate.*

Panels (a) and (b) in Figure 2 summarize the differences between the horizontal and vertical views. Note that in their downward sloping segments, demands are equal to $(ak+M)/(1+i_1^d)$.

In the horizontal case, the increase in domestic net worth of distressed firms caused by expanding monetary policy raises date 1 investment, leaving i_1^d unaffected. In the vertical region, the same increase has *no effect* on equilibrium investment, and only raises i_1^d. The obvious date 1 policy conclusion in the vertical region is to contract rather than expand monetary policy.

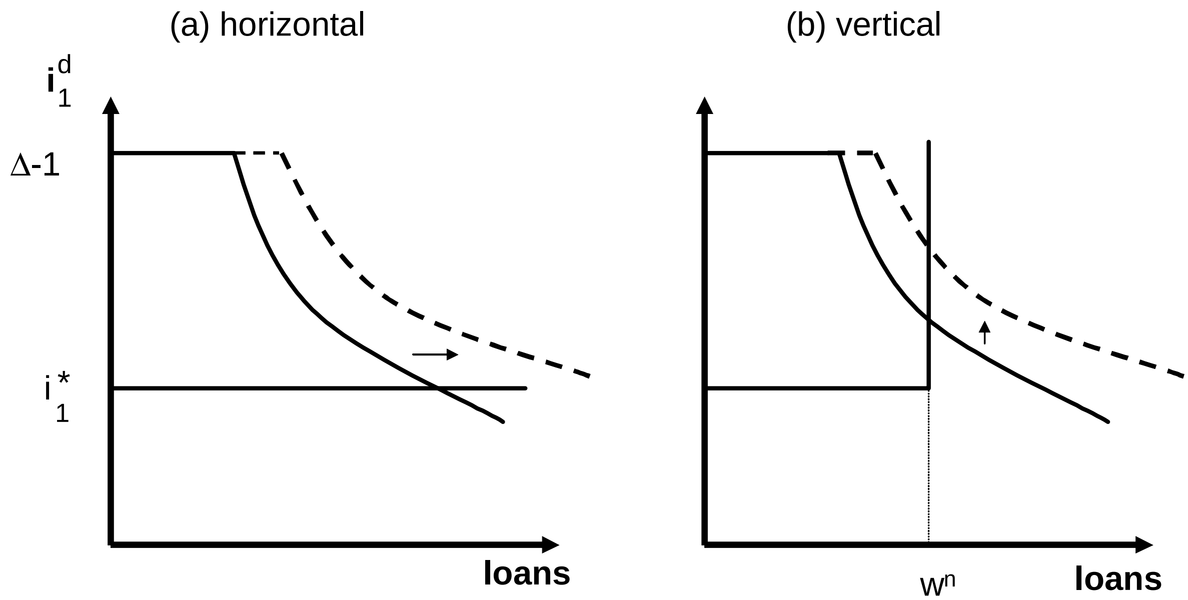

Figure 2: Domestic liquidity expansion

4 Optimal Monetary Rule

Now we show that the date 1 discretionary monetary policy is suboptimal ex-ante. With a date 0 commitment to a state-contingent date 1 policy, the central bank does better by expanding money more than it is inclined to do during a crisis. The gap between the commitment and the discretionary solutions occurs because central bank interventions affect i_1^d. Expectations about this price are central in determining firms' financing and investment decisions at date 0.

4.1 Private Sector Date 0 Decisions and i_1^d

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 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,

$$c(k) \leq \frac{1}{(1+i_0^*)(1+i_1^*)}\left((1-\pi)f^g + \pi f^b\right). \tag{14}$$

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,

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

while the other half are intact and make profits of,

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

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

PRIV:

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

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 i_1^d 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 tradeoff between increasing f^b and reducing k. At date 0, building a marginally larger plant increases (expected) date 2 profits by,

$$(1-\pi)A + \pi\frac{1}{2}\left(A + a\frac{\Delta}{1+i_1^d}\right). \tag{15}$$

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,

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

which can be simplified to:

$$c'(k)(1+i_0^*)\left(\frac{\Delta+1+i_1^d}{2}\right). \tag{16}$$

The optimal choice of k by the private sector equalizes (15) and (16). We note two comparative statics, and the conclusion that follows from them: (1) The benefit of building a larger plant size is decreasing in i_1^d; (2) The marginal cost of investing is increasing in i_1^d. For both reasons, k is decreasing with respect to i_1^d.

Intuitively, the opportunity cost of using resources at date 0 to increase k is that they are not available at date 1 for lending or for use in production. This opportunity cost is increasing in i_1^d. As a result, k is decreasing in i_1^d.

4.2 Date 0 Central Bank Problem in the Vertical Region

Let us now turn to the central bank's policy choice at date 0 to establish that it is optimal for the central bank to commit to a looser monetary policy during crises than is indicated by the discretionary solution of Proposition 1.

We show this in three steps. First, focusing purely on maximizing the value of date 2 (aggregate) consumption, we show that the private sector's date 0 choices are inefficient. More precisely, date 2 consumption is maximized at choices of (k, f^g, f^b) different from the private sector's choices. Appealing to the results of the previous subsection, we then argue that date 1 monetary policy can affect and improve these choices. Finally, we reintroduce the inflation cost of the previous section, and characterize the optimal policy choices.

4.2.1 Consumption Maximizing Choices

Let us first present the central bank's program to maximize date 2 aggregate consumption when it can choose (k, f^g, f^b) directly. We show that this program differs from the private sector's program by eliminating i_1^d from **PRIV**. If we substitute the market clearing condition for i_1^d from (6) into **PRIV** we find that,

CENT:

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

The tradeoff 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 $i_1^d < \Delta - 1$, 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 $i_1^d < \Delta - 1$, the cost lies strictly above the private sector's computation.

We conclude that, so long as $i_1^d < \Delta - 1$ in the competitive equilibrium, if the central bank could choose (k, f^b) directly, its choices would differ from those of the private sector. The private sector over-invests at date 0, and underinsures against the date 1 liquidity shocks.

Intuitively, the cause of this date 0 over-investment is the private sector misvaluing (relative to the central bank) date 1 resources in the b-state. At the aggregate level, resources in the b-state always generate a return of $\Delta - 1$ from date 1 to date 2. On the other hand, firms see the cost of not having date 1 resources as proportional to i_1^d. As long as $i_1^d < \Delta - 1$, the private sector's investment choices do not lead to maximization of date 2 aggregate consumption.

4.2.2 The Value of Central Bank Commitment

Since the central bank can affect i_1^d in its choice of M, it can use monetary policy to align the private sector's choices more closely with the consumption maximizing choices. Let us now characterize the optimal monetary rule from this perspective.

Define $U(k)$ as the value of the objective in **CENT,** a function of the date 0 choice of plant size. Recall that in the private sector's problem, k solves

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

which yields a strictly decreasing and continuous function $k(i_1^d)$ as a solution.

Since in **CENT**, the objective is linear while the constraint is convex, $U(k)$ is a concave function. Let k^* be the solution in **CENT**. We know that $U'(k) < 0$ as long as $k > k^*$. In other words, total output will increase if the value of this k is less than the private sector's value of k.

Note that since k is decreasing in i_1^d, we can re-write the central bank's problem purely in terms of i_1^d (for $p > 0$):[10]

$$\max_{i_1^d \in [\underline{i}_1^d, \Delta - 1]} U(i_1^d) - \pi \Pi^{cost}(M(i_1^d)), \tag{17}$$

where, $\underline{i}_1^d$ is the value of i_1^d that prevails if the central bank chooses $M = 0$ at date 1 in the b-state.

By comparing the objectives in (17) and (11), we can see the value of commitment. For $i_1^d < \Delta - 1$, $U'(i_1^d) > 0$ in (17). However, in the central bank objective at date 1 there was no benefit from expanding money. In both programs, the cost term is the same. Thus:

Proposition 2 *The optimal monetary rule with commitment is $M^c > M^{nc}$.*

5 Constrained Monetary Regimes

In practice, there are limits to implementing counter-cyclical monetary policy. The main result of the previous two sections is that monetary policy is time inconsistent in a vertical environment. Ex-post, the central bank will "fear floating" and thereby follow pro-cyclical monetary policy.

But even if the time consistency problem that we have identified is resolved, the central bank may have conventional credibility problems: its announcement of $e_2 = 1$ may not be fully credible, and its actions at date 1 may affect agents' expectations with respect to e_2. In this case, monetary policy also will be constrained.

Similarly, in emerging markets where the central bank has inflation credibility problems, a substantial fraction of domestic liabilities are dollarized. This also constrains monetary policy. The depreciation brought about by an expansionary monetary policy — by raising the peso value of their dollar-liabilities — reduces the domestic liquidity of distressed firms.[11] This may force the central bank to abandon counter-cyclical monetary policy.

Now we extend our model to incorporate limited inflation credibility of the central bank. We study the interaction between this credibility problem and optimal monetary

[10] The market clearing condition at date 1 in the b-state is,

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

Since $k(i_1^d)$ is decreasing and $w^n(i_1^d)$ is increasing, for every $i_1^d \in [\underline{i}_1^d, \Delta - 1]$ there exists a choice of M that will induce an equilibrium with that i_1^d. This allows us to write the central bank's program in (17) in terms of i_1^d.

[11] We present an extension of our model that addresses this issue in the appendix.

policy. Then we consider alternative policy instruments, in the event that monetary policy cannot be used. There is an important difference in the costs of losing monetary policy in our vertical model vis-a-vis the horizontal model. In the latter, as well as in the standard Mundell-Fleming framework, the cost is that the central bank loses a countercyclical instrument to smooth aggregate demand. In the vertical environment, on the other hand, the cost is mainly an "insurance" cost. 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 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

We introduce inflation-credibility problems by invoking a form of the fiscal theory for price-level determination (e.g., Woodford, 1994) and by assuming that the government's tax revenues at date 2 are uncertain.

At the beginning of date 1, the central bank has $\underline{M}$ outstanding and held by firms. If it does not inject any more money, it redeems $\underline{M}$ at date 2 with planned taxes of $\underline{T}$, giving an exchange rate (price level) of:

$$e_2 = \frac{\underline{M}}{\underline{T}}.$$

We normalize this no-intervention exchange rate to one, so that $\underline{M} = \underline{T}$. As before, the central bank may intervene by injecting $(M - \underline{M})$ more money into firms.

There are two polar states of the (tax) world realized at date 2: In the high-tax-revenue state, the central bank (government) has enough tax base to redeem all of its money and maintain the price level of one ($e_2^{HIGHTAX} = 1$). In the low-tax-revenue state, the central bank's tax base is only $\underline{T}$ and the exchange rate must depreciate if M exceeds $\underline{M}$. Thus,

$$e_2^{LOWTAX} = \max\left[1, \frac{M}{T}\right], \qquad T \leq \underline{T}.$$

We have used the max operator because it is possible that the central bank chooses $M < \underline{M}$, in which case it removes money from the economy. In a growing economy, this can be viewed as a lower rate of money growth. If $M < \underline{M}$, we assume that government also reduces taxes collected on date 2 so that the date 2 exchange rate remains at one. There is little at stake in making this assumption, as opposed to another assumption, that tax revenues are independent of M.

The tax states occur with probability p (high tax revenue) and $1-p$. Since a central bank with a larger tax base can inject more money without creating inflation at date 2, credibility is increasing in p. That is, the higher p is, the lower the expected depreciation of e_2 is in response to a monetary injection.

As before, the central bank does not inject money at date 1 in the g-state. Thus,

$$e_2^g = 1, \qquad\qquad e_1^g = 1 + i_1^*. \tag{18}$$

In the b-state, the central bank may inject $M - \underline{M}$ into firms, and

$$e_2^b = \max\left[1, \frac{M}{T}\right], \qquad T \leq \underline{T}. \tag{19}$$

Post-injection, a distressed firm has total domestic net worth (collateral value of ak plus liquid monetary asset, measured in date 2 goods),

$$ak + E\left[\frac{M}{e_2}\right],$$

where the expectation is taken over the realizations of the tax base at date 2. In equilibrium, this domestic net worth is exchanged for:

$$\frac{ak + E[M/e_2]}{1 + i_1^d} \tag{20}$$

units of international liquidity.

For an intact firm to be willing to exchange a unit of international liquidity for a unit of money, it must expect a return on purchasing currency equal to the domestic dollar rate, i_1^d. Thus, the expected appreciation of the currency equals i_1^d, which is reflected in the domestic interest parity condition:

$$e_1 = (1 + i_1^d)\left(E\left[\frac{1}{e_2}\right]\right)^{-1}. \tag{21}$$

Given a money stock of M, the date 2 exchange rate is:

$$e_2^b \in \left\{1, \max\left[1, \frac{M}{T}\right]\right\}.$$

Note that a choice of M greater than $\underline{T}$ results in $e_2^b > 1$ if the low revenue occurs. Since the inflation cost is minimized when $e_2^b = 1$, the central bank always uses all of its taxes to redeem money as long as $e_2^b > 1$ (see (8) and (18)). Thus, e_2^b is either one or $\max\{1, M/\underline{M}\}$, and by the interest parity condition, the date 1 exchange rate is:

$$e_1^b = \frac{1 + i_1^d}{\gamma(M; p)}, \qquad \gamma(M; p) \equiv \left(p + (1-p)\min\left[1, \frac{\underline{M}}{M}\right]\right). \tag{22}$$

The term $\gamma(M;p)$ is always less than or equal to one. It is increasing weakly in p and decreasing weakly in M. When multiplied by M, it measures the effectiveness of money injections in raising real balances. At one extreme, a central bank with no-credibility ($p=0$) finds that $M\gamma(M;p) = \min\{M, \underline{M}\}$. Money injections have no real effect when $M > \underline{M}$. At the other extreme, a fully credible central bank ($p=1$) finds that $M\gamma(M;p) = M$. Thus, money injections raise real balances one-for-one. The latter case is the one we analyzed in earlier sections.

It is apparent that as long as $p > 0$, the optimal monetary policy is still to inject money in the horizontal region, although if $p < 1$ there is a cost of doing so: injecting M leads to a depreciation of the currency through its impact on the expected depreciation of e_2.

In the vertical region, market clearing at date 1 results in the domestic dollar rate of,

$$1 + i_1^d = \left(\frac{ak + M\gamma(M;p)}{w^n}\right) > 1 + i_1^*. \tag{23}$$

Equations (22) and (23) yield an expression for e_1^b which is increasing with respect to M:

$$e_1^b = \left(\frac{ak\gamma(M;p)^{-1} + M}{w^n}\right).$$

We now state the main result of this subsection.

Proposition 3 *Consider two economies indexed by $\hat{p}$ and p, where $\hat{p} > p$. Then the optimal monetary rule will yield $\hat{i}_1^d > i_1^d$.*

Inflation-credibility problems limit the extent to which the underinsurance problem can be corrected by monetary policy in the vertical region. A more (inflation) credible central bank commits to act more aggressively at date 1. This results in a higher i_1^d and higher aggregate consumption. A higher p leads to a lower depreciation in e_1^b for each choice of i_1^d and to a date 2 exchange rate that is more insulated from the date 0 policy choice. This means that the cost of raising i_1^d in (17) falls, allowing for a higher i_1^d.[12] The formal proof of this proposition can be found in the appendix.

5.2 A Silver Lining: Insurance Substitutes

In the vertical environment, the problem created by being unable to inject M at date 1 is that $\Delta - (1+i_1^d)$ remains high. Thus the return to hoarding international liquidity until date 1 remains undervalued, and private insurance decisions are distorted. These considerations

[12]For simplicity, we have not altered the inflation cost term of the central bank to include a cost of e_2 differ from 1. This has no qualitative implications for our conclusions.

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 the optimal ex-ante tax and i_1^d.

The first order condition in **CENT** is,

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

whereas for the private sector the condition sets (15) equal to (16).

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:

Proposition 4 *For any equilibrium level of $i_{1,\tau}^d$, the optimal tax solves,*

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

The tax is increasing in $\Delta - (1+i_{1,\tau}^d)$. Thus, a corollary of the last two propositions is that economies with low p need higher capital-inflow taxes. More generally, economies where the central bank cannot follow counter-cyclical monetary policy, and therefore $\Delta - 1 - i_1^d$ remains high, 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 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 Extensions

We have made a number of extreme assumptions in order to highlight the novel aspects of our results. In this section, we relax some of these assumptions and sketch realistic extensions of the model.

6.1 "Diagonal" Supply

In the V region at date 1, the supply of international funds in our model is inelastic at w^n, for $i_1^d \geq i_1^*$. Let us consider instead a supply curve of,

$$w^n s(i_1^d) \quad \text{where} \quad s(i_1^*) = 1, \;\; s'(\cdot) > 0.$$

That is, the supply of international funds is "diagonal" as opposed to vertical.[13]

Equilibrium at date 1 is now:

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

As in the pure vertical model, i_1^d is increasing in M. However, consider the expression for total consumption at date 2. This is,

$$C^V = \left(\frac{A + a}{2}\right) k + w^n s(i_1^d)\Delta + y^c.$$

In comparison to the previous expression, (10), the only difference is that C^V is now an increasing function of i_1^d 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 through which expanding money increases aggregate consumption. As in the vertical model, the money expansion increases i_1^d and thereby leads to an exchange rate depreciation ($e_1 = 1 + i_1^d$). At date 1, the diagonal model yields the standard monetary policy tradeoff between output and inflation. The terms of this tradeoff depend on the slope of $s(\cdot)$. A near vertical supply curve favors supporting the exchange rate over increasing output. A near horizontal supply curve favors increasing output over supporting the exchange rate.

[13] The diagonal supply also captures the idea that depreciating the currency (higher i_1^d) increases exports and, if the export sector is an important part of international collateral, thereby expands supply. Christiano et al (2003) 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.

Now let us shift back to date 0. At date 0, 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 i_1^d. A higher i_1^d induces a firm to save some dollar resources until date 1, at which point these resources can always be lent to return i_1^d. Moreover, as long as $i_1^d < \Delta - 1$, 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 causes i_1^d to rise, and causes the private sector to reduce investment at date 0, and increase its insurance against the date 1 shock.

The critical point is that the terms of the tradeoff between output and inflation are always different between date 0 and date 1. For any positively sloped $s(\cdot)$, at date 0 the central bank sees a higher benefit to expanding M at date 1 than it does once at date 1.

If output only rises with unanticipated money injections, then moving to a diagonal supply also reintroduces the standard time-consistency problem (e.g. Barro and Gordon, 1983). At date 1, the central bank will want to inject money. At date 0, the private sector will anticipate the injection, and therefore the actual injection will have no effect. This sort of time-consistency problem can exacerbate the problem we have identified. Note that the central bank's incentive to inject money at date 1 is higher when the supply curve is less steep. Now suppose that the steepness of the supply curve is due to a date 1 shock. Then the central bank will inject less money upon more vertical shocks, and more money upon more horizontal shocks. Moreover, if private sector expectations are set at date 0, then the private sector will expect some money to be injected at date 1. If the shocks make the supply curve more vertical, then the central bank will inject *less* money than the private sector had anticipated. The result is that the central bank's policy is contractionary in the states where the central bank needs to be most expansionary.[14]

6.2 Money, Interest Rates, and Exchange Rates

We have focused on a "no-monetary-frictions" model of money, 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.[15]

At the end of date 1, the government has liabilities of B bonds and M units of money

[14] We have explored this issue in greater depth in an application of this paper to inflation targeting — Caballero and Krishnamurthy (2003b).

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

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 1 (i.e. this is the $p = 1$ model of the previous sections).

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 up to M units of money to the intact firms in exchange for up to w^n units of international liquidity. Focusing on the V region and the b aggregate state,

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

We introduce a date 1^- in order to study interest rates and the effects of open market operations. At date 1^- the aggregate state of the world (b or g) 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^-.

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. The money is sold for international liquidity at a price of $\frac{1}{1+i_1^d}$. Each unit of international liquidity yields Δ at date 2. Thus the expected return on holding money from date 1^- to date 2 is $\frac{1}{2}\left(\frac{\Delta}{1+i_1^d} + 1\right)$. As before, $\Delta \geq 1 + i_1^d$, which means that the net return is positive.

It immediately follow that indifference between holding money and bonds requires that,

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

Note that increasing M lowers the peso interest rate. This is the usual liquidity effect of expansionary open market operations. There is no competing inflation effect that increases interest rates because we have assumed that the central bank is credible in maintaining the date 2 price level at one (i.e. $p = 1$). More realistically, one could consider the case where $p < 1$ and there would be both a liquidity and an inflation effect.

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 $\frac{1}{2}(\Delta + 1 + i_1^d)$.

Thus the interest parity condition is,

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

Solving for the exchange rate yields,

$$e_{1^-} = \frac{1}{2}\frac{\Delta + 1 + i_1^d}{1 + i_1^p} = \frac{M}{w^n}.$$

As in the previous sections, an open market purchase of bonds with money in the V region causes the exchange rate to depreciate.

Finally, let us consider the effects on output of an open market purchase of bonds with money. For any level of M at date 1, the output equation in V is,

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

Thus output in the V region is unaffected by M. However, an open market purchase of bonds with money raises M and therefore raises i_1^d. This creates an insurance effect as in the previous sections: The anticipation of a high i_1^d increases the private sector's incentives to insure against the V region and increases total consumption.

7 Final Remarks

Much of the discussion of monetary policy and exchange rate systems focuses on the issue of inflation credibility. This is largely a historical artifact. Inflation stabilization has been the dominant monetary concern of emerging economies, especially in Latin America, for many decades. Today, as many emerging economies begin to leave behind high and unstable inflation, monetary policy again may become a useful macroeconomic policy instrument.

But how should it be used? Our argument in this paper is that the main cyclical concern of emerging economies is with sudden stops. Monetary policy should be built around this central concern. In particular, we argue that central bank actions should be directed toward correcting the chronic tendency of emerging economies to underinsure against external shocks. Moreover, we argue that the standard inflation-stabilization concern can be a serious obstacle to implementing optimal monetary policy, because it creates a time-consistency problem. Central banks should follow counter-cyclical monetary policy; if they are unable to commit to this policy, inflation concerns will lead them to act in the opposite way.

Monetary policy is not the only instrument that can help with insurance against sudden stops. Indeed, governments do consider other policies to provide such insurance. We have shown that capital inflow taxes or liquidity requirements can offer such insurance. But there are many other such policies that we have not touched on. Restrictions against short-term debt, international reserves management, and contracting external credit lines are all policies that central banks consider which are aimed at insuring against sudden stops.[16] Recent proposals for a sovereign bankruptcy court are designed to reduce the costs of financial distress for emerging economies. These proposals also provide a way to create insurance for emerging economies.

On the one hand, we find it encouraging for our model that the unifying theme behind so many government policies is insurance. At the least, it suggests that we are on the right track in our modeling. On the other hand, the existence of so many alternative policies raises questions regarding how these policies should be used together. Our joint analysis of monetary policy and capital-inflow taxes is a step in that direction. However a richer analysis will require consideration of the relative costs/effectiveness of each of these policies. Our analysis in Section 5 only included an inflation-credibility cost of monetary policy. Nevertheless, we hope our analysis provides a starting point for a more integrated analysis of policy in emerging markets.

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 was no commitment. In fact, the costs in terms of the additional financial distress imposed on the domestic private sector is, to a large extent, comparable to the costs of the ex-ante measures

[16]See Caballero and Krishnamurthy (2003a, b).

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.

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A Appendix

A.1 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 both* w *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 arrangments that transfer resources from distressed firms to intact firms.

Assumption 3 (Non-observability 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 **CENT**. There is also a banking arrangement that in principle may get around the private information constraint, but this is very fragile.

A.2 Technical Assumptions

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

CENT:

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

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

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

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 assumption can be jointly met by choosing Δ large enough

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

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

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

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

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

Assumption 6 (Equilibrium in Vertical Region)

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

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,

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

This leads to:

Assumption 7 (Reinvestment constraint does not bind in V)

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

A.3 Proof of Proposition 3

The proof is complicated by the fact that the program in (17) may not be concave, since $k(i_1^d)$ is not concave.

Consider two economies where $\hat{p} > p$. We first show that for any value of i_1^d:

$$\frac{\partial \Pi^{cost}(i_1^d;p)}{\partial i_1^d} > \frac{\partial \Pi^{cost}(i_1^d;\hat{p})}{\partial i_1^d}.$$

The marginal cost in the p-economy is,

$$\frac{\alpha}{1+i_1^*}\left(\frac{1+i_1^d}{1+i_1^*}\gamma(M;p)^{-1}-1\right)\frac{\partial(1+i_1^d)\gamma(M;p)^{-1}}{\partial i_1^d}.$$

Consider evaluating this marginal cost for the same value of i_1^d for each of the two economies. If i_1^d is to be the same in the two economies, then from market clearing and since $\gamma(M;p) = \left(p+(1-p)\min\left\{1,\frac{\underline{M}}{M}\right\}\right)$, it must be that $M\gamma(M;p)$ and $p(M-\underline{M})$ are constant across the two economies. This means that $\gamma(p) < \gamma(\hat{p})$ at the same value of i_1^d. Thus the first term in parentheses in the marginal cost expression is higher in the p-economy than in the $\hat{p}$-economy.

The second term reinforces this conclusion. It can be written as,

$$\gamma(M;p)^{-1}+(1+i_1^d)\frac{\underline{M}}{(\gamma(M;p)M)^2}(1-p)\frac{\partial M}{\partial i_1^d}.$$

By implicitly differentiating the market clearing condition, we can easily show that $\frac{\partial M}{\partial i_1^d}$ is higher in the p-economy than in the $\hat{p}$-economy. It requires a smaller change in nominal money to affect i_1^d when the central bank is more credible. Thus, we conclude that the marginal cost of raising i_1^d is uniformly lower in the $\hat{p}$-economy than in the p-economy.

Next, define $V(i_1^d;p)$ as the value of the objective in (17). Suppose in contradiction to the proposition that $\hat{\imath}_1^d < i_1^d$. Then, since i_1^d and $\hat{\imath}_1^d$ are maximizing choices for each of these economies respectively,

$$\begin{aligned} V(\hat{\imath}_1^d;\hat{p})-V(i_1^d;\hat{p}) &= \int_{\hat{\imath}_1^d}^{i_1^d}\left(\pi\frac{\partial\Pi^{cost}(i_1^d;\hat{p})}{\partial i_1^d}(x)-U'(x;\hat{p})\right)dx \geq 0 \\ V(\hat{\imath}_1^d;p)-V(i_1^d;p) &= \int_{\hat{\imath}_1^d}^{i_1^d}\left(\pi\frac{\partial\Pi^{cost}(i_1^d;p)}{\partial i_1^d}(x)-U'(x;p)\right)dx \leq 0. \end{aligned}$$

Since the marginal benefit of increasing i_1^d is independent of p, it must be that $U'(x;p) = U'(x;\hat{p})$. However, since the marginal cost of raising i_1^d is lower in the $\hat{p}$-economy, these two inequalities can hold only if $\hat{\imath}_1^d > i_1^d$.

A.4 Dollarization of Domestic Liabilities

We sketch an extension to the model of Section 6.2 in order to address dollarization of liabilities. As mentioned in Section 5, this is one of the primary reasons that policy-makers give for being unable to lower interest rates during a crisis.

Suppose that firm 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,

$$NW = \frac{\underline{B}}{1+i_1^p}+\underline{M}+\frac{ak}{1+i_1^p}-De_{1^-} \tag{24}$$

Now suppose that the government does an open market operation where it purchases bonds with money. Since this is transaction is done at market prices, the net worth remains as in (24).

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 has no effects 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.