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ABSTRACT

International Lending of Last Resort and Moral Hazard: A Model of the IMF's Catalytic Finance*

The provision of liquidity by international institutions such as the IMF to countries experiencing balance of payment problems could prevent liquidity runs but could also cause moral hazard distortions: expecting to be bailed out by the IMF, debtor countries would have weak incentives to implement good but costly policies, thus raising the probability of a crisis. This Paper presents an analytical framework to study the trade-off between official liquidity provision and debtor moral hazard. In our model international financial crises are caused by the interaction of bad fundamentals, self-fulfilling runs and policies by three classes of optimizing agents: international investors, the local government and the IMF. We show how an international financial institution helps prevent liquidity runs via coordination of agents' expectations, by raising the number of investors willing to lend to the country for any given level of the fundamental; i.e., partial liquidity support can have a catalytic effect on investors. The influence of such an institution is increasing in the size of its interventions and the precision of its information: more liquidity support and better information make agents more willing to roll over their debt and reduce the probability of a crisis. Different from the conventional view stressing debtor moral hazard, we show that official lending may actually strengthen a government incentive to implement desirable but costly policies. By worsening the expected return on these policies, destructive liquidity runs may well discourage governments from undertaking them, unless they can count on contingent liquidity assistance.

JEL Classification: F33, F34 and N20
Keywords: bank runs, capital account crises, International Monetary Fund, lender of last resort and speculative attacks

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1 Introduction

In the past decade many emerging market economies have experienced currency, debt, financial and banking crises: Mexico, Thailand, Indonesia, Korea, Russia, Brazil, Ecuador, Turkey, Argentina and Uruguay, to name the main ones. At different times, each of these countries faced massive reversal of capital flows and experienced a large drop in economic activity. In every case, large external financing gaps emerged because of strong capital outflows and the unwillingness of investors to rollover short-term claims on the country (including those on its government, its banks and its residents).

A leading view is that these international crises are primarily driven by liquidity runs and panics, and could therefore be avoided via the provision of sufficient international liquidity to countries threatened by a crisis. According to this view, the global financial architecture should be reformed by creating an international lender of last resort (ILOLR). Not only would such an institution increase efficiency ex-post by eliminating liquidation costs and default in the event of a run: by severing the link between illiquidity and insolvency, it would also prevent crises from occurring in the first place (see Sachs (1995) and Fischer (2001)). An opposing view doubts that international illiquidity is the main factor driving crises. When crises can also be attributed to fundamental shocks and policy mismanagement, liquidity support may turn into a subsidy to insolvent countries, thus generating debtor and creditors moral hazard (see the Meltzer Commission Report (2001))[1]. Accordingly, IMF interventions should be limited in frequency and size so as to reduce moral hazard distortions, even if limited support would not prevent liquidity runs.

The official IMF/G7 position is somewhere between the two extreme views described above: provided a crisis is closer to illiquidity than to insolvency, a *partial* bailout granted conditional on policy adjustment by the debtor country can restore investors' confidence and therefore stop destructive runs — i.e., can have a "catalytic effect".[2] If the "catalytic" approach is successful, official resources do not need to be unlimited (i.e.,

[1]See Jeanne and Zettelmeyer (2001) for an empirical study on whether IMF programs have a subsidy component and Eichengreen (2003) and Roubini and Setser (2004) for surveys of the empirical evidence on moral hazard from IMF bailout packages.

[2]For the official sector's views of "catalytic finance," see Cottarelli and Giannini (2002) and Roubini and Setser (2004).

so large as to fill in any potential financing gap), since some official liquidity provision and policy adjustment will convince private investors to rollover their positions (rather than run) while restoring market access by the debtor country. But can partial "catalytic" bailouts ever be successful or, as argued by many, only corner solutions of full bailouts or full bailins (i.e., debt suspension or standstill) can be effective in preventing destructive runs?[3]

This paper contributes to the current debate on these issues by providing a theoretical model of financial crises and the main policy trade-offs in the design of liquidity provision by an international financial institution. In our model, a crisis can be generated both by fundamental shocks and by self-fulfilling panics, whereas liquidity provision affects the optimal behavior of the government in the debtor country (possibly generating moral hazard distortions). Our study draws on the theoretical model by Corsetti, Dasgupta, Morris and Shin (2004) and the policy analysis by Corsetti, Pesenti and Roubini (2002), on the role of large speculative traders in a currency crisis. Consistent with these contributions, we model the official creditor (the IMF or ILOLR) as a *large player* in the world economy, with a well-defined objective function and financial resources. In our model, the strategies of the official creditor, international speculators and domestic governments are all endogenously determined in equilibrium.

There are two major areas in which our model contributes to the debate on the reform of the international financial architecture: the effectiveness of catalytic finance and the trade-off between liquidity support and moral hazard distortions. As regards the *first area*, our analysis lends support to the hypothesis that catalytic liquidity provision by an official institution can work to prevent a destructive run — although in our model the success of partial bailouts is realistically limited to cases in which macroeconomic fundamentals are not too weak. In reality, the IMF does not have infinite resources and cannot close by itself the possibly very large external financing gaps generated by speculative runs, i.e., the IMF cannot rule out debt defaults due to illiquidity runs. According to our results, however, even when relatively small, contingent liquidity support lowers the likelihood of a crisis by enlarging the range of economic fundamentals at which inter-

[3] For a detailed and general discussion of the "bailouts versus bailins" debate, see Roubini (2000) and Roubini and Setser (2004).

national investors find it optimal to rollover their credit to the country. This 'catalytic effect' is stronger, the larger the size of IMF funds, and the more accurate the IMF information. But our results also make clear that catalytic finance cannot and will not be effective when the fundamental turns out to be very weak ex post: as more and more agents receive bad signals about the state of the economy, massive withdrawals will cause a crisis regardless of whether the IMF intervenes.

Our result runs counter to the hypothesis, first suggested by Krugman and then formalized by Zettelmeyer (1999) and Jeanne and Wyplosz (2001), that IMF bailouts can work only when there are enough resources to fill financing gaps of any possible size. These authors base their view on models with multiple equilibria, in which partial bailouts cannot rule out the possibility of self-fulfilling runs. In such a framework, liquidity support is effective only insofar as it is large enough to prevent a run and eliminate all liquidation costs in the presence of a run.[4]

As regards the *second area*, contrary to the widespread view linking provision of liquidity to moral hazard distortions, we show that under some circumstances liquidity assistance can actually make a government willing to implement efficiency-enhancing but costly reforms. Specifically, the conventional view on debtor moral hazard is that, by insulating the macroeconomic outcome from ruinous speculative runs, liquidity assistance reduces the government's incentive to implement good policies. But this is not the only possible effect of an ILOLR. It is also plausible that some governments may be discouraged from implementing good but costly policies *because* speculative runs jeopardize the chances of their success. In this case, liquidity support that reduces liquidation costs in the event of a run can actually make socially desirable policies more attractive to the government. Our model shows that liquidity support can have either effect depending on circumstances — very large bailouts induce moral hazard distortions, but moderately large support can be complementary to good policy behavior.

The following example conveys the two main points in this paper. In late 2002, as the

[4] Models drawing on the traditional bank run literature prescribe that the IMF should have very deep pockets. Usually, in the analysis underlying such a view, the cost of a crisis is independent of the size of the financial gap, i.e. the difference between short term obligations and the liquid financial resources available to the country. More general and realistic models would allow for partial liquidation of long term investment.

Brazilian elections were approaching and Lula was expected to win, there was an incipient run on Brazil: foreign banks cut their exposure to Brazilian banks, and there was a risk of a rollover crisis on government debt (which had very short maturity). Once elected, Lula had to choose between pursuing politically painful reforms and restructuring the country's debt, with the risk of triggering a financial meltdown similar to Argentina's. The IMF supported the former option with a US $30 billion loan conditional on the pursuit of sound fiscal policy and implementation of structural reforms. Arguably, the IMF loan had a 'catalytic effect.' Without it Brazil was very likely to experience a severe crisis, even if the government signalled its willingness to pursue sound policies: given the uncertainty surrounding the incoming government's goals and the size of the potential external financing gap, most investors were ready to "rush to the exits". Most important, without sizeable IMF support to fence off disruptive speculative runs and make the country less vulnerable to investors' withdrawal, the incentive for Lula to pursue politically difficult policies would have been substantially weaker. By containing the risk of a run, instead, the expectations of a large IMF package raised the expected benefits from implementing sound policies: effectively, the IMF intervention induced good policies rather than trigger moral hazard. Reinforcing the willingness to pursue sound policies, contingent liquidity assistance was a key factor in avoiding an Argentine-style meltdwon. Indeed, capital flight subsided and eventually reversed.[5]

Building on the main insights from the literature on global games,[6] this paper contributes to our understanding of how and why catalytic finance could work in this and other crisis cases. Our analysis is related to a vast and fast-growing literature on the merits of alternative crisis resolution strategies and the arguments in favor of an ILOLR. We contribute to this literature in a number of dimensions.

First, we model the role of official financial institutions as large players whose behavior

[5]For a detailed assessment of this and other cases of 'catalytic finance', see chapter 4 of Roubini and Setser (2004).

[6]Specifically, our framework draws on the literature on global games as developed by Carlsson and van Damme (1993) and Morris and Shin (2000). As is well known, in global games the state of the economy and speculative activity is not common knowledge among agents. With asymmetric information, there will be some heterogeneity in speculative positions even if everybody follows the same optimal strategy in equilibrium. Moreover, the precision of information need not be the same across individuals. Arguably, global games provide a particularly attractive framework to analyze the coordination problem in financial markets.

is endogenously derived in equilibrium. Relative to global games and the literature on the ILOLR building on them (see Morris and Shin (2003) but also the closed-economy model by Goldstein and Pauzner (2002) and Rochet and Vives (2002)) much of our new analytical insight stems exactly from this feature of our model. In specifying the preferences of its shareholders or principals, we model a 'conservative' IMF, in the sense that it seeks to lend to illiquid countries, but not to insolvent countries. Consistently, in our equilibrium the IMF is more likely to provide liquidity support when the crisis is caused by a liquidity run, as opposed to crises that are closer to the case of insolvency.

Second, in our framework domestic expected GNP is a natural measure for national welfare — which may differ from the objective function of the domestic government because of the (political) costs of implementing reforms and adjustment policies. We can therefore analyze the impact on the welfare of domestic citizens and the government of alternative intervention strategies by the IMF.

Third, we develop a model where a crisis may be anywhere in the spectrum going from pure illiquidity to insolvency. Most studies of ILOLR build on Diamond and Dybvig (1983) — D&D henceforth — interpreting crises as a switch across instantaneous (rational-expectations) equilibria, but ignoring or downplaying macroeconomic shocks or any other risk of fundamental insolvency.[7] Relative to this literature, we present a more realistic specification of an open economy where fundamentals, in additions to speculation, can cause debt crises.

Fourth, in our global games model the probability of a crisis and coordination among agents are endogenous, and the equilibrium is unique. We can therefore study the equilibrium implications of varying the size of the IMF support, the precision of its information and other parameters of the model without relying on arbitrary assumptions on the likelihood of a speculative attack. This is in sharp contrast with multiple equilibrium models.

While the model of catalytic finance shapes the traditional, official view of liquidity provision by the IMF, until very recently there was no theoretical analysis of it. Haldane et al. (2002) present a model that allows for fundamentals-driven runs, and assess

[7] Open economy variants of Diamond and Dybvig bank run models and other models of self-fulfilling runs are many; see for example Chang and Velasco (2001) and Cole and Kehoe (1996).

the arguments in favor of debt standstills, relative to official finance, as crisis resolution mechanisms. These authors discuss the implications of moral hazard but do not develop a model of the trade-off between these objectives and the optimal intervention policy. Gale and Vives (2002) study the role of dollarization in overcoming moral hazard distortions deriving from domestic (but not international) bailout mechanisms (such as central bank injection of liquidity in a banking system subject to a run). Allen and Gale (2000, 2001) introduce moral hazard distortions in a model of fundamental bank runs, but do not consider analytically the role of an international lender of last resort. Rochet and Vives (2002) study domestic lending of last resort as a solution to bank runs in a global game model.[8] They find that liquidity and solvency regulation can solve the creditor coordination problem that leads to runs but that their cost is too high in terms of foregone returns. Thus, emergency liquidity support is optimal in addition to such regulations. However, they do not model the lender of last resort as a player and do not analyze the trade-off between bailouts and moral hazard that is central to our study. In independent research, Morris and Shin (2003) developed a model of catalytic finance and moral hazard, reaching conclusions that are close to ours. However, they do not model the IMF as a strategic player and focus on a one-period game, as opposed to our two-period bank-run framework.[9]

The structure of the paper is as follows. Section 2 introduces the model. Sections 3, 4 and 5 present our main results, regarding the effect of IMF lending on the likelihood and severity of crises and the trade-off between IMF assistance and moral hazard distortions. Section 6 concludes.

[8]See also Goldstein and Pauzner (2002).

[9]Several recent studies (Cottarelli and Giannini (2001), Mody and Saravia (2003) and Roubini and Setser (2004)) have provided useful empirical evidence on catalytic finance. According to these studies, and consistent with the main results of our analysis, catalytic finance is more likely to be sucessful when fundamentals are not bad and/or the amount of policy adjustment required to achieve debt sustainability is feasible and credible. Hovaguimian (2003) provides a more skeptical assessment.

2 The model

Consider a small open economy with a three-period horizon — periods are denoted 0, 1 (or interim) and 2. The economy is populated by a continuum of agents of mass 1, each endowed with E units of resources. These agents can borrow up to D from a continuum of international fund managers also of mass 1, willing to lend to the country only short term. Moreover, there exists one international financial institution, the International Monetary Fund (IMF), which may provide the country with international liquidity. We model such institution as an additional player that is large in the world economy, with access to loanable resources up to L (which is common knowledge in the economy). To account for the fact that the actual disbursement of IMF loans is not certain and unconditional, in our specification we let the IMF take the actual decision to disburse L conditional on its information (i.e., its private signal) about the economic conditions of the country, and based on its institutional objectives (to be described below). For simplicity, all international lending and borrowing by domestic agents (including IMF loans) takes place at the same international interest rate r^*, which is normalized to zero.

Domestic agents invest in domestic projects which yield a stochastic rate of return equal to R in period 2, or to $R/(1+\kappa)$ if projects are discontinued and liquidated early in the interim period. The expected return from these projects in period 2 is well above the international interest rate, i.e., $E_0 R > 1 + r^*$. Yet, investment is illiquid, in the sense that projects can be discontinued in period 1 at the cost $\kappa > 0$ per unit of investment.[10]

The sequence of decisions can be summarized as follows. *In period 0*, knowing the potential size of L, agents in the economy invest their own endowment and the borrowed resources $E + D$ in the domestic risky technology I and in an international liquid asset M. L, D, E, I and M are all given parameters

[10] While our model analyzes speculative portfolio positions given prices, a more general model should also derive risk premia in equilibrium. The well know difficulty in this step is that market prices reveal information, and therefore reduce the importance of agents' private signal. Interestingly, however, the empirical evidence on the IMF catalytic effect on asset prices is consistent with many of our results. For instance, Mody and Saravia (2003) find that IMF programs improve market access and the frequency of bond issuance, and lower spreads. IMF programs seem to contain the negative effect on spread of high export variability. Finally, the IMF influence is larger for intermediate level of the fundamentals, while the catalytic role of the IMF increases with the size of its programs. The link between these empirical findings and our theoretical conclusions are apparent (see Mody and Saravia (2003) for a review of the empirical literature).

In the interim period, fund managers decide whether to rollover their loans or withdraw and, *simultaneously*, the IMF decides whether to intervene, in which case the country obtains funds equal to L.[11] Denoting with x the fraction of managers who decide to withdraw, xD measures the short-term liquidity need of the country. To meet short-term obligations, domestic agents can use their stock of liquid resources, the loan from the IMF if disbursed, but can also liquidate some fraction z of the long term investment I, getting $zRI/\left(1+\kappa\right)$.

Let Λ denote total international liquidity available to the country, including both the predetermined component M and the contingent component L. Clearly, the country will incur some liquidation costs when $xD > \Lambda$ (i.e., z will be such that $xD - \Lambda = zRI/(1+\kappa)$); it will default when $xD > \Lambda + RI/\left(1+\kappa\right)$ (i.e., domestic agents will not be able to meet their short-term obligations despite complete liquidation of long-term investment). When the country defaults, we assume that all lenders will be paid pro-rata (i.e., both official and private creditors have the same seniority), up to exhausting the resources available to the country.

In the last period, the country total resources consist of $R\left(1-z\right)I$ (corresponding to GDP), plus any money left over from the previous period, i.e., $\max\{\Lambda - xD, 0\}$. Its liabilities consist of private debt $\left(1-x\right)D$ plus any outstanding IMF loan L. As for the case of default in the interim period, we assume that lenders are treated symmetrically and paid pro-rata also when the country defaults in period 2.

Note that the difference (if any) between total resources and debt obligations is the country GNP, available to domestic consumption:

$$\begin{aligned} Y &= \max\left\{R(1-z)I + (\Lambda - xD)_+ - (1-x)D - L_+, 0\right\} \qquad (1) \\ &= \max\left\{RI\left[1 - \frac{z\kappa}{1+\kappa}\right] + M - D, 0\right\} \end{aligned}$$

[11] We model a simultaneous game to capture the coordination problem in actual crises, when each agent's decision — a fund manager's decision whether to withdraw from the country, the IMF's decision whether to disburse a loan to the country, and the government's decision whether to pursue costly policy changes — is taken independently, and with incomplete information about the actions taken by all the other players in the economy. In particular, during a crisis the IMF's *actual* decision to disburse a loan and the investors' decision about their exposure to the country are taken in an environment of strategic uncertainty. While at the onset of a crisis the IMF may decide to provide a loan L, the actual disbursement is never guaranteed: it is always 'tranched' over time and can be suspended depending on the IMF's assessment of the probability that its financial support will be successful.

whereas we make use of the notation convention $(\Lambda - xD)_+ = \max\{\Lambda - xD, 0\}$.[12] Note that GNP and domestic consumption are zero in the event of default. In what follows, we take GNP as a measure of national welfare.

2.1 Payoffs and information

In this subsection we describe the objective function and the information set of fund managers and the IMF. The objective function of the government will be introduced later on, in the subsection on moral-hazard distortions.

As in Rochet and Vives (2002), fund managers face a structure of payoffs that depend on taking the "right decision". When the country does not default, rolling over loans in period 1 is the right thing to do, and yields a benefit that is higher than withdrawing — the difference in utility between rolling over debt and withdrawing is equal to a positive constant b. When the country defaults, managers who do not withdraw in the interim period make a mistake and therefore pay a cost. The difference in utility between rolling over loans and withdrawing is negative, and equal to $-c$.

In specifying the IMF objective function, we want to capture the idea that the IMF is concerned with the inefficiency costs associated with early liquidation, but cannot provide subsidized loans or grants to a country with bad fundamentals. The payoff of the managing board of the IMF is isomorphic to that of private fund managers: if the country ends up not defaulting, lending L is the right thing to do. By providing liquidity, the IMF gets a benefit B. If the country defaults, instead, the IMF loses money when lending. Relative to not disbursing L, the benefit from providing liquidity is negative and equal to $-C$.

Note that, in the above specification of payoffs, the utility for funds' managers and the IMF is independent of the extent of default. Our analysis thus abstracts from

[12] To derive the expression in the second line (1) note that the term $(\Lambda - xD)_+$ is zero when liquidation costs are positive (i.e., when $z > 0$). Adding and subtracting xD we get:

$$Y = RI(1 - z) + xD - D - L_+$$

whereas accounting for liquidation costs we have:

$$xD = M + L_+ + \frac{RI\kappa}{1 + \kappa}.$$

distributional issues between the country and the creditors, as well as between private creditors and the IMF, that arise in debt crises.

As regards the stochastic process driving the fundamental, we assume that the rate of return R is distributed normally with mean R_j and variance $1/\rho$. The mean R_j — with $j = A, N$ — depends on the "effort" of the government, as analyzed later on in the paper. In period 0, the distribution of R (but the value of its mean) is common knowledge in the economy; R is realized in the interim period.

In the interim period, international fund managers do not know the true R but each of them receives a private signal $\widetilde{s}_i$ such that

$$\widetilde{s}_i = R + \varepsilon_i \tag{2}$$

whereas individual noise is normally distributed with precision α and its cumulative distribution function is denoted by $G(.)$. By the same token, the management of the IMF also ignore the true R, but receive a signal $\widetilde{S}$ such that

$$\widetilde{S} = R + \eta \tag{3}$$

where η is also normally distributed, with precision β and its cumulative distribution function is denoted by $H(.)$.

Note that the posteriors of both funds managers and the IMF will depend on public information (the prior distribution of R), private signals *and* on probability assigned to the event 'government took action A' (call it p_A). The posterior s for a fund manager that gets signal $\widetilde{s}_i$ is equal to:

$$s = p_A \left(\frac{R_A \rho + \widetilde{s}_i . \alpha}{\rho + \alpha} \right) + (1 - p_A) \left(\frac{R_N \rho + \widetilde{s}_i \alpha}{\rho + \alpha} \right) \tag{4}$$

Analogously, the posterior of the IMF is:

$$S = p_A \left(\frac{R_A \rho + \widetilde{S} . \beta}{\rho + \beta} \right) + (1 - p_A) \left(\frac{R_N \rho + \widetilde{S} \alpha}{\rho + \beta} \right) \tag{5}$$

The interaction between private and public signals in coordination games is the focus of recent literature including Hellwig (2002) and Morris and Shin (2002). Encompassing the main results of these papers in the context of our model would complicate our analysis considerably, without necessarily adding insights. To keep our work focused, we abstract from the above issue altogether. In Sections 4 and 5 below, we will proceed as in Corsetti, Dasgupta, Morris and Shin (2004) by assuming a very uninformative public signal ($\rho \to 0$). In section 6, instead, we will focus on government behavior, affecting the mean of the distribution of R. Hence, we will set ρ equal to a finite value, and consider the limiting case in which private information is arbitrarily precise, although precision is not necessarily identical for funds' managers and the IMF. In either cases — $\rho \to 0$ (for α and β finite) or α, $\beta \to \infty$ (for ρ finite) —,

$$\lim_{\frac{\rho}{\alpha}\to 0} s_i = \widetilde{s}_i \tag{6}$$

$$\lim_{\frac{\rho}{\beta}\to 0} S = \widetilde{S} \tag{7}$$

so that we can disregard public information in building our equilibrium.[13]

2.2 Solvency and liquidity

To illustrate the logic of the model, suppose that no early withdrawal of funds could ever occur (debt is effectively long-term), so that $x = 0$. In this case, the country is solvent if the cash flow from investment is at least equal to its net debt[14]

$$RI \geq D - M. \tag{8}$$

Thus, the minimum rate of return at which the country is solvent conditional on no liquidity drain in the interim period (the break-even rate) is

$$R_s = \frac{D - M}{I}. \tag{9}$$

In the presence of liquidity runs, a return on investment as high as R_s may no longer be sufficient for the country to avoid default. Specifically, if the IMF has not lent to the country in the interim period, the country will be solvent in period 2 if and only if:

$$R(1-z)I = RI - (1+\kappa)\left[xD - M\right]_+ \geq (1-x)\,D. \tag{10}$$

[13] See Hellwig (2002) (Theorem 1) among others.

[14] Note that the following is true whether or not the IMF lends to the country — if it does so, the country will increase its gross stock of international safe assets in period 1, and use the additional reserves to pay back the IMF in period 2.

Denoting by $\bar{R}$ the minimum rate of return at which the country is solvent conditional on no IMF intervention, we can write:

$$\bar{R} = R_s + \kappa \frac{[xD - M]_+}{I} \geq R_s. \tag{11}$$

With early liquidation of investment (i.e., when $xD - M > 0$), the break-even rate must increase above R_s, as the failure of international investors to roll over their debt results in wasteful liquidation costs and hence ex-post efficiency losses.

Conversely, if the IMF intervenes in the first period, ex-post efficiency losses will be contained, and the solvency threshold for the rate of return conditional on a given x will be lower. Namely, the country will be solvent if

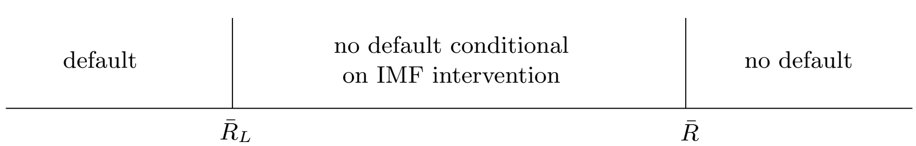
$$R(1-z)I = RI - (1+\kappa)\left[xD - M - L\right]_+ \geq (1-x)\,D + L. \tag{12}$$

Denoting by $\bar{R}_L$ the relevant threshold for default, we have

$$\bar{R}_L = R_s + \kappa \frac{[xD - M - L]_+}{I} \geq R_s. \tag{13}$$

IMF interventions increase the country GNP to the extent that they reduce early liquidation. Figure 1 displays $\bar{R}$ and $\bar{R}_L$ for some $L > 0$ and $x > 0$, partitioning the set of the fundamental R into three regions: there is no crisis when $R > \bar{R}_L$; there is a crisis when $R < \bar{R}$; for R in between, a crisis occurs if the IMF does not intervene.

Figure 1: Partition of Fundamental R



It is worth noting that there are two ways in which the IMF can have a catalytic effect and thus reduce early liquidation: *directly*, as the IMF provides liquidity against fund withdrawals it reduces the amount of illiquid investments that need to be liquidated; and *indirectly*, as the presence of the IMF may reduce the fund managers' willingness to withdraw for any given fundamental (lowering x for any given realization of R) and thus, again, reduce the liquidation costs from runs.[15]

[15]Default in the interim period is also possible. For this to happen, it must be the case that the speculative attack in

3 Speculative runs and liquidity provision in equilibrium

We now turn to the characterization of the equilibrium in our three-period economy for given government policies (i.e., for a given distribution of the fundamental R). According to our specification, in the interim period the IMF and the fund managers take their decisions independently and simultaneously. In effect, we envision a world in which the contingent fund L initially committed by the IMF may not be available ex post, and this is understood by fund managers, who correctly compute the likelihood of IMF interventions. As mentioned above, the idea here is that the IMF will refuse to lend if, according to its information, there is no prospect to recover its loans L fully — so that contingent financial assistance would turn into a subsidy.

At the heart of our model lies the coordination problem faced by fund managers in the interim period. Fund managers are uncertain about the information reaching all other managers and the IMF, and therefore face strategic uncertainty about their actions. But the expected payoff of each fund manager from rolling over a loan to the country depends positively on the fraction $(1-x)$ of managers not withdrawing in the interim period, as well as on the IMF willingness to provide liquidity. The IMF expected payoff from providing liquidity, in turn, depends positively on the fraction of agents who roll over their debt. Clearly, the decision by the fund managers and the IMF are strategic complements.

As in Corsetti, Dasgupta, Morris and Shin (2004) — hereafter CDMS — in our model there is a unique equilibrium[16] in which agents employ trigger strategies: a fund manager will withdraw in period 1 if and only if her private signal on the rate of return of the risky

the interim period exceeds all liquidity resources plus the liquidation value of domestic investment

$$xD \geq \frac{RI}{1+k} + M + L_+$$

The minimum rate of return at which early liquidation x leads to early default is

$$\begin{aligned}\bar{R}_{ED} &= (1+\kappa)\left[\frac{[xD-M]_+}{I} - \frac{L_+}{I}\right] \\ &= (1+\kappa)\,R_s\left[\frac{[xD-M]_+}{D-M} - \frac{L_+}{D-M}\right]\end{aligned}$$

where ED stands for early (period 1) default.

[16]The equilibrium is familiar to readers of the global-game literature. It is a Bayes Nash equilibrium in which, conditional on a player signal, the action prescribed by this player's strategy maximize his conditional expected payoff when all other players follow their equilibrium strategy.

investment is below some critical value $\widetilde{s}^*$, identical for all managers. Analogously, the IMF will intervene in support of a country in distress if and only if its own private signal is above some critical value $\widetilde{S}^*$. Using the argument in CDMS , it can be shown that a focus on trigger strategies is without loss of generality, as there is no other equilibrium in other strategies. The proof is omitted, since it can be derived from the appendix A of the CDMS paper.

The equilibrium is characterized by *four critical thresholds.* The first two thresholds are critical values for the fundamental R, below which the country always defaults — one conditional on no IMF intervention, $\bar{R}$, the other conditional on IMF intervention, $\bar{R}_L$. The other two are the thresholds $\widetilde{s}^*$ and $\widetilde{S}^*$ for the private signal reaching the funds managers and the IMF, discussed above. In this and the next section we will assume that the public signal is arbitrarily uninformative — i.e., $\rho \to 0$, so that posteriors will coincide with private signals (see (6) and (7)). We will therefore express signals and thresholds of individual managers and the IMF in terms of these agents' posterior, denoted without tilde (i.e., s_i, S, s^* and S^*).

Let us first derive the equations determining $\bar{R}$ and $\bar{R}_L$. If funds managers follow a trigger strategy with threshold s^*, the proportion of fund managers who receive a signal such that their posterior is below s^* and hence withdraw in the first period crucially depends on the realization R:

$$x = prob\,(s_i \leq s^* \mid R) \equiv G(s^* - R). \tag{14}$$

Using our definition of the threshold for failure $\bar{R}$, if the IMF does not intervene, there will be a crisis for any R such that $R \leq \bar{R}$. Then, at $R = \bar{R}$ the mass of international managers that withdraw is just enough for causing the country to fail. This mass is $x = G(s^* - \bar{R})$. Using (11), we can write the first equilibrium condition — defining $\bar{R}$ — as follows:

$$\bar{R} = R_s \left[1 + \kappa \frac{\left[G(s^* - \bar{R}) \cdot D - M\right]}{D - M} \right]. \tag{15}$$

If the IMF intervenes, there will be a crisis for any R such that $R \leq \bar{R}_L$. As above, at $\bar{R}_L$ the critical mass of speculator to cause debt liquidity-related problems is $x =$

$G(s^* - \bar{R}_L)$. From (13), the threshold for failure conditional on IMF intervention $\bar{R}_L$ is:

$$\bar{R}_L = R_s \left[1 + \kappa \frac{\left[G(s^* - \bar{R}_L) \cdot D - M - L\right]}{D - M}\right]. \tag{16}$$

This is the second equilibrium condition — defining $\bar{R}_L$. At the thresholds $\bar{R}$ and $\bar{R}_L$, xD must be greater than M conditional on no IMF intervention, and greater than $M+L$ otherwise. So, in equilibrium

$$\left[G(s^* - \bar{R}) \cdot D - M\right] > 0 \quad \text{and} \quad \left[G(s^* - \bar{R}_L) \cdot D - M - L\right] > 0.$$

Equations (15) and (16) imply $\bar{R}_L < \bar{R}$. [17]

We now turn to the equations determining the triggers s^* and S^*, starting from the latter. Upon receiving the signal $\widetilde{S}$, the IMF assigns probability $H(\bar{R}_L - S)$ to the failure of the country despite its intervention. The IMF expected payoff (denoted $\mathcal{W}_{IMF}$) is therefore

$$\mathcal{W}_{IMF} = B \cdot \left(1 - H(\bar{R}_L - S)\right) - C \cdot H(\bar{R}_L - S)$$

which is decreasing in S. The optimal strategy consists of lending to the country if and only if this expected payoff is non-negative, that is, if and only if $S \geq S^*$ where S^* is defined by

$$S^* = \bar{R}_L - H^{-1}\left(\frac{B}{B+C}\right). \tag{17}$$

The investor's problem is more complex, as discussed in CDMS. Whether or not the IMF intervenes, the country will default for $R < \bar{R}_L$. So, a fund manager receiving signal $\widetilde{s}$ will assign probability $G(\bar{R}_L - s)$ to the event 'default regardless of the IMF's action'. However, for R comprised between $\bar{R}_L$ and $\bar{R}$, the country will default only if the IMF fails to intervene. So, the managers' expected payoff (denoted $\mathcal{W}_{FM}$) from rolling over

[17] From (15) and (16) we have:

$$\begin{aligned} s^* &= \bar{R} + G^{-1}\left[\left(\frac{\bar{R}}{R_s} - 1\right)\frac{D-M}{\kappa D} + \frac{M}{D}\right] = \\ &= \bar{R}_L + G^{-1}\left[\left(\frac{\bar{R}_L}{R_s} - 1\right)\frac{D-M}{\kappa D} + \frac{M+L}{D}\right]. \end{aligned}$$

Taking differences:

$$\bar{R} - \bar{R}_L = G^{-1}\left[\left(\frac{\bar{R}_L}{R_s} - 1\right)\frac{D-M}{\kappa D} + \frac{M+L}{D}\right] - G^{-1}\left[\left(\frac{\bar{R}}{R_s} - 1\right)\frac{D-M}{\kappa D} + \frac{M}{D}\right].$$

Suppose $\bar{R} \leq \bar{R}_L$. Then the LHS of the above equation would be less or equal to zero, while the RHS is positive. So it must be the case that $\bar{R} > \bar{R}_L$.

their fund in period 1 includes a term accounting for the conditional probability that the IMF fails to provide liquidity to the country, $H(S^* - R)$:

$$\begin{aligned} \mathcal{W}_{FM} &= b\left[1 - \left(G(\bar{R}_L - s) + \int_{\bar{R}_L}^{\bar{R}} g(R - s) \cdot H(S^* - R) dR\right)\right] \\ &\quad - c\left(G(\bar{R}_L - s) + \int_{\bar{R}_L}^{\bar{R}} g(R - s) \cdot H(S^* - R) dR\right) \end{aligned} \tag{18}$$

where g is the probability density function. The optimal trigger s^* for funds' managers is implicitly defined by the zero-profit condition (in expected terms) below:

$$\frac{b}{b+c} = G(\bar{R}_L - s^*) + \int_{\bar{R}_L}^{\bar{R}} g(R - s^*) \cdot H(S^* - R) dR. \tag{19}$$

The appendix A2 shows that there is a unique value s^* that solves this equation.

The four equations (15), (16), (17) and (19) in four endogenous variables ($\bar{R}$, $\bar{R}_L$, S^* and s^*) completely characterize the equilibrium. Note that in our equilibrium the country will always default when the realization of the fundamentals is worse than $\bar{R}_L$, it will never default when R is above $\bar{R}$ (when $R \geq \bar{R}$, whether or not the IMF intervenes, the fundamentals are good enough for the country to withstand any speculative run in the interim period). But for R comprised between $\bar{R}$ and $\bar{R}_L$, default may or may not occur, depending on the IMF. Analytical solutions for the general case are not available, but after identifying the relevant questions we want to address, we can resort to numerical simulations and derive some analytical results.

4 The effect of IMF lending on the likelihood and severity of debt crises

A distinctive feature of our global-game model is that crises have both a fundamental component and a speculative component. Not only must the rate of return be low enough for a speculative withdrawal to cause a solvency crises: withdrawals are more likely when the fundamentals are weak. The presence of an institutional lender of liquidity – even if with limited resources – affects the strategy of the fund managers. By changing the likelihood of speculative withdrawals, its presence can therefore influence the macroeconomic performance of the country.

In this section, we analyze the effects of IMF lending on the likelihood and severity of debt crises. More specifically, we can articulate our analysis addressing the following four questions:[18]

1. Does a larger availability of resources to the IMF increase the 'confidence' of the fund managers in the country — as captured by their willingness to roll over their loans for a relatively worse signal on the state of fundamentals?

2. To what extent does IMF lending affect the likelihood of a crisis?

3. Does the precision of the information of the IMF relative to the market matter? In other words, is the impact of IMF lending stronger as its information becomes more accurate?

4. To what extent IMF lending creates moral hazard, in the sense that because of liquidity support governments and/or corporations do not take (costly) steps to reduce vulnerability to crises?

We discuss the first three questions in this section. The last question on moral hazard — where our work yields the most novel result — will be analyzed in detail in the next section. Throughout our analysis, we will constrain L such that $L < D - M$. Obviously, when L becomes large enough to cover all possible withdrawals, liquidity is no more a concern — the break even rate is R_s.

4.1 Size of interventions

As regards questions 1 and 2 above, we summarize our comparative static exercise by means of the following proposition:

Proposition 1 *All thresholds ($\bar{R}_L$, $\bar{R}$, s^* and S^*) are decreasing in L.*

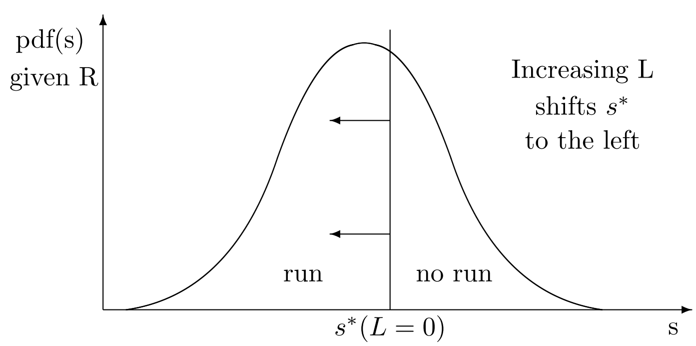
Proof: see appendix.

To see how this proposition answers to question 1, note that if a larger L lower s^*, funds managers are now willing to rollover their loans for weaker private signals

[18] CDMS analyze questions related to the first three in our list in the context of a study focused on the role of large speculative players in currency crises.

about fundamentals — hence they are less aggressive in their trading. A larger IMF raises the proportion of investors who are willing to roll over their debt at *any* level of the fundamental. This is illustrated by figure 2. Since the rate of return is normally distributed, if $\bar{R}$, $\bar{R}_L$ and S^* are all decreasing in L, the ex-ante probability of a crisis also falls with L. Then, the answer to question 2 is that bigger IMF interventions indeed lower the likelihood of a crisis. The effect of a larger L on the thresholds $\bar{R}$ and $\bar{R}_L$ is shown in figure 3. Note that a lower S^* increases the probability of the IMF intervention for each level of the fundamentals, therefore also for R between $\bar{R}$ and $\bar{R}_L$. As a consequence of a lower probability of a crisis, a larger L raises expected GNP.

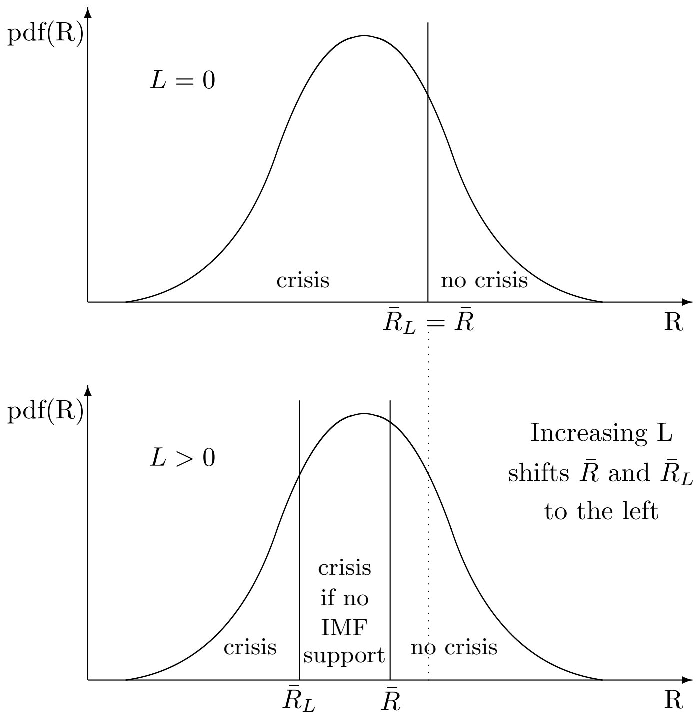
Figure 2: A larger L makes investors less agressive



These results lend theoretical support to the notion that an international lender of last resort increases the country's expected GNP not only through the direct effects of liquidity provision (interventions obviously reduce costly liquidation of existing capital). There is also an indirect effect on the coordination problem faced by fund managers: the possibility of interventions of size L lowers the threshold at which private managers refuse to roll over their debt, to an extent that increases with the size of contingent interventions. It follows that an international lender can avoid some early liquidation even if it does not act ex post.

To enhance the comparison between our analysis and the literature (especially contributions stressing multiple equilibria and self-fulfilling runs in the framework of models after D&D), it is useful to look at the equilibrium in our model when the precision of signals becomes arbitrarily large. When the errors ε_i go to zero, all private signals are

Figure 3: A larger L makes a crisis less likely



arbitrarily close to the true fundamental R and all thresholds ($\bar{R}_L$, $\bar{R}$, s^* and S^*) converge to the same value. Yet, signals are not common knowledge and agents still face strategic uncertainty about each other actions (i.e., they do not 'know' each other action in equilibrium). But with $\alpha, \beta \to \infty$, except in a measure-0 set in which the fundamental happens to be arbitrarily close to the threshold $\bar{R}_L$, either everybody withdraws early and the IMF does not intervene or nobody withdraws early. In this limiting case, there is no heterogeneity in managers' action, and there will be (almost surely) no provision of liquidity in equilibrium. Thus, the prediction of our model is observationally equivalent to the model with common knowledge after Diamond and Dybvig [1983] (see Corsetti, Guimarães and Roubini (2003) for a discussion).

With $\alpha, \beta \to \infty$, *all* the benefit of a lender of last resort come through the coordination effect (as the IMF almost never intervenes saving liquidation costs). To coordinate markets, however, the IMF need not have 'deep pockets'. A marginal increase in the size of conditional interventions L lowers the threshold s^* chosen by all agents in equilibrium (at which x endogenously drops from 1 to 0).[19]

4.2 The precision of IMF information

Above we have characterized the equilibrium when private signals become arbitrarily precise. Question 3 raises an issue regarding the role, if any, of the *relative* precision of the information of the IMF. This is a central issue in the analysis of the influence of large players in currency crises by CDMS, as these players are usually believed to act on superior information. In our context, the main interest is in the equilibrium effect of improving the quality of IMF information.

What happens when the IMF private information becomes more accurate? The following proposition synthesize our result.

Proposition 2 *An increase in the IMF information precision decreases all thresholds.*

Proof: see appendix[20]

Ceteris paribus, a higher precision of information by the IMF increases the willingness by fund managers to roll-over their loans to the country, and reduces the probability of default. Intuitively, if the IMF has the ability to estimate the state of the country fundamentals arbitrarily well, funds' managers need not worry about idiosyncratic noise in the IMF intervention decisions. Provided that the IMF's objective function is common knowledge, private investors understand its strategy (lending to possibly illiquid but not

[19] In our model, the strategies of all agents are endogenous in equilibrium. The parameters describing investors' payoffs affect more than the fund managers' own investment thresholds: because of their influence on the market coordination problem, these parameters also affect the equilibrium strategy by the IMF. In our analysis, we focus on IMF's incentives and strategy. Yet our framework can also shed light on the general equilibrium effect of corporate governance and managers' behavior. For instance, in Corsetti, Guimarães and Roubini (2003) we prove that all thresholds ($\bar{R}_L$, $\bar{R}$, s^* and S^*) are decreasing in b and increasing in c. Intuitively, a weaker reward to successful long-term investment makes fund managers more wary about rolling over their credit. This in turn leads the IMF to be more cautious in providing liquidity. The likelihood of debt default correspondingly increases in equilibrium. This proposition touches upon a topic extensively discussed by the literature, regarding the reason why rewards to long-term investment strategies may be perceived as weak by managers. For instance, funds' performance may be assessed against industry-wide benchmarks, so that individual managers may be reluctant to take positions at odds with those benchmarks, even if these position may have good risk-adjusted payoffs in the long term. Although our example is admittedly stylized, it shows the potential importance of general equilibrium analysis of these issues.

[20] CDMS show an analogous result for the limiting case when all players have arbitrarily accurate information. Our proposition generalizes their result.

to insolvent countries). At the margin, increasing the accuracy of IMF information makes them more willing to lend, because they will be confident that the IMF assessment of the fundamentals will not be far away from their own assessment — they can therefore expect the IMF to intervene when they believe that the state of the economy grant intervention.[21]

4.3 Seniority of IMF loans

The IMF is usually assumed to have, "de facto" even if not "de jure", a 'preferred creditor status', i.e. its loans may have seniority in repayment relative to private credits. Would our main insights carry over in an economy where IMF loans have priority over private loans? This subsection addresses this question. To start with, note that the solvency threshold for the return on the risky investment that is relevant for the IMF decision is

$$R(1-z)I = RI - (1+\kappa)\left[xD - M - L\right]_{+} \geq L \tag{20}$$

Provided that $[xD - M - L] > 0$ we can write

$$\begin{aligned} \bar{R}_{IMF} &= (1+\kappa)\frac{[xD-M]}{I} - \kappa\frac{L}{I} = \\ & R_s\left[(1+\kappa)\frac{[xD-M]}{D-M} - \kappa\frac{L}{D-M}\right] \end{aligned} \tag{21}$$

The international liquidity provider keeps lending up the point in which the country has just enough resources to repay L.

Assuming, as in section 4, that $\rho \to 0$, the following equations characterize the equilibrium when the IMF loans have seniority) — all variables in this case are denoted with a prime ($'$):

$$\bar{R}' = R_s\left[1 + \kappa\frac{\left[G(s'^{*} - \bar{R}') \cdot D - M\right]}{D-M}\right] \tag{22}$$

[21] We find a simultaneous game a more appropriate and realistic description of the strategic uncertainty surrounding private and public behavior in a crisis. One could however think of stressing sequential decision making. For example, one could assume that funds managers take their portfolio decisions after being informed about the IMF's actual intervention. This amendment would raise a complex issue of strategic 'signalling' by the IMF, making the model much more difficult to solve. There are however some restrictions to the game that would lead to an equilibrium with features similar to the one in our simultaneous game setup — see for example CDMS and Dasgupta (1999). Even under these restrictions, however, one cannot rule out the existence of other equilibria, when the game is sequential.

$$\bar{R}'_L = R_s \left[1 + \kappa \frac{\left[G(s'^* - \bar{R}'_L) \cdot D - M - L\right]}{D - M}\right] \tag{23}$$

$$S'^* = \bar{R}'_{IMF} - H^{-1}\left(\frac{B}{B + C}\right) \tag{24}$$

$$\bar{R}'_{IMF} = R_s \left[(1 + \kappa)\frac{\left[G(s'^* - \bar{R}'_{IMF}) \cdot D - M\right]}{D - M} - \kappa \frac{L}{D - M}\right] \tag{25}$$

$$\frac{b}{b + c} = G(\bar{R}'_L - s'^*) + \int_{\bar{R}'_L}^{\bar{R}'} g(R - s'^*) \cdot H(S'^* - R)dR \tag{26}$$

There are now 5 equations and 5 variables, instead of 4 equations in 4 variables. Note that the derivatives of the above expressions with respect to L are all negative, and, as in the version of our model without IMF seniority, $\bar{R}'_L < \bar{R}'$. We can show that:

$$\bar{R}'_{IMF} < \bar{R}'_L \tag{27}$$

We hereafter state our result:

Proposition 3 *When the IMF has seniority, there is a positive coordination effect that reduces all thresholds making the crisis less likely (ex-ante):* $s^{*\prime} < s^*$, $\bar{R}' < \bar{R}$, $\bar{R}'_L < \bar{R}_L$.

Proof: see appendix.

This proposition confirms our previous result, that more liquidity provision (induced by IMF seniority) tends to increase the willingness of fund managers to roll over their debt, and decrease the likelihood of crises.

Does IMF seniority makes a difference in terms of equilibrium allocation? There are two effects to consider. On the one hand, the above proposition shows that, as the IMF gets a larger share of the country's resources in case of default, it is more willing to intervene. This effect makes a crisis less likely. On the other hand, conditional on a crisis, private investors are junior relative to the IMF, so that the return on their investment is lower. To compare equilibria with and without IMF seniority, the cost c falling on debt managers — if they invest in a country that ends up defaulting — should be higher in the case when IMF loans are senior. As shown in Corsetti, Guimarães and Roubini (2003), an increase in the penalty parameter c will tend to raise all thresholds — i.e., move them in the opposite direction relative to what predicted by proposition

(3). Fund managers will therefore be less willing to roll over debt, making a crisis more likely. In the rest of the paper, we will exclusively focus on our model where in the case of default all creditors have the same seniority.

5 Liquidity and moral hazard

In the previous section we have shown that the expected GNP of the country — our measure of national welfare — is increasing in the size of the IMF liquidity support for any given distribution of the fundamental. However, moral hazard considerations may invalidate such a conclusion, since liquidity assistance by the IMF could reduce the incentive for the government to implement costly policies that enhance the likelihood of good macroeconomic outcomes.

We now develop our framework and assume that the government can take a costly action improving the expected value of R without affecting the variance of the distribution. The government decides its level of effort in period 0, when international investors lend D to the country and the IMF states the size of its contingent intervention L. The action by the government is not observed at any point (and the IMF cannot make the provision of liquidity conditional on it).[22]

For simplicity, we assume that the government can take one single action A (say, a policy reform and fiscal adjustment) that raises $E_0 R$ from R_N to R_A (let $\Delta R = R_A - R_N$). The welfare cost of undertaking action A is Ψ. This cost falls on the government only, and is motivated by exogenous considerations, say, electoral costs of reforms and fiscal adjustment. The government welfare function is

$$\mathcal{W} = \mathcal{U} - \Psi = E_0 Y - \Psi \tag{28}$$

where $\mathcal{U}$ is the utility of the domestic representative agent. Note that $\mathcal{W}$ does not coincide with social welfare $\mathcal{U}$, which is measured by expected GNP only. In an appendix, we will show that our results below carry over to a more general setup in which the government can choose from a continuous set of actions.

[22]In our model we focus on debtor moral hazard. Clearly, international liquidity support may also induce creditor moral hazard. To consider this latter issue in our framework, the initial debt level D should be taken as an endogenous choice variable — allowing for investors' risk aversion.

5.1 Liquidity provision can either induce or prevent debtor's moral hazard

It is convenient to focus our analysis on the limiting case when private signals become arbitrarily precise. An important reason is that, as the government affects the mean of the prior distribution, we need to relax the assumption of an uninformative public signal and conduct our analysis by setting a strictly positive ρ. With arbitrarily precise private information, we can do so without unnecessarily complicating the analysis. A second reason is that, as we have shown in the previous section, the case of arbitrarily precise private information brings the results of our model more closely into line with the predictions of models after Diamond-Dybvig, and therefore makes it easier to stress core differences between the two. Namely, with $\alpha \to \infty$, all agents will take the same action in equilibrium for almost all realizations of R (except when R happens to be arbitrarily close to $\bar{R}_L$), so that in equilibrium there will be no heterogeneity (but the equilibrium is unique) and no partial liquidation (except in a measure-zero set). Thus, the utility of the government conditional on its action simplifies to:[23]

$$\begin{aligned} \lim_{\alpha \to \infty} \mathcal{W}(A) &= \int_{\bar{R}_L}^{\infty} [R \cdot I + M - D] \ f(R \mid R_A) \ dR \ - \ \Psi \\ \lim_{\alpha \to \infty} \mathcal{W}(N) &= \int_{\bar{R}_L}^{\infty} [R \cdot I + M - D] \ f(R \mid R_N) \ dR \end{aligned} \tag{29}$$

Taking the difference in government welfare with and without the costly action we obtain:

$$\begin{aligned} \lim_{\alpha \to \infty} \mathcal{W}(A) - \mathcal{W}(N) \ \equiv \ \Delta\mathcal{W} &= I \cdot \Delta R \cdot \left(1 - F\left(\bar{R}_L \mid R_N\right)\right) \\ &+ \int_{\bar{R}_L}^{\bar{R}_L + \Delta R} [R \cdot I + M - D] \ \cdot \ f(R \mid R_A) \ dR - \Psi \end{aligned} \tag{30}$$

In deciding whether to undertake the action A, the government compares the utility costs of a reform Ψ with the gains in expected GNP that come both in terms of higher average realization of R (first term on the RHS), and in terms of lower expected liquidation costs (second term on the RHS) because of the drop in the probability of a run on debt.

As the size of the IMF liqudity provision impacts the limits of integration, depending on parameter values there may be some critical L at which the government switches

[23] Notably, the integrand in (29) does not depend on the liquidation cost κ — the set of realizations of R at which funds' withdrawals in period 1 lead to partial liquidation has measure zero. But the above expression is not independent of κ: in fact the lower extreme of integration (i.e., the threshold $\bar{R}_L$) crucially depends on this cost.

policy. The question is therefore how the net gain from the action A, $\Delta\mathcal{W}$, varies with the size of the IMF, L. The answer is stated by the following proposition.

Proposition 4 *$\Delta\mathcal{W}$ is decreasing in L if and only if $\bar{R}_L < \frac{R_A+R_N}{2}$.*

Proof: using our proposition (1), we know that for a given distribution of the fundamental, $\bar{R}_L$ is decreasing in L. We can therefore study the response of $\Delta\mathcal{W}$ to changes in $\bar{R}_L$, rather than in L. We have:

$$\frac{d\left(\Delta\mathcal{W}\right)}{d\bar{R}_L} = \left(\bar{R}_L I + M - D\right)\left[f\left(\bar{R}_L \mid R_N\right) - f\left(\bar{R}_L \mid R_A\right)\right] \tag{31}$$

The first term in brackets is non-negative (because $(\bar{R}_L I + M - D) = (\bar{R}_L - R_s)I$ and $\bar{R}_L \geq R_s$) but the second term can have either sign. As $R_A > R_N$, we have that

$$f\left(\bar{R}_L \mid R_N\right) > f\left(\bar{R}_L \mid R_A\right) \Leftrightarrow \bar{R}_L < \frac{R_A + R_N}{2} \tag{32}$$

which is the condition for a positive $\frac{d(\Delta\mathcal{W})}{d\bar{R}_L}$. $\square$

The commonly held view of moral hazard distortions from IMF interventions corresponds to the case in which $\bar{R}_L$ is lower than both R_N and R_A — implying that the probability of a crisis is less than 50 percent irrespective of government behavior. In this case, the difference on the RHS is positive: a *decrease* in $\bar{R}_L$, corresponding to a more abundant liquidity provision L, reduces the extra utility a government gets for taking the costly action A. At the margin, liquidity provision lowers the government net gains from taking the costly action.

This case is illustrated by figure 4-a.[24] In equilibrium, the position of $\bar{R}_L$ in this figure is such that the density at $\bar{R}_L$ is higher conditional on R_N than conditional on R_A. A decrease in $\bar{R}_L$ will therefore *reduce* the gain in expected GNP from 'good' government behavior.

But suppose that the country fundamentals are relatively weak, in the sense that the ex-ante probability of a crisis is more than 50 percent even if the government chooses the costly action A. Then, according to proposition 4, $\Delta\mathcal{W}$ will be *increasing* in L: more liquidity support raises the expected net gains from policy effort.

[24] Parameters employed: $R_A = 1.25$, $R_N = 1.20$, $\sigma_R = 0.08$ and $\bar{R}_L = 1.15$.

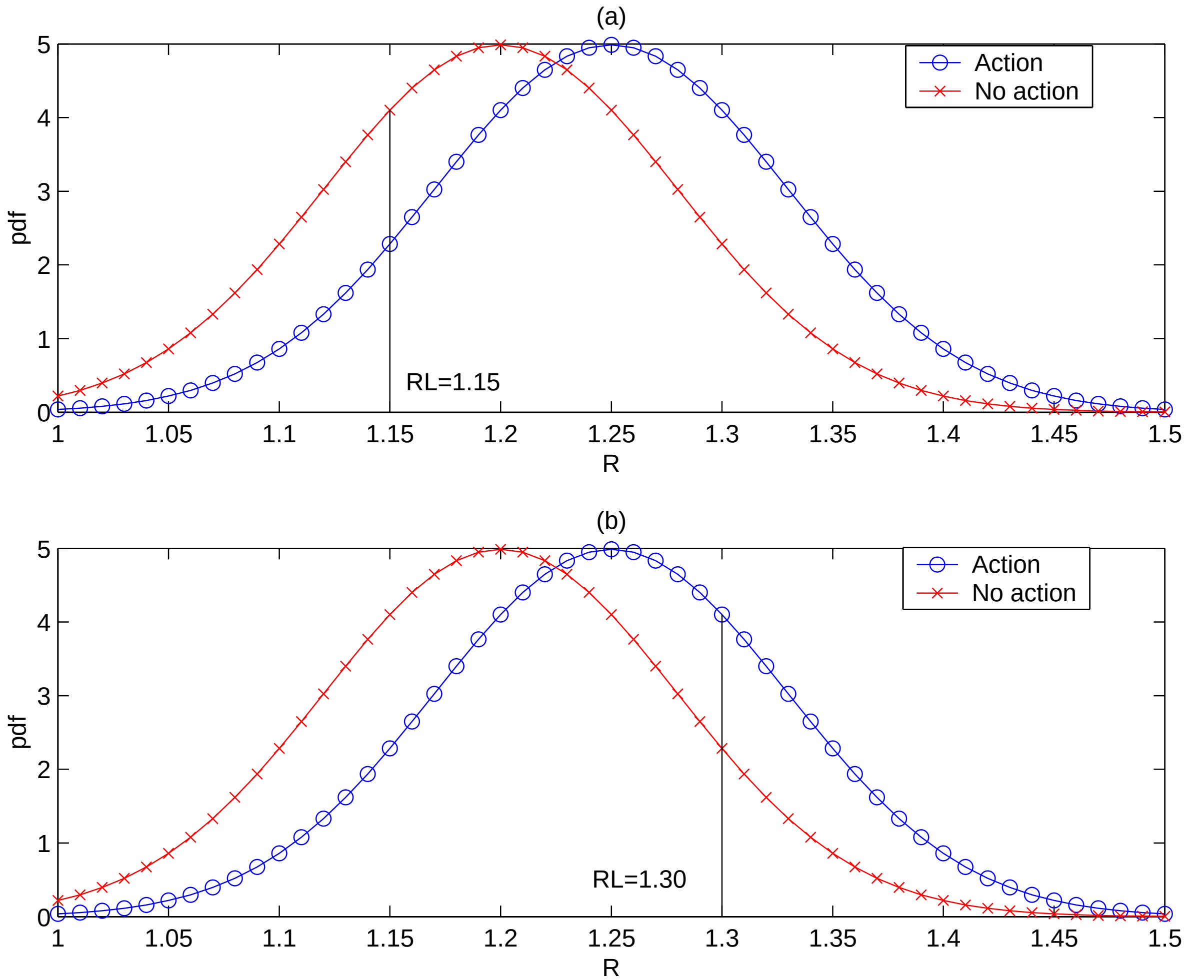


Figure 4: Government's decision: $\Delta\mathcal{W}$ and $\bar{R}_L$

Intuitively, if — at some given L — the probability of a failure is relatively high, the government has little incentive to bear the costs of improving the macro outcome: the chance that a good outcome will materialize is low whether or not it exerts any effort. In this case, additional liquidity provision is more likely to be helpful if the government takes the costly action, so it *increases* the incentives for good behavior. By reducing the likelihood of runs and their costs in terms of forgone output, larger support by an international lender of last resort improves the trade-off between the cost of government effort and the related improvement in the country's GNP. This case is illustrated in figure 4-b where the equilibrium $\bar{R}_L$ falls to the right of R_A. Clearly, a decrease in $\bar{R}_L$ raises the gains in expected GNP from the government action A.

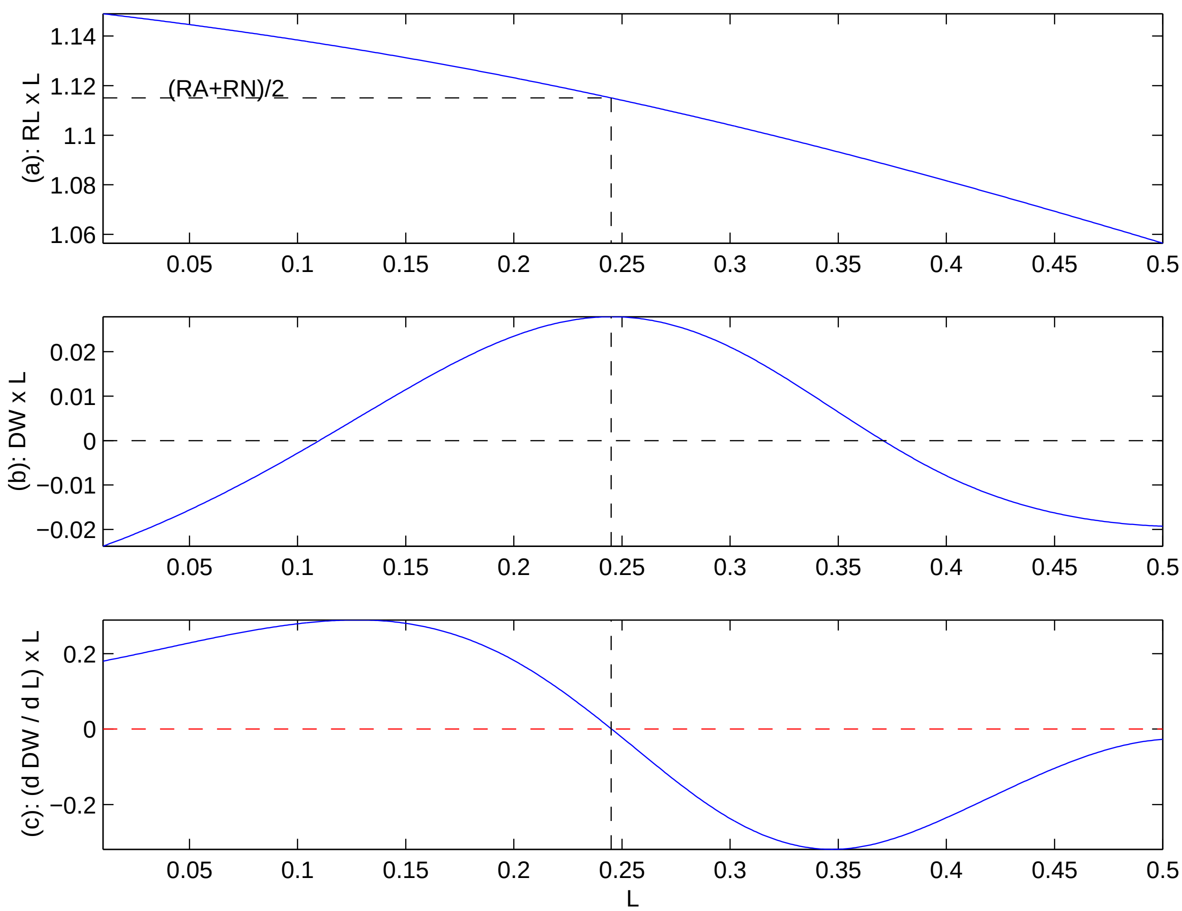


Figure 5: An example of the effects of L

Figure 5 illustrates with a numerical example the effects of liquidity support on the incentives for the government to take costly action. Figure 5-a shows $\bar{R}_L$ as a function of L. In accordance to proposition 1, $\bar{R}_L$ is decreasing in L. In the example, $R_A = 1.13$ and $R_N = 1.10$, so $(R_A + R_N)/2 = 1.115$.[25]

Figures 5-b-c illustrate the result shown by proposition 4: $\Delta\mathcal{W}$ is decreasing in L if and only if $\bar{R}_L < (R_A + R_N)/2$. As figure 5-a shows, $\bar{R}_L$ is smaller than $(R_A + R_N)/2$ (that is equal to 1.115 in this example) when L is larger than (around) 0.25. So, $\Delta\mathcal{W}$ is decreasing in L only when $L > 0.25$.

The costly action is taken whenever we are above the dotted line in figure 5-b. Changes in the cost Ψ would move the $(\Delta\mathcal{W} = 0)$-line up or down. When L is too low, the

[25]Other parameters of this example: $\sigma_R = 0.02$, $\kappa = 0.25$, $M = 0.2$, $I = 1$, $D = 1.2$, $\Psi = 0.05$, $b = B = 1$, $c = C = 2$.

prospects of a liquidity run discourage the government from undertaking the action. As L goes up, incentives for taking the action increase and when L is around 0.11, the government switches behavior and chooses to take the action. When L is around 0.25, moral hazard kicks in and the incentives for taking the costly action start to decrease. For $L > 0.37$, moral hazard effects dominate and the government does not take the action anymore.

Moral hazard in our model can be understood as a reduction in the incentives for taking the costly action - that is, a reduction in $\Delta\mathcal{W}$. Thus, an increase in the size of liquidity support causes moral hazard whenever we are below the horizontal dotted line in figure 5-c — that is, only when $L > 0.25$.

Relative to the traditional view, global-game models point to a different and intriguing possibility, one of *strategic complementarity* between the actions by the IMF and the domestic government (see the discussion of a similar result in Morris and Shin (2003)). When the ex-ante probability of a crisis is high, the payoff to the government from action A is increasing in L. Note also that the payoff of the IMF is increasing in the action A undertaken by the government.[26]

5.2 Policy trade-offs at different levels of L: numerical examples

The properties of our model can be illustrated by means of four numerical examples, all depicted in figure 6. To draw this figure, we adopt the parameter values shown in table 1, and set $D = 1.2$ and $I = 1$. For each example, we plot $\mathcal{W}(A)$, $\mathcal{W}(N)$ and expected GNP — $E(GNP)$ in the figure — against different values of L. As shown above, the government chooses the costly action whenever $\mathcal{W}(\mathcal{A}) > \mathcal{W}(\mathcal{N})$. Note that the country's GNP is therefore $\mathcal{W}(\mathcal{N})$ if the action is not taken, and $\mathcal{W}(A) + \Psi$ if the action is taken.

[26] Our conclusion remains unchanged when government welfare depends on GDP, rather than GNP — this is equivalent to assuming that the amount paid to foreigners is independent of the realization of R, perhaps because there are other resources in the economy in addition to the payoffs of domestic investment I. It is worth stressing that our results are not driven by the assumption of "limited liability" for the economy as a whole. Even if the government cares about GDP, a marginal increase in the size of the IMF would still reduce $\bar{R}_L$, producing *marginal saving on liquidation costs*. Its effect on the incentives to take the costly action A depends on the likelihood that it will benefit the government in either situation (conditional on choosing R_A or R_N). The intuition is exactly the same as provided in the text, whereas the government cares about GNP (see Corsetti, Guimarães and Roubini (2003)).

Table 1: Value of the parameters in figure 6

figure	6-a	6-b	6-c	6-d
κ	.3	.25	.25	.25
M	.25	.20	.20	.20
Ψ	.06	.05	.05	.05
b	2	1	1	1
c	10	10	10	10
B	2	2	2	2
C	10	10	10	10
R_A	1.18	1.25	1.19	1.12
R_N	1.16	1.22	1.16	1.065
σ_R	.03	.05	.05	.05

Figures 6-a and 6-b illustrate the case in which a large ILOLR unambiguously creates moral hazard distortions. Comparing $\mathcal{W}(A)$ with $\mathcal{W}(N)$ in figure 6-a: the former exceeds the latter — i.e., governments prefer to take the costly action — only for relatively low values of L, between 0 and (approximately) 0.18. Liquidity provision in excess of this value creates a clear incentive for the government not to act. Increasing the size of the IMF contingent interventions above 0 at first raises expected GNP monotonically. At L around 0.18, however, the moral hazard distortion kicks in, determining a discrete drop in expected GNP and national welfare to $\mathcal{W}(N)$. Conditional on R_N, providing more liquidity assistance has again a positive effect on $E(GNP)$.

In a global sense, there could be different trade-offs between liquidity provision and moral hazard. In figure 6-b, we increase the gains in $E(GNP)$ when the government takes the action A relative to figure 6-a. Then the country's $E(GNP)$ is at a maximum when liquidity provision is just below the level at which the government would give up its costly action. From the point of view of the country's citizens, moral hazard distortions are more important than the costs of liquidity crises. Conversely, in figure 6-a, the country GNP is highest for high values of L despite moral hazard distortions. Liquidity costs in this case are more important than the output costs due to moral hazard.

Figures 6-c and 6-d illustrate the possibility of strategic complementarity between IMF lending and government action A. In figure 6-c the trade-off between liquidity and

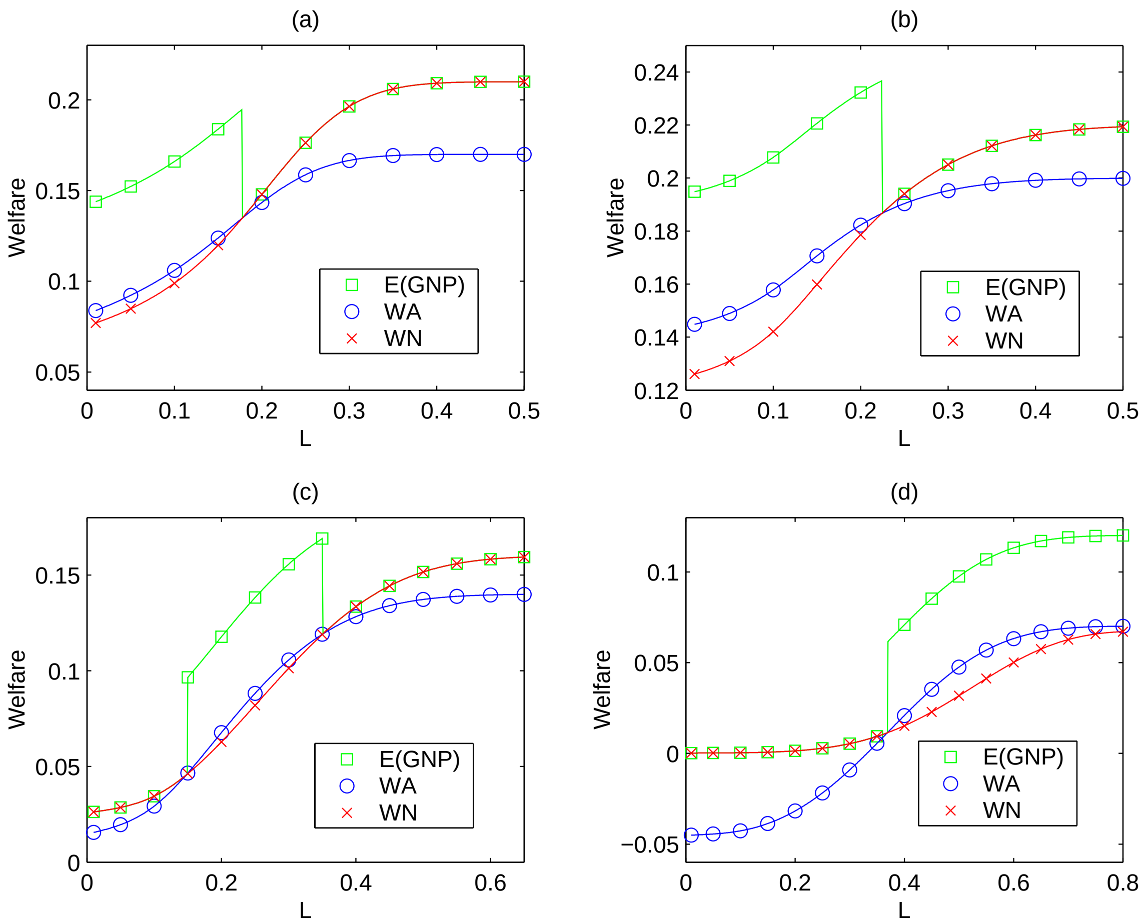


Figure 6: Policy tradeoffs

moral hazard varies with L. For sufficiently low values of L, $\mathcal{W}(A) < \mathcal{W}(N)$ and the government does not undertake any action because it is discouraged by bleak prospects of success. However, for intermediate level of liquidity support — i.e., for $0.15 < L < 0.35$ —, the government welfare becomes higher conditional on undertaking the action A. Liquidity provision eventually becomes excessive. For levels of L in excess of 0.35, once again $\mathcal{W}(A) < \mathcal{W}(N)$: the government does not exert any effort, and the country's expected GNP falls. Note that, relative to figure 6-b, the crucial parameter change consists of decreasing both R_A and R_N by a few percentage points — enough to worsen the macroeconomic outcome in such a way that, within some range of the fundamental, the government would not undertake any costly policy without liquidity provision by the IMF.

Relative to figure 6-c, in figure 6-d we further reduce R_A and R_N, while allowing for a larger difference ΔR. In this last figure, government welfare conditional on the costly action is actually higher than $\mathcal{W}(N)$ if the IMF provides sufficiently large contingent funds. Although the difference shrinks as L get bigger, the country GNP is always higher conditional on A: in a global sense, there is no trade-off between liquidity provision and moral hazard.

These considerations may be useful as building blocks towards a normative study of the optimal size of IMF interventions. As apparent from figure 6, local governments weakly prefer the highest possible level of liquidity assistance by the IMF. Once moral hazard considerations are taken into account, however, the level of liquidity assistance preferred by policymakers may not be the one that maximizes expected GNP and national welfare. Since the cost Ψ does not fall on the country's citizens, these may prefer a low L to a large L. This is the case in the economy depicted by figure 6-b.

The level of L preferred by the IMF need not coincide with either the level preferred by national governments, or the level preferred by the country's citizens. In our specification, the structure of IMF preferences penalizes any loss of funds in case of national default, yet as a simplification the penalty from lending liquidity to crisis countries does not depend on the level of funds L at stake. Thus, for any given disutility from losing its loans to the country, the reason why the IMF could optimally choose to limit L would be to prevent moral-hazard distortions from raising the likelihood of a crisis (as a large L induces the government to abandon the costly action A).

6 Conclusions

As the main results of the model have been stated in the introduction, we devote the conclusions to some policy-related considerations, and a brief discussion of perspectives for future research. In the last decade the IMF systematically adopted a catalytic approach of large financial loans to support the main emerging market economies that experienced a crisis (see Cottarelli and Giannini (2002)). Arguably, 'catalytic interventions' succeeded in some cases (Mexico in 1995, Brazil in 1999 and again in 2002); they clearly failed in other cases (Russia in 1998, Argentina in 2001, Indonesia in 1998); there are a few examples that could be dubbed as 'partial success,' such as the IMF intervention in Korea during the 1997-1998 crisis. A number of contributions have attempted to perform systemic empirical studies of why and to what extent catalytic finance may work. While there is a clear need for further research, these studies point out formidable methodological difficulties in this area — whereas the actions by investors, governments and the IMF are all endogenous and interdependent. Because of these difficulties, the available empirical evidence is still not fully conclusive about catalytic finance even if some evidence is consistent with the implications of our model.

Two arguments have been commonly presented against the provision of liquidity as a way to resolve crises. First, it has been argued that 'limited' liquidity support cannot work. Unless the IMF package can match a financing gap of any size — in most cases exceeding the amount of resources realistically available to an international institution operating as an international lender of last resort — self-fulfilling speculative runs leading to bad equilibria with default and high economic costs cannot be ruled out (see e.g. Zettelmeyer (2000) and Jeanne and Wyplosz (2001)). The second argument is that IMF liquidity support necessarily induces debtor moral hazard, i.e., expectations of a bailout always exacerbate welfare-reducing policy distortions. Based on these arguments, some have argued that 'standstills' (the international equivalent of bank holidays in a domestic bank run model) could be a superior approach to stem liquidity crises, and could possibly lessen moral hazard distortions due to bailout expectations.

The model in this paper contributes to refute the two arguments against internal liquidity provision. First, it shows that 'corner solutions' in the form of exceptionally large and potentially unlimited liquidity provision are not necessary to reduce the incidence of liquidity runs. The presence of limited contingent liquidity support can be effective in inducing a fraction of private investors to decide to rollover their exposure to the country. Thus, partial support that does not fill ex ante the whole possible financing gap for a country can have an impact on individual portfolio decisions and therefore on the likelihood and the possible incidence of a crisis.

Second, the model suggests that the standard argument that liquidity support 'always' induces moral-hazard distortions is similarly incorrect. In our results, the availability of contingent liquidity funds may tilt the incentives of a government towards implementing desirable but politically difficult policies and reforms — whereas the same government would have found them too costly and risky to implement if the outcome of its efforts were highly exposed to disruptive speculative runs. Thus liquidity support may encourage good policy behavior — rather than discouraging it.

We should note here that moral hazard distortions may also derive from domestic guarantees of the banking system. These observations suggests that the one-sector model presented in the paper could be usefully developed into a multi-sector model, to analyze the possibility of twin sovereign debt and banking crises. Twin crises have been experienced in a number of recent episodes of financial crises, including Ecuador, Russia, Argentina, Uruguay, Dominican Republic.

Are 'standstills' superior to 'catalytic finance' as an international policy strategy to contain destructive liquidity runs? Standstill solutions to liquidity runs have been studied in closed economy models (see e.g. Goldstein and Pauzner (2002)), as well as in open economy models (see e.g. Gai, Hayes and Shin (2004), Shin (2001), Martin and Penalver (2003) and Gai and Shin (2002)), but without providing a systematic comparison of costs and benefits of alternative solutions, standstills versus catalytic finance. An important direction for future research consists of addressing this issue within a rigorous analytical framework. Our model — we believe — provides a simple but natural setup to undertake a study of which approach is superior, in welfare terms, in dealing with liquidity runs and moral hazard distortions, at both the creditors' and debtor's level.

A Appendix

A.1 Uniqueness and existence of equilibrium

We have seen in the main text that the equilibrium value of s^* is determined by the following equation:

$$\frac{b}{b+c} = G(\bar{R}_L - s^*) + \int_{\bar{R}_L}^{\bar{R}} g(R - s^*) \cdot H(s^* - R) dR$$

We want to show that there is a unique value that solves this equation. Define $w = R - s^*$, $\bar{w} = \bar{R} - s^*$, and $\bar{w}_L = \bar{R}_L - s^*$ (where clearly $\bar{w} > \bar{w}_L$). Changing variables in equation

(19) and using (17) we get:

$$G(\bar{w}_L) + \int_{\bar{w}_L}^{\bar{w}} g(w) \cdot H\left(\bar{w}_L - w - H^{-1}\left(\frac{B}{B+C}\right)\right) dw - \frac{b}{b+c} = 0 \tag{33}$$

Key to the proof is that the RHS of this equation is monotonically increasing in $\bar{w}$ and $\bar{w}_L$ and both $\bar{w}$ and $\bar{w}_L$ in turn are monotonically increasing in s^*. To see this, substituting (16) in the definition of $\bar{w}_L$ we get:

$$-\bar{w}_L - \frac{\kappa R_S \cdot D}{D-M} G\left(\bar{w}_L\right) - s^* + \text{constant} = 0$$

Differentiating

$$\frac{\partial \bar{w}_L}{\partial s^*} = \frac{1}{1 + \frac{\kappa R_S \cdot D}{D-M} g(\bar{w}_L)} > 0$$

By the same token

$$\frac{\partial \bar{w}}{\partial s^*} = \frac{1}{1 + \frac{\kappa R_S \cdot D}{D-M} g(\bar{w})} > 0$$

just as in CDMS. Thus, for sufficiently large s^* the LHS of (33) is positive, while it is negative for sufficiently small s^*. Since the LHS is continuous in s^*, there is a unique solution to (33). Once s^* is uniquely determined, S^* follows from (17).

A.2 Proof of proposition 1

This appendix proves proposition 1. Differentiating equations (15) and (16) and rearranging, we get:

$$\frac{ds^*}{dL} = \left(1 + \frac{1 - M/D}{R_s \cdot \kappa \cdot g(s^* - \bar{R})}\right) \cdot \frac{d\bar{R}}{dL} \tag{34}$$

$$\frac{ds^*}{dL} = \left(1 + \frac{1 - M/D}{R_s \cdot \kappa \cdot g(s^* - \bar{R}_L)}\right) \cdot \frac{d\bar{R}_L}{dL} + \frac{1}{g(s^* - \bar{R}_L)} \tag{35}$$

To ease notation, define ζ_1 and ζ_2 as follows

$$\zeta_1 = \left(1 + \frac{1 - M/D}{R_s \cdot \kappa \cdot g(s^* - \bar{R})}\right)^{-1}$$

$$\zeta_2 = \left(1 + \frac{1 - M/D}{R_s \cdot \kappa \cdot g(s^* - \bar{R}_L)}\right)^{-1}$$

Note that $\zeta_1, \zeta_2 \in (0, 1)$.

Now, define $w = R - s^*$, $\bar{w} = \bar{R} - s^*$, and $\bar{w}_L = \bar{R}_L - s^*$. Using (34) and (35) we have:

$$\frac{d\bar{w}}{dL} = -(1-\zeta_1)\,\frac{ds^*}{dL} \tag{36}$$

$$\frac{d\bar{w}_L}{dL} = -(1-\zeta_2)\,\frac{ds^*}{dL} - \frac{\zeta_2}{g(\bar{w}_L)} \tag{37}$$

Changing variables in equation (19) and using (17) we get:

$$\frac{b}{b+c} = G(\bar{w}_L) + \int_{\bar{w}_L}^{\bar{w}} g(w).H\left(\bar{w}_L - w - H^{-1}\left(\frac{B}{B+C}\right)\right) dw \tag{38}$$

Differentiating 38 and rearranging terms:

$$\frac{d\bar{w}}{dL}\,\zeta_3 \;+\; \frac{d\bar{w}_L}{dL}\,\zeta_4 \;=\; 0$$

where:

$$\zeta_3 = g(\bar{w})\; H\left(\bar{w}_L - \bar{w} - H^{-1}\left(\frac{B}{B+C}\right)\right) > 0$$

$$\zeta_4 = g(\bar{w}_L)\left(\frac{B}{B+C}\right) \;+\; \int_{\bar{w}_L}^{\bar{w}} g(w)\; h\left(\bar{w}_L - w - H^{-1}\left(\frac{B}{B+C}\right)\right)\; dw \;>\; 0$$

This yields:

$$\frac{ds^*}{dL} = -\frac{\zeta_2\zeta_4}{g(\bar{w}_L)\left[(1-\zeta_1)\,\zeta_3 \;+\; (1-\zeta_2)\,\zeta_4\right]} \;<\; 0$$

Using (34), (35) and (17) we get that:

$$\frac{d\bar{R}}{dL} < 0\;,\;\; \frac{d\bar{R}_L}{dL} < 0 \text{ and } \frac{dS^*}{dL} < 0$$

which completes the proof.

A.3 Proof of Proposition 2

Let Φ be the standard normal distribution. Then, equation (17) can be written as:

$$\Phi\left(\sqrt{\beta+\rho}\;(S^* - \bar{R}_L)\right) = \frac{B}{B+C}$$

Differentiating with respect to the precision of IMF information (β), we get:

$$\phi\left(\sqrt{\beta+\rho}\;(S^* - \bar{R}_L)\right).\left[\sqrt{\beta+\rho}\;\left(\frac{dS^*}{d\beta} - \frac{d\bar{R}_L}{d\beta}\right) + \frac{S^* - \bar{R}_L}{2\sqrt{\beta+\rho}}\right]$$

Defining $w_S^* = S^* - s^*$, using $\bar{w}_L$ as defined above and rearranging, we obtain:

$$\sqrt{\beta+\rho}\,\frac{dw_S^*}{d\beta}=\sqrt{\beta+\rho}\,\frac{d\bar{w}_L}{d\beta}-\frac{(w_S^*-\bar{w}_L)}{2\sqrt{\beta+\rho}} \tag{39}$$

Moreover, as above:

$$\frac{d\bar{R}}{d\beta}=\zeta_1\frac{ds^*}{d\beta}$$

$$\frac{d\bar{R}_L}{d\beta}=\zeta_2\frac{ds^*}{d\beta}$$

So:

$$\frac{d\bar{w}}{d\beta}=-(1-\zeta_1)\,\frac{ds^*}{d\beta} \tag{40}$$

$$\frac{d\bar{w}_L}{d\beta}=-(1-\zeta_2)\,\frac{ds^*}{d\beta} \tag{41}$$

Differentiating (19), using (39), (40), (41) and rearranging, we get:

$$\frac{ds^*}{d\beta}=\frac{\int_{\bar{w}_L}^{\bar{w}} g(w)\;h\left(w_S^*-w\right)\;(\bar{w}_L-w)\;dw}{2\sqrt{\beta+\rho}\left[(1-\zeta_1)\,\zeta_3\;+\;(1-\zeta_2)\,\zeta_5\right]}\;<\;0$$

where

$$\zeta_5=g(\bar{w}_L)\left(\frac{B}{B+C}\right)\;+\;\int_{\bar{w}_L}^{\bar{w}} g(w)\;h\left(\bar{w}_L-w-H^{-1}\left(\frac{B}{B+C}\right)\right)\sqrt{\beta+\rho}\,dw\;>\;0$$

Finally, using (39), (40), (41), we obtain:

$$\frac{d\bar{R}_L}{d\beta},\;\frac{d\bar{R}}{d\beta},\;\frac{dS^*}{d\beta}\;<\;0$$

which concludes our proof.

A.4 Proof of Proposition 3

Equations (15) and (16) are identical to equations (22) and (23). A bit of algebra shows that (check the proof for the derivatives with respect to L):

$$s'^*\geq s^*\;\Rightarrow\;(\bar{R}'_L-s'^*)\leq(\bar{R}_L-s^*)\text{ and }(\bar{R}'-s'^*)\leq(\bar{R}-s^*) \tag{42}$$

Moreover,

$$s'^*<s^*\;\Leftrightarrow\;\bar{R}'<\bar{R}\;\Leftrightarrow\;\bar{R}'_L<\bar{R}_L$$

Now, suppose that $s'^*\geq s^*$.

From equations (26) and (19), we have that:

$$G(\bar{R}_L - s^*) + \int_{\bar{R}_L}^{\bar{R}} g(R - s^*) \cdot H(\bar{R}_L - H^{-1}\left(\frac{B}{B+C}\right) - R)dR \ =$$
$$G(\bar{R}'_L - s'^*) + \int_{\bar{R}'_L}^{\bar{R}'} g(R - s'^*) \cdot H(\bar{R}'_{IMF} - H^{-1}\left(\frac{B}{B+C}\right) - R)dR$$

Using relations (27) and (42), we get a contradiction that proves our claim.

A.5 Moral hazard with a continuous set of actions for the government

This appendix reconsiders our analysis of moral hazard in a more general framework. Let ΔR denote policy effort, raising linearly the expected value of the fundamental, i.e., $E_0 R = R_0 + \Delta R$. Policy effort entails a utility cost $\Psi\left(\Delta R\right)^{\nu}/\nu$, affecting the government only. Thus, assuming that the noise in private signal is arbitrarily small ($\alpha \to \infty$), the policy problem is to maximize:

$$\begin{aligned} \lim_{\alpha\to\infty} \mathcal{W}\left(\Delta R\right) &= \int_{\bar{R}_L}^{\infty} \left[R \cdot I + M - D\right] \, f\left(R \mid R_0 + \Delta R\right) \, dR \, - \, \frac{\Psi\left(\Delta R\right)^{\nu}}{\nu} \qquad (43) \\ &= \int_{\bar{R}_L - \Delta R}^{\infty} \left[(R + \Delta R) \cdot I + M - D\right] \, f\left(R \mid R_0\right) \, dR \, - \, \frac{\Psi\left(\Delta R\right)^{\nu}}{\nu} \end{aligned}$$

Taking the derivative with respect to ΔR, we get:

$$\begin{aligned} \frac{d\mathcal{W}\left(\Delta R\right)}{d\Delta R} &= (\bar{R}_L I + M - D) f\left(\bar{R}_L - \Delta R \mid R_0\right) + \int_{\bar{R}_L - \Delta R}^{\infty} I \cdot f\left(R \mid R_0\right) dR - \, \Psi\left(\Delta R\right)^{\nu-1} \\ &= (\bar{R}_L - R_s) I f\left(\bar{R}_L - \Delta R \mid R_0\right) + I\left(1 - F(\bar{R}_L - \Delta R \mid R_0)\right) - \, \Psi\left(\Delta R\right)^{\nu-1} (44) \end{aligned}$$

It is easy to show that, for $\nu > 1$ and reasonable values of Ψ, our results for the binary-action case still apply. Namely, when ex-ante odds of a crisis are high enough, the government chooses little or no policy effort. By reducing the ex-ante probability of a crisis, a larger L would then raise the government incentive to choose a higher effort ΔR. Conversely, when the ex-ante probability of a run is small, additional liquidity provision induces the government to reduce ΔR.

These results are illustrated by figures 7-a,b,c, which plot the optimal effort level ΔR as a function of $\bar{R}_L$, for ν equal to 2, 1.2 and 3, respectively. Figure 7-d, instead, shows the ex-ante odds of a crisis as a function of $\bar{R}_L$ conditional on $\Delta R = 0$.[27] The first three

[27] Parameters used in the figures: $R_s = 1$, $R_0 = 1.15$, $\sigma_R = 0.05$, $I = 1$.

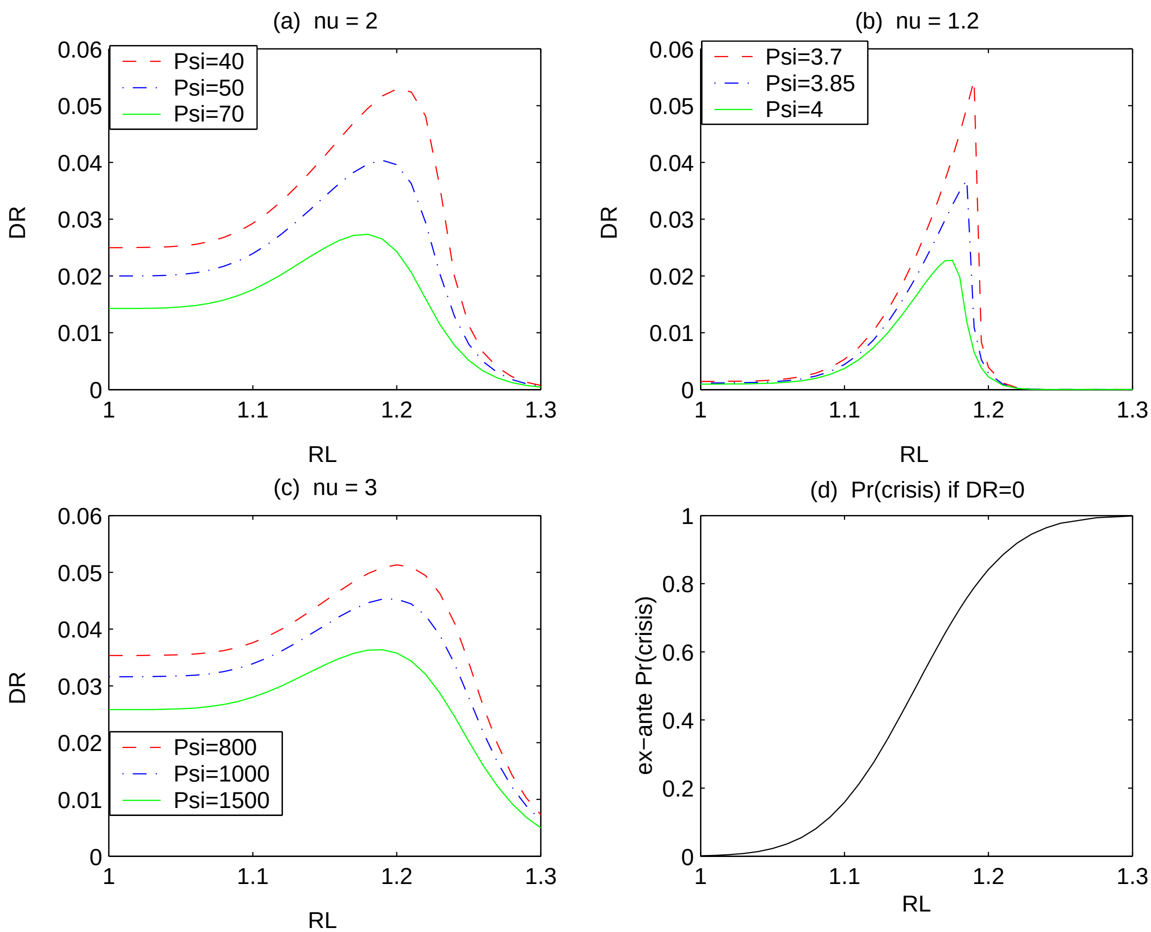


Figure 7: Continuous set of actions for the government

graphs appear quite similar: effort (ΔR) is increasing in $\bar{R}_L$ up to a point (around 1.18 or 1.20, depending on parameters' values), after which it is decreasing in $\bar{R}_L$. Note that the elasticity of ΔR falls with ν.

References

[1] Allen, Franklin and Douglas Gale (2000) "Optimal Currency Crises", unpublished mimeo, NYU, April.

[2] Allen, Franklin and Douglas Gale (2001), "Comparative Financial Systems", MIT Press.

[3] Carlsson, Hans and Eric van Damme (1993) "Global Games and Equilibrium Selection," Econometrica 61, 989-1018.

[4] Chang, Roberto and Andres Velasco (2001), "A Model of Financial Crises in Emerging Markets", Quarterly Journal of Economics, Volume 116, No.2, May.

[5] Cole, Harold and Patrick Kehoe (1996) "A Self-Fulfilling Model of Mexico's 1994-1995 Debt Crisis", Journal of International Economics, Vol. 41, No. 3/4, November, 309-330.

[6] Corsetti, Giancarlo, Amil Dasgupta, Stephen Morris and Hyun Song Shin (2004), "Does One Soros Make a Difference? A Theory of Currency Crises with Large and Small Traders", Review of Economic Studies 71, 87-114.

[7] Corsetti, Giancarlo, Bernardo Guimarães and Nouriel Roubini (2003), "International Lending of Last Resort and Moral Hazard: A Model of IMF's Catalytic Finance", NBER Working Paper 10125.

[8] Corsetti, Giancarlo, Pesenti Paolo and Roubini Nouriel (2002), "The Role of Large Traders in Currency Crises", in "Preventing Currency Crises in Emerging Markets" edited by Edwards and Frankel, University of Chicago Press.

[9] Cottarelli, Carlo and Curzio Giannini, (2002), "Bedfellows, Hostages, or Perfect Strangers? Global Capital Markets and the Catalytic Effect of IMF Crisis Lending", mimeo, IMF.

[10] Dasgupta, Amil (1999) "Social Learning with Payoff Complementarities", mimeo Yale University

[11] Diamond, Douglas and Philip Dybvig, (1983), "Bank Runs, Deposit Insurance, and Liquidity", Journal of Political Economy 91, 401-419.

[12] Eichengreen, Barry (2003) "Restructuring Sovereign Debt", Journal of Economic Perspectives, Fall, 17:4, 75-98.

[13] Fischer, Stanley (1999) "On the Need for an International Lender of Last Resort", unpublished, IMF (http://www.imf.org/external/np/speeches/1999/010399.HTM)

[14] Gai, Prasanna and Hyun Song Shin (2002) "Debt Maturity Structure with Preemptive Creditors," mimeo, Bank of England.

[15] Gai, Prasanna, Simon Hayes and Hyun Song Shin (2004) "Crisis Costs and Debtor Discipline: The Efficacy of Public Policy in Sovereign Debt Crises,", Journal of International Economics 62, 245-262.

[16] Gale, Douglas and Xavier Vives (2002) "Dollarization, Bailouts and the Stability of the Banking System", Quarterly Journal of Economics 117, 467-502.

[17] Goldstein, Itay and Ady Pauzner (2002), "Demand Deposit Contracts and The Probability of Bank Runs", mimeo.

[18] Haldane, Andrew Simon Hayes, Adrian Penalver, Victoria Saporta and Hyun Song Shin (2002), "Binding-in the Private Sector", unpublished, Bank of England, August. (http://www.bankofengland.co.uk/conferences/conf0207/bindinginps.pdf)

[19] Hellwig, Christian (2002) "Public Information, Private Information and the Multiplicity of Equilibria in Coordination Games" Journal of Economic Theory 107, pp.191-222.

[20] Hovaguimian, Catherine (2003), "The Catalytic Effect of IMF Lending: a Critical Review," No.15. Financial Stability Review, December, Bank of England.

[21] Jeanne, Olivier and Charles Wyplosz (2001) "The International Lender of Last Resort: How Large is Large Enough?" NBER Working Paper 8381, National Bureau of Economic Research.

[22] Jeanne, Olivier and Jeromin Zettelmeyer (2001) "International Bailouts, Moral Hazard, and Conditionality," Economic Policy 16, issue No 33, October.

[23] Martin, Benjamin and Adrian Penalver (2003) "The Effect of Payments Standstills on Yields and the Maturity Structure of International Debt," Bank of England Working Paper No. 184.

[24] Meltzer Commission (2000) Report of the International Financial Institutions Advisory Commission ("Meltzer Commission"), Washington D.C.

[25] Mody, Ashoka and Diego Saravia (2003), “Catalyzing Capital Flows: Do IMF-Supported Programs Work as Commitment Devices?”, IMF Working Paper No. 03/100, May.

[26] Morris, Stephen and Hyun Song Shin (2000) “Global Games: Theory and Applications”, invited paper for the Eighth World Congress of the Econometric Society, Seattle, 2000, http://www.econ.yale.edu/~smorris/seattle.pdf.

[27] Morris, Stephen and Hyun Song Shin (2002), “Social Value of Public Information”, American Economic Review 92.

[28] Morris, Stephen and Hyun Song Shin (2003), “Catalytic Finance: When Does It Work?”, Cowles Foundation Discussion Paper No. 1400, Yale University, February.

[29] Rochet, Jean-Charles and Xavier Vives, (2002), “Coordination Failure and the Lender of Last Resort: Was Bagehot Right After All?”, mimeo.

[30] Roubini, Nouriel (2000) “Bailin, Burden-Sharing, Private Sector Involvement (PSI) in Crisis Resolution and Constructive Engagement of the Private Sector. A Primer: Evolving Definitions, Doctrine, Practice and Case Law,” September 2000. (http://www.stern.nyu.edu/globalmacro/psipaper.pdf).

[31] Roubini, Nouriel and Brad Setser (2004), *Bailouts or Bailins? Responding to Financial Crises in Emerging Economies*, Institute for International Economics, Washington D.C., forthcoming.

[32] Sachs, Jeffrey (1995), “Do We Need an International Lender of Last Resort,” Frank D. Graham Lecture at Princeton University 8, April 20, unpublished manuscript. (http://www.ksg.harvard.edu/cid/ciddirector/publicat.html#Working).

[33] Shin, Hyun Song (2001) “Co-ordination and the Term Structure of Interest Rates for Defaultable Securities”, mimeo, April.

[34] Zettelmeyer, Jeronim (2000) “Can Official Crisis Lending be Counterproductive in the Short-Run?”, Economic Notes, Vol. 29, No.1.