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IMF-Supported Programs and Crisis Prevention: An Analytical Framework

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Abstract

This paper presents an analytical framework for considering the role of IMF-supported programs in preventing crises, particularly capital account crises. The model builds upon the global games framework to establish a unique relationship between the crisis probability and the parameters of the program, which is assumed to be negotiated between the IMF and the member country, taking explicit account of each party's interests. In the model, from the perspective of the borrowing country, IMF financing and policy adjustment are (perfect) substitutes inasmuch as they both contribute to the country's liquidity and thus reduce the likelihood of a crisis. In equilibrium, however, IMF financing promotes stronger policies, implying that financing and adjustment are strong complements in crisis prevention. Conditionality plays a crucial role in sustaining the program, providing mutual assurances—to the member country that, if it undertakes the agreed policies, financing will indeed be forthcoming, and to the IMF that the country will implement the agreed policies as the IMF disburses its resources. The model helps explain how liquidity crises may come about, how IMF support can reduce the likelihood of a crisis by providing liquidity and sustaining stronger policies, and why the observed mix between financing and adjustment may vary across programs.

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Contents Page

I. Introduction

The capital account crises that struck a number of emerging market countries beginning in the early 1990s have proved especially challenging for the design of IMF-supported programs. Although official financing was exceptionally large in many of these cases, the unprecedented reversals of capital flows dwarfed available financing, resulting in severe macroeconomic disruption and underscoring the importance of crisis prevention. While there is a large body of literature on the role of IMF-supported programs in crisis resolution—including their catalytic effects on private capital flows[2]—much less attention has been paid to their role in crisis prevention.

Recent theoretical work has tried to fill this gap. For example, Zettelmeyer (2000) shows that official crisis lending that falls short of covering all potential outflows may help prevent a self-fulfilling run only if a crisis equilibrium existed before IMF support, but in the presence of multiple equilibria can also have counterproductive short-run effects—financing, rather than forestalling, a run.

In contrast, Morris and Shin (2006) and Corsetti, Guimaraes, and Roubini (2004) explicitly model the creditor coordination problem within the framework of global games, allowing for a unique equilibrium. Morris and Shin demonstrates that the catalytic effect of IMF support would be most likely to work and no debtor moral hazard would arise when the economy is weak but not hopelessly so. Corsetti, Guimaraes, and Roubini find very similar results to Morris and Shin that IMF liquidity support has a catalytic effect and can encourage good policy behavior if the probability of a crisis under no policy adjustment is relatively high. The model by Penalver (2004) reaches a similar conclusion regarding the nonlinearity of catalytic effect (with respect to prevailing conditions) but focuses on the effect on debtor adjustment and longer-term capital flows of the subsidized liquidity support by the IMF (provided at below the market rate).

Existing theoretical work, however, is relatively quiet about the interaction between the liquidity support provided by the IMF, the policy adjustment undertaken by the country, and the resulting likelihood of a crisis in which private creditors seek to exit and the country defaults. Because an IMF-supported program is a package of envisaged policies which, combined with approved financing, is expected to achieve certain economic objectives, it is unlikely that these elements will be independent of each other. Moreover, the authorities always have the option of not seeking the support by the IMF for their proposed policies, while the IMF always has the option of deciding not to support the authorities' program if it is not confident that the proposed policies will be sufficient to achieve the intended objectives. The agreed program must therefore

[2] Cottarelli and Giannini (2002) discuss in greater detail five possible channels through which IMF-supported programs can catalyze capital flows and economic performance, and provide a survey of empirical work.

be Pareto-improving for both the member country and the IMF, which imposes constraints on what are feasible programs (in terms of the envisaged adjustment and the associated financing).

In this paper, I develop an analytical framework for considering the design of IMF-supported programs—the optimal mix of adjustment and financing and the role of conditionality—intended explicitly for crisis prevention. The model extends the work of Morris and Shin (2006) by explicitly modeling the preferences of the IMF and the member country, as well as the structure of program negotiation. It departs from the existing global games models of the catalytic role of the IMF in two important respects. First, it considers not only financing but also policy adjustment in the context of program design, allowing for interactions between the two. Second, the model addresses the issue of program ownership by explicitly taking account of the strategic incentives of a member country to renege ex post on an agreed program, including those arising from political considerations. Program conditionality and phased disbursements emerge as natural devices for ensuring incentive compatibility.

The model has a number of important policy implications. First, programmed policy adjustment and financing are complements in program design, although from the perspective of the borrowing country, they are substitutes in crisis prevention. Financing is essential in the sense that, without it, no policy adjustment can be supported beyond the level that would be optimally chosen by the member country with no program. Second, program conditionality is also essential as it enables IMF lending to have an effect on crisis prevention beyond the effects of any unconditional liquidity such as the country's own foreign reserves. Indeed, unconditional liquidity support by the IMF—unless extremely large—would be of limited effect, if not completely ineffective, for crisis prevention because of possible debtor moral hazard whereby the country relaxes its policies because IMF support is available. Third, both policy adjustment and financing generally help lower the crisis probability, but their effects depend on country characteristics and the strength of economic fundamentals. Finally, comparative statics on key parameters of the model shows how the wide range of the mix of financing and adjustment observed across IMF-supported programs can be explained by country characteristics, including its importance as a possible source of contagion.

The paper is organized as follows. Section II presents a basic setup of the model by specifying the informational structure; the objectives of private creditors, the IMF, and a member country; and the structure of program negotiation. Section III derives representative equilibrium solutions of the model by establishing an explicit link between the crisis probability and program design in the context of the global games framework. Section IV undertakes some comparative statics to show how program design may be geared to country-specific characteristics as well as the potential for crisis contagion. Section V summarizes key policy implications of the model, and Section VI concludes.

II. The Model

The model consists of a member country, private creditors who hold the country's short-term debt, and an official creditor such as the IMF. There is a continuum of private creditors whose total mass is normalized to 1. Suppose that, facing liquidity pressures, national authorities formulate an adjustment program for which they seek assistance from the IMF. The program is characterized by the triple (A, L, L_1) where A and L refer to (programmed) policy adjustment and IMF financing, respectively, and L_1 stands for initial disbursement by the IMF (to be discussed later).

The country faces a liquidity constraint, which requires that, at any point in time, the proportion of investors who seek to exit must be less than the country's available liquid assets (its own foreign exchange reserves *R* and IMF financing *L*) plus the current account balance, which is stochastic. Specifically, the country remains liquid and thereby avoids a crisis (or default) only if

$$(1) \qquad x D \le CAB + L + R = \theta + A + L + R \qquad \text{(liquidity condition)}$$

where $x \in [0, 1]$ is the mass of creditors who foreclose, *D* short-term debt on a remaining maturity basis, CAB the current account balance, and *R* the own foreign reserves.[3] The current account balance is assumed to depend on an economic fundamental that is comprised of two components: the stochastic component $\theta \sim N(\phi, 1/\alpha)$ that reflects the underlying current account balance with no policy change, and policy adjustment A. With this specification, policy adjustment, own reserves, and IMF financing are perfect substitutes in terms of meeting the country's liquidity needs: one dollar of IMF lending or foreign exchange reserves can be used to pay off private creditors who want to exit just the same as one dollar earned through a current account surplus.

The IMF is concerned with the solvency of the member country to safeguard its financial resources committed for program financing. Solvency requires:

$$(2) \qquad D \le CAB + R + V(A) = \theta + A + R + (kA + \gamma\phi) \quad k > 0, \ \gamma > 0 \qquad \text{(solvency condition)}$$

where $V(A) = kA + \gamma\phi$ represent the expected present value of future current account balances. The dependence of *V* on *A* may be well justified by the fact that IMF-supported programs typically involve structural measures that have lasting effects on the country's economic fundamental. For given θ, the member country is fundamentally sound if the inequality in (2) holds for $A = 0$.

The liquidity condition (1) indicates that the occurrence of a liquidity crisis depends on the behavior of creditors represented by *x*, which, in turn, would depend on *A* and *L* for given *R*. In order to model the behavior of creditors, we build upon the global games framework developed by Morris and Shin (2006). As is well known, multiple equilibria are common in many models

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[3] Without loss of generality, non-debt-creating capital flows are ignored in the model because the current account balance could be defined broadly to include them. The model also abstracts from long-term debt.

of currency or banking crisis in which the outcome of creditor or depositor coordination is not uniquely pinned down. By assuming noisy information for creditors/depositors, however, the global games framework generates a unique equilibrium solution to the coordination problem. In what follows, short-term debt D is normalized to 1 without loss of generality, and other parameters of the model—such as θ, L, A and R—are accordingly normalized relative to D. We also use the terms "liquidity crisis" and "default" interchangeably.

Creditors

Following Morris and Shin (2006), we assume that θ is not directly observable but each creditor i receives a private signal s_i for θ, which is modeled as $s_i = \theta + \varepsilon_i$ where $\varepsilon_i \sim N(0,\ 1/\beta)$ is identically and independently distributed. The distribution parameters—ϕ, α and β—are public information, implying that the IMF has no informational advantage relative to creditors or the member country with regard to θ.

The creditor who forecloses has an investment opportunity that gives payoff λ where $0 < \lambda < 1$. The creditor who rolls over faces an uncertain payoff. If the country defaults (and a crisis occurs), he gets nothing. Otherwise, his payoff is 1. Denoting the probability of a crisis by $P(A, L)$, the expected payoff of the creditor who rolls over is simply given by $1 - P(A, L)$.

Member Country

The member country wants to minimize the likelihood of a crisis but is assumed to face political or other costs of undertaking adjustment. National authorities must therefore trade off the costs of adjustment against the risks of a crisis. Specifically, the member country's objective is to minimize the expected cost given by

$$(3) \qquad Z(A, L) = P(A, L) \cdot C + h\,A, \quad C > 0, \quad h > 0, \quad h / C \le \sqrt{\alpha / 2\pi}$$

where C is a fixed cost of a crisis, and the term $h\,A$ represents the adjustment cost. The fixed cost of a crisis reflects not only output loss associated with a crisis but also political costs.[4] The adjustment cost parameter $h > 0$ reflects the member country's (political) tolerance for policy

[4] Frankel (2005) finds from a sample of 103 developing countries over the period 1971–2003 that the currency crash doubles the probability of a change in the top political leadership within six months, which is highly statistically significant. He also finds that the finance minister or central bank governor is 63 percent more likely to lose office within 12 months from the currency crash, which is also highly statistically significant.

adjustment.[5] The parameter restriction, $h / C \leq \sqrt{\alpha / 2\pi}$, is introduced to ensure the existence of equilibrium solutions of the model.

The member country must either meet the liquidity pressure by itself or with the help of the IMF, in which case national authorities must negotiate an agreed package of policies and financing from the IMF. In any case, the member country minimizes the expected cost $Z(A, L)$ by choosing A for given L, subject to the constraint that $0 \leq A \leq A^{\max}$ where $A^{\max}$ is the maximum feasible policy adjustment.

The specification of $Z(A, L)$ may be rationalized in the context of optimal reserve holding under adjustment costs. Given costs of acquiring and holding reserves, the country may have a desired level of reserves that trades off these costs against the probability (and associated economic disruption) of a crisis. For instance, suppose that the country determines the optimal level of reserves by minimizing the expected cost given by

$$\tilde{Z}(R) = P(R) \cdot C + \rho R, \quad \rho > 0$$

where $P(R)$ is the probability of a crisis for given R, and ρ is the opportunity cost of holding reserves. At any given moment, however, the country may find itself with a lower level of reserves than desirable, for instance because of a negative shock to the current account and/or an unexpected rise in the world interest rate which makes an exit by creditors more likely.[6] Faced by this situation, the country would want to undertake at least some adjustment but not necessarily enough to fully replenish reserves immediately because of adjustment costs—leaving the country in a state of heightened vulnerability.

The IMF

Like the member country and private creditors, the IMF is also interested in minimizing the likelihood of a crisis, both because of the reputational risk to the IMF's surveillance and because of the risk of cross-country contagion to other members. At the same time, the IMF's

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[5] For simplicity, we assume a linear adjustment cost. Moreover, no explicit account is made of the expected cost of future adjustment needed to repay the IMF in the specification of the country's objective function—effectively making IMF financing L no different from pure grant from the perspective of the country. These simplifying assumptions are not crucial for the main results of the model. See Appendix III for a more general specification of the country's objective function.

[6] As will be shown below, a rise in the risk-free interest rate tends to increase the probability of a crisis (for a given level of reserves), and thus the optimal level of reserves.

own resources are limited. To reflect this resource constraint, we assume that there is a binding upper bound on IMF lending, denoted by $L^{\max}$, which is determined outside the model.

One way to model the IMF's lending decision is to simply assume that IMF lending is exogenously given. More generally, IMF lending can be endogenized by postulating a specific objective function of the IMF. To that end, we assume that the IMF's utility function is given by

$$F(A, L) = \{1 - P(A, L)\} \cdot U - bL, \quad U > 0, \quad b > 0 \tag{4}$$

where U is a fixed payoff that the IMF gets if a member country avoids a crisis, and b represents a unit financing cost which reflects repayment risks, including the risk of repudiation by a program country for political reasons. The first term on the right hand side coincides not only with the interest of the creditor who rolls over but also with the preference of the member country to avoid a costly crisis. In this way, the distributional issues between the member country and creditors can be avoided as much as possible. The IMF maximizes (4) subject to the resource constraint $0 \le L \le L^{\max}$.

Program Negotiation

In principle, program negotiation, i.e., an agreement to the triple (A, L, L_1), could be explicitly modeled as a bargaining game between the member country and the IMF. Although rich in implications, explicit modeling of a bargaining game between the IMF and the member country is beyond the scope of this paper. Instead, therefore, we focus on the set of IMF-supported programs that are Pareto-improving for both parties, i.e., makes the member country and the IMF better off relative to a no-program situation.

In addition, we introduce several assumptions in order to capture the most crucial aspect of IMF-supported programs—conditionality and phased disbursements. Specifically, program disbursement is phased with two tranches so that $L = L_1 + L_2$. The first tranche L_1 is disbursed before any policy adjustment by the member country to signal the IMF's commitment to the agreed program. Moreover, we assume that L_1 must be greater than or equal to $\underline{L}_1 \ge 0$ in order for the IMF's commitment to be credible. Program conditionality states that the second tranche L_2 will be disbursed after, and only if, the member country adjusts by as much as programmed or more.[7]

[7] Implicit in the specification of program conditionality is the assumption that the IMF is fully credible for the enforcement of conditionality. This assumption rules out any possibility of program renegotiation. In reality, however, the IMF may not be fully credible in this regard as indicated by the waiver process.

III. Model Solution

In this section, we solve the model by assuming complete information among the IMF, the member country, and private creditors with regard to their objective functions. To be precise, the timeline of the game is assumed as follows:

- The IMF and the member country enter into program negotiations; the member announces the agreed adjustment, *A*, and the IMF announces the agreed financing *L* and tranching, so that the program may be characterized by the triple (A, L, L_1).
- The first tranche L_1 is disbursed to officially launch the agreed program.
- Observing the announced program and the disbursement of the first tranche, each creditor formulates its switching strategy to roll over or foreclose.
- θ is realized and each creditor observes his private signal $\{s_i\}$.
- Creditors and the member country move simultaneously to effect their respective optimal strategy, followed by the IMF's disbursement of L_2 conditional on whether the member country's policy adjustment meets program conditionality.

This timeline necessitates that the model be solved backward because the optimal program design should take into account the creditors' reaction as well as the member country's strategic incentive. Therefore, we begin by solving the creditors' problem for given *A* and *L*.

Creditors

For tractability of the model, we focus on the limiting case where $\beta \to \infty$ so that the private signal becomes arbitrarily precise.[8] In this limiting case, each creditor faces effectively no informational uncertainty regarding the underlying fundamental θ, but is subject to the highest level of strategic uncertainty regarding the behavior of other creditors. Appendix I derives the unique equilibrium solution of the creditor coordination problem for this limiting case.

In the limiting case with $\beta \to \infty$, the unique equilibrium solution of the creditor coordination problem is characterized by

$$x = \begin{cases} 1 & \text{if } \theta \le \theta^* \\ 0 & \text{otherwise} \end{cases}$$

[8] It is crucial for the unique equilibrium solution of the creditor coordination problem that informational uncertainty—no matter how small—exists regarding θ as assumed in the paper. If θ is public information known to all creditors with certainty, multiple equilibria cannot be ruled out.

where $\theta^* = \lambda - R - (A + L)$ is the default threshold for the current account balance. In equilibrium, therefore, either no creditor rolls over and the member country defaults, or all creditors roll over and the country avoids default.[9]

The probability of a liquidity crisis (and default) in equilibrium is accordingly given by

$$(5) \qquad P(A, L) = \Pr[\theta \le \theta^*] = \Pr[\theta \le \lambda - R - (A + L)] = \Phi\left(\sqrt{\alpha}\{(\lambda - \phi) - (R + A + L)\}\right)$$

where Φ is the cumulative distribution function of the standard normal. The monotonocity of Φ ensures that $P(A, L)$ is uniquely determined by the sum of policy adjustment and financing.

Member country

The member country minimizes the expected cost $Z(A, L)$ taking into account the crisis probability given by (5), as well as program conditionality. To begin with, we first construct the optimal response of the member country when the IMF provides unconditional liquidity support, which would also describe the optimal response under no program but with the same amount of foreign reserves as IMF financing. As discussed below, this exercise provides an important insight on the strategic consideration of the member country to decide first whether to enter into a program and then whether to adjust as programmed once program is put into effect.

Appendix II discusses in greater detail the derivation of the member country's optimal response for given unconditional IMF support of L. Specifically, the member country's optimal choice of A with no program conditionality is given by:

$$(6) \qquad \hat{A}(L) = \begin{cases} \bar{A} - R - L & \text{for } 0 \le L \le \bar{A} - R \\ 0 & \text{otherwise} \end{cases}$$

where

$$\bar{A} = (\lambda - \phi) + \kappa, \quad \kappa = \sqrt{-\frac{2}{\alpha}\ln\left(\frac{h/C}{\sqrt{\alpha/2\pi}}\right)} > 0$$

Inspection of (6) shows that adjustment and IMF financing (and own foreign reserves) are substitutes in crisis prevention *from the perspective of the member country*. Since the country seeks to minimize the likelihood of a crisis (given the costs of adjustment), and a dollar earned through adjustment or obtained through financing has the same effect on the country's liquidity position, financing and adjustment will, in general, be substitutes in crisis prevention. They are

[9] The binary nature of the equilibrium solution suggests that herd behavior of creditors may be justified as optimal. In a more general case with $\beta < \infty$, however, x will remain between 0 and 1 in equilibrium (see Appendix I).

perfect substitutes in the model because the adjustment cost is assumed to be linear.[10] Therefore, for every dollar of (unconditional) liquidity the country obtains, it reduces its adjustment by a corresponding amount.

Since the probability of a crisis depends upon the sum of liquidity and adjustment as shown in (5), more unconditional official lending or foreign exchange reserves cannot, in themselves, reduce the likelihood of a crisis—as they are offset by lower adjustment—unless they are large enough to exceed $\overline{A} - R$. Assuming $L \leq \overline{A} - R$ and denoting by $P(\overline{A} - R)$ the crisis probability for $\hat{A}(L) + L = \overline{A} - R$, the member country's expected cost is given by

$$Z(\overline{A} - R - L, L) = P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R - L)$$

Now we construct the member country's expected cost for two benchmark cases, which form a basis for the decision to enter into a program, as well as for the decision to keep the program on track once launched. First, the member country may opt for no program at the outset. Since $L = 0$ in this case, the resulting expected cost is simply given by

$$Z(\overline{A} - R, 0) = P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R)$$

Second, the member country may enter into a program but strategically renege after receiving the first tranche L_1. In this case, the second tranche L_2 would not be disbursed according to the assumed program conditionality, and hence, $L = L_1$. When the program goes off-track, the optimal choice of policy adjustment would still be characterized by (6) with $L = L_1$. Therefore, the resulting expected cost can be expressed as:

$$Z(\overline{A} - R - L_1, L_1) = P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R - L_1)$$

The member country would enter into a program in the first place only if

$$Z(A, L) \;\leq\; Z(\overline{A} - R, 0)\,.$$

This is an ex ante incentive-compatibility condition that the member country should be no worse off by seeking assistance from the IMF. Once entered into a program, the member country would implement the agreed policy adjustment in full only if:

[10] In general, the offset would be less than perfect and unconditional liquidity would have some effects on reducing the probability of a crisis. In fact, even a negative offset cannot be ruled out a priori if adjustment cost is convex, although this case is of little practical relevance. As will be shown below, however, key insights of the model regarding the role of conditionality remain unaltered regardless of the extent of the offset. See Appendix III for further discussion.

$$Z(A, L) \leq Z(\bar{A} - R - L_1, L_1)$$

This is an ex post incentive-compatibility condition that the member country should be no worse off by carrying out the programmed policy adjustment.

Since $Z(\bar{A} - R - L_1, L_1) \leq Z(\bar{A} - R, 0)$ for $L_1 \geq 0$ where the equality holds for $L_1 = 0$, the ex post condition is always more stringent than the ex ante condition suggesting that the latter can be ignored unless the member country is committed to adjust in full as programmed. Appendix II shows that the ex post incentive-compatibility condition can be reformulated to yield:

$$A \leq \tilde{A}(L) \tag{7}$$

where $\tilde{A}(L)$, defined for $L \geq L_1$, represents the country's indifference (iso-cost) curve associated with $Z(\bar{A} - R - L_1, L_1)$, which also constitutes an upper bound of the programmed policy adjustment that can be supported in equilibrium for given IMF lending *L*. Appendix II shows that $\tilde{A}(L)$ is upward sloping and concave in *L*, converges to a finite level beyond $\bar{A} - R$ as $L \to \infty$, and shifts to the right and downward along the iso-probability line $\hat{A}(L)$ as L_1 increases.

The IMF

The IMF's optimization is subject to several constraints, some of which are related to the nature of program negotiation. First, since the IMF has the option not to support the authorities' program, the incentive-compatibility constraint for the IMF implies:

$$F(A, L) \geq F(\bar{A} - R, 0) = (1 - P(\bar{A} - R)) \cdot U$$

where $F(\bar{A} - R, 0)$ is the expected utility of the IMF under no program given the optimal response of the member country. This ex ante incentive-compatibility condition for the IMF can be reformulated to yield:

$$A \geq A^F(L) \tag{8}$$

where $A^F(L)$ is the IMF's indifference curve associated with $F(\bar{A} - R, 0)$, and constitutes a lower bound of the programmed policy adjustment that can be supported in equilibrium for given IMF lending *L*. $A^F(L)$ is upward sloping and convex in *L* if $h / C \leq b / U$.[11]

[11] Appendix II discusses in greater detail how the shape of the IMF's indifference curve would change depending on the parameter values of *b*/*U* and *h*/*C* , as well as *A* and *L*.

Second, at the time of program design, the IMF must be reasonably assured of the member country's post-program solvency. Given the stochastic nature of the country's fundamental θ, crises do occur in the model even under an IMF-supported program, and thus solvency cannot be guaranteed for all possible states. For this reason, we assume that the IMF would support a program only if solvency is assured at least for the case in which there is no liquidity crisis. This requires that the solvency condition (2) should hold for all $\theta \geq \theta^*$.

By replacing θ by $\theta^* = \lambda - R - (A + L)$ in (2), the solvency condition can be rewritten to yield

(9) $$A \geq A^S(L) = \frac{1}{k}L + \frac{1}{k}(1 - \gamma\phi - \lambda)$$

This solvency constraint is less likely to be binding, the stronger the member's economic fundamentals. Larger IMF lending helps the member country avoid default for larger current account deficits. At the same time, however, solvency would be undermined because larger current account deficits increase the country's indebtedness. At the margin, therefore, policy adjustment needs to be strengthened to maintain solvency when L increases, as indicated by the positive slope of $A^S(L)$.

Third, since program implementation is carried out by the country, the ex post incentive-compatibility condition (7) must hold . Finally, the inspection of (7) and (8) suggests that any program can be arranged through voluntary program negotiation only if $A^F(L) \geq \tilde{A}(L)$. Appendix II shows that this condition can be reduced to the following inequality:

$$L_1 \leq \overline{L}_1$$

where $\overline{L}_1$ is the upper limit for L_1 beyond which no program can be arranged voluntarily.

Collecting all these constraints, the optimization problem of the IMF can be specified as follows:

$$\underset{L, L_1}{Max} \;\; F(A, L) = \{1 - P(A, L)\} \cdot U - bL$$
$$\textit{subject to} \;\; \underline{L}_1 \leq L_1 \leq \overline{L} \leq L \leq L^{\max}, \; A \leq A^{\max}, \; (7), \; (8), \text{ and } (9)$$

The optimal mix of policy adjustment and financing can be identified from the solution of the IMF's optimization problem.

Equilibrium solutions of the model

1. Exogenous IMF Lending

Before discussing the solutions of the IMF's optimization problem, we first present a simple partial equilibrium solution of the model by treating IMF lending as exogenously given. This exercise, albeit simple, generates key insights of the model regarding the role of conditionality and IMF lending in crisis prevention, implying that the model's implications do not depend on particular specification of the IMF's objective function.

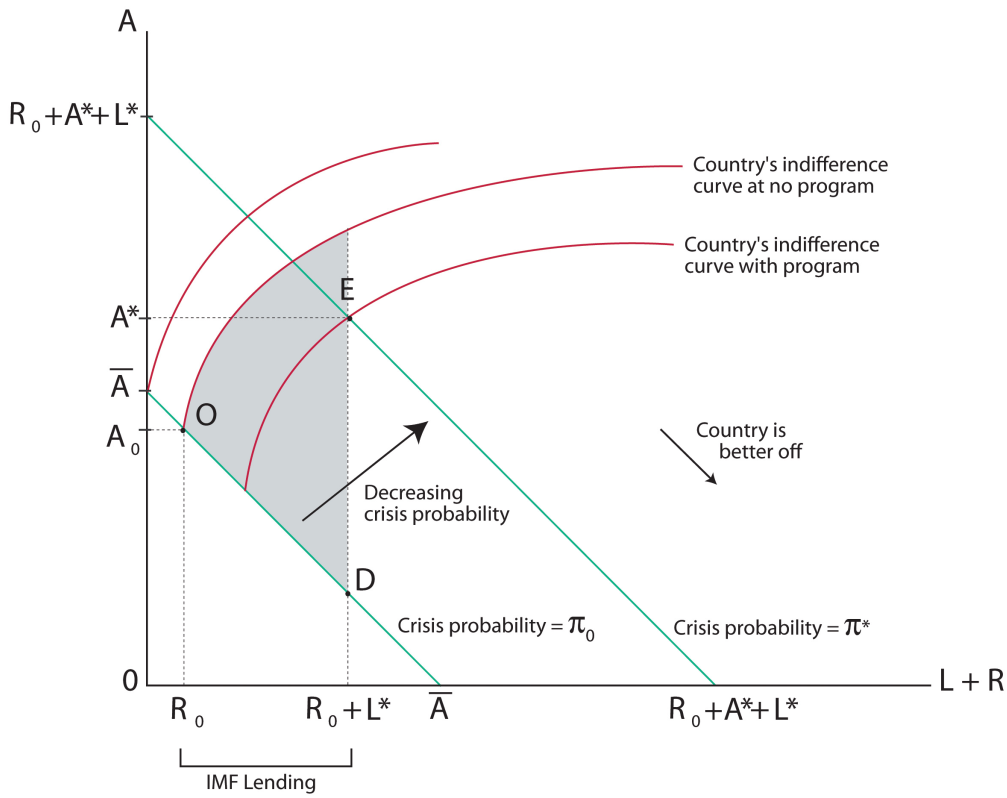
Figure 1 depicts the determination of the country's adjustment for exogenously given IMF lending when the country's initial foreign reserves R_0 and IMF lending L^* are not too large so that $R_0 + L^* < \overline{A}$ where $\overline{A}$ is as defined in (6). The straight line $\overline{AA}$ represents the country's optimal response function $\hat{A}(L) = \overline{A} - R_0 - L$ shown in (6), which is also an iso-probability line. At no program (point O), the country's optimal adjustment is given by $A = A_0$. Given this adjustment, the country's total liquidity $(A + L + R_0)$—the sum of own reserves, adjustment, and IMF lending—equals $A_0 + R_0 = \overline{A}$, resulting in the probability of a crisis given by $\pi_0 = P(\overline{A} - R_0)$.

Suppose first that L^* is provided *unconditionally*. This will immediately increase the country's reserves by an equal amount. However, the country will reduce adjustment effort (starting from A_0) along the line $\overline{AA}$ until the liquidity effect of IMF lending L^* is fully offset by weaker adjustment (point D). Since the offset is perfect (due to the assumed linear adjustment costs), unconditional IMF support results in no change in total liquidity and thus no change in the probability of a crisis. Therefore, with unconditional IMF support, $\partial A / \partial L = -1$, $\partial(A + L + R) / \partial L = 0$, and $\partial P / \partial L = 0$.[12]

Now consider conditional IMF lending. Since the country benefits from a lower probability of a crisis but faces costs of undertaking adjustments, its indifference (iso-cost) curves are upward sloping and concave in IMF lending as depicted in Figure 1. Along the indifference curve, a lower likelihood of a crisis—an outward shift of the iso-probability line—compensates for the costs of greater adjustment. Moreover, the indifference curves are pointing toward southeast since the country is better off with more liquidity but less adjustment. Accordingly, the shaded area, which lies below the country's indifference curve with no program but above the iso-probability line $\overline{AA}$, denotes the set of IMF-supported programs that are Pareto-improving for both the country and the IMF.

[12] The offset would in general be less than perfect (i.e., $-1 < \partial A / \partial L < 0$) if, for instance, adjustment costs are convex and/or future adjustment burden required to repay the IMF is explicitly taken into account. See Appendix III for further discussion.

Figure 1. IMF-Supported Program in Crisis Prevention: Exogenous IMF Lending



The equilibrium solution given by point E, for example, is achievable by making IMF support conditional on adjustment, which entails adjustment A^* that is strictly larger than A_0 (i.e., $\partial A/\partial L > 0$). Consequently, the country's total liquidity increases from $\bar{A}$ to $(R_0 + A^* + L^*)$ under the IMF-supported program at point E, leading to a correspondingly lower likelihood of a crisis, $\pi^* = P(A^*, L^*) < \pi_0$. Note that total liquidity increases by more than L^* since $A^* > A_0$. With conditional IMF lending, therefore, $\partial A/\partial L > 0$, $\partial(A + L + R)/\partial L > 1$, and $\partial P/\partial L < 0$. The comparison between the two solutions with and without conditionality reveals that program conditionality creates the complementarity between policy adjustment and financing (as indicated by $\partial A/\partial L > 0$ under conditional IMF support), which are substitutes in crisis prevention from the perspective of the member country. It also suggests that program conditionality is crucial for containing the risk of debtor moral hazard, which is likely to be greater in crisis prevention than in crisis resolution situations.[13]

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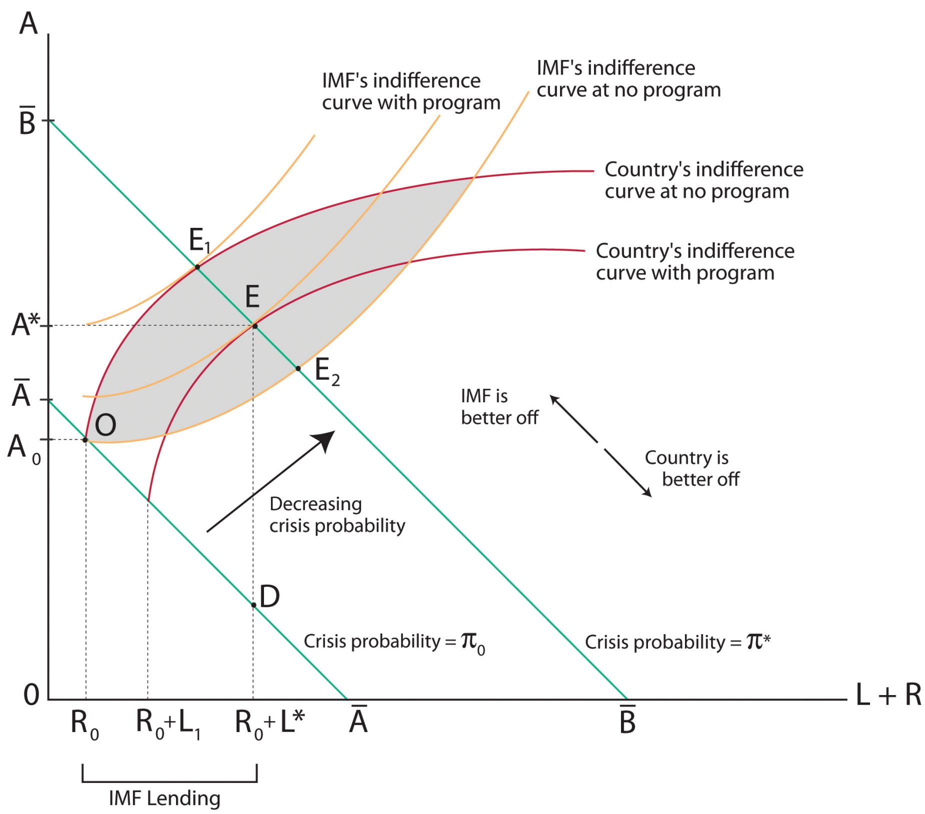
[13] In a typical capital account crisis (once it has erupted), the degree of external adjustment is often determined residually, given the withdrawal of private financing and the availability of

(continued…)

Figure 2. IMF-Supported Program in Crisis Prevention: Endogenous IMF Lending



2. Endogenous IMF Lending

These key insights of the model carry over when the IMF lending decision is endogenized. To see this, we focus on interior solutions of the IMF's optimization problem in which neither the resource constraint of the IMF nor the solvency constraint (9) is binding. For ease of exposition and without loss of generality, we assume that $b/U \geq \sqrt{\alpha/2\pi}$ so that the IMF's indifference curve is upward sloping.

Appendix II derives fully specified interior solutions in which IMF lending is determined endogenously. Key features of interior solutions are characterized by

$$A^* + L^* + R = \bar{B} > \bar{A}, \quad A^* \geq A_0, \quad \text{and} \quad \partial A^* / \partial L_1 < 0 \tag{10}$$

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official financing (see Ghosh and others, 2002). In crisis prevention situations, by contrast, since private financing has not withdrawn, national authorities have greater latitude in determining how much adjustment to undertake.

where $A_0 = \bar{A} - R$ represents the country's optimal adjustment with no program, and $\bar{B}$ is given by

$$\bar{B} = (\lambda - \phi) + \delta \; > \; \bar{A}, \quad \delta = \left\{ -\frac{2}{\alpha} \ln \left\{ \left(\frac{h/C}{\sqrt{\alpha / 2\pi}} \right) \cdot \left(\frac{b/U}{h/C + b/U} \right) \right\} \right\}^{1/2}$$

According to (10), all interior solutions with endogenously determined IMF lending are associated with the same level of total liquidity and, hence, the same crisis probability. Because $\bar{B} > \bar{A}$, it immediately follows that the crisis probability implied by interior solutions, denoted by $P(A^*, L^*) = P(\bar{B} - R)$, is strictly smaller than the crisis probability with no program. Moreover, programmed adjustment is always stronger than what the country would choose under no program. Finally, the optimal mix of adjustment and financing in IMF-supported programs depends on the extent of front-loading of program disbursements—adjustment is weaker and financing is larger for a more front-loaded program. This last result arises from the fact that the ex post incentive-compatibility condition for the country becomes more stringent as L_1 increases.

These features of interior solutions constitute the central prediction of the model. Intuitively, the member country prefers to achieve a given reduction in the likelihood of a crisis by obtaining more IMF financing rather than through costly adjustment. From the IMF's perspective, the same reduction in the likelihood of a crisis is better achieved through adjustment than by risking IMF resources through lending. As both the member country and the IMF would like to reduce the probability of a crisis (albeit with different preferences on how to do so), the Pareto-improving outcome is a program in which the member country does more adjustment and obtains more liquidity (because of IMF lending), both of which contribute to a lower likelihood of a crisis relative to a no-program situation.

Program conditionality plays a crucial role in providing mutual assurances. Since the member country would not choose to undertake (as much) adjustment without the benefit (in terms of the lower risk of a crisis) of IMF financing, it requires the assurance that the disbursements will be forthcoming as long as the agreed policies are implemented. By the same token, the IMF requires assurances that the country will indeed undertake the agreed adjustment as it disburses its resources.

Figure 2 illustrates the determination of the optimal mix of adjustment and financing in IMF-supported programs when IMF lending is endogenous. The IMF's indifference curves are upward sloping and convex, and point toward northwest. With no program (point O), the country's optimal adjustment for given reserves R_0 is given by A_0 and the associated probability of a crisis is $\pi_0 = P(\bar{A} - R_0)$. The shaded area (lens) represents the set of IMF-supported programs that are Pareto-improving for both the country and the IMF. Clearly, the area lies above the iso-probability line $\overline{A}\overline{A}$, implying that the likelihood of a liquidity crisis is lower with IMF-supported programs than with no program.

As in Figure 1, unconditional IMF support of L^* will lead to debtor moral hazard as the country reduces the adjustment effort along the line $\overline{A}\overline{A}$ until point D is reached. In contrast, conditional IMF lending induces stronger adjustment by the country and thus lowers the probability of a crisis. All interior solutions lie on the iso-probability line $\overline{B}\overline{B}$ between E_1 and E_2. Within the line segment E_1E_2, the extent of front-loading L_1 will determine the optimal mix of adjustment and financing. The equilibrium solution approaches E_2 as L_1 increases toward its upper limit $\overline{L}_1$. A typical interior solution would be represented by point E, which is characterized by policy adjustment $A^* > A_0$ supported by IMF lending L^*, and the crisis probability $\pi^* = P(\overline{B} - R_0)$ that is strictly lower than π_0.

Catalytic effect of IMF support for crisis prevention

The catalytic effect of IMF support, which lies at the center of the discussion on capital account crisis programs, is typically understood to mean a multiplier effect of official on private capital inflows so that, for each dollar of IMF support, the country receives more than one dollar in total inflows. Here, we focus on the impact of IMF support on crisis prevention—which can be considered a form of catalytic effect inasmuch as a dollar of IMF lending leads to more than a dollar of *net* capital inflows (relative to the counterfactual in which there was a crisis) by helping to prevent a crisis from erupting in the first place. Specifically, we define a catalytic effect of IMF support in crisis prevention to be present if:

$$\frac{\partial Ex}{\partial A} < 0 \quad \text{and} \quad \frac{\partial Ex}{\partial L} < 0$$

where Ex represents the ex ante expected value of *x*, or equivalently, the *expected* volume of net capital outflows.[14]

$Ex = P(A, L)$ in equilibrium, and so it immediately follows from (5) that $\partial Ex / \partial A < 0$ and $\partial Ex / \partial L < 0$. More explicitly, the catalytic effect of an IMF-supported program in crisis prevention can be gauged by the reduction in the probability of a crisis engendered by IMF support, which is denoted by $\Delta P = P(\overline{A} - R) - P(A, L)$. By this metric, an IMF-supported

[14] We focus on Ex instead of actual net outflows *x*, since *x* is state contingent and takes either 0 or 1 in equilibrium. In a more general case with $\beta < \infty$, the catalytic effect of the IMF-supported program could be defined in terms of *x*, which is a smooth logit function of *A* and *L*.

program is catalytic if ΔP is positive. The specification of interior solutions shown in (10) clearly points to such a catalytic effect since $\Delta P = P(\overline{A} - R) - P(\overline{B} - R) > 0$.

What factors would affect the catalytic effect of IMF support on crisis prevention? The expressions for $\overline{A}$ and $\overline{B}$ shown in (6) and (10) suggest the following results:

$$\frac{\partial \Delta P}{\partial (h/C)} > 0, \quad \frac{\partial \Delta P}{\partial (b/U)} < 0, \quad \text{and} \quad \frac{\partial \Delta P}{\partial \phi} = 0$$

The first result indicates that other things being equal, the program is more likely to be catalytic when arranged for countries with weaker tolerance for policy adjustment. Intuitively, the crisis probability under no program would be high for intolerant countries which would adjust little in the absence of the program (i.e., $\overline{A}$ is small). The program helps reduce the crisis probability significantly starting from an already high level.[15] The second result suggests that the more the IMF cares about crisis prevention, the larger the catalytic effect of the program. This is because the IMF would be more willing to increase the *total size* of the program, which is defined as $A + L$, by providing larger financing.

The final result implies that the catalytic effect is invariant to the member country's economic fundamental. The member country optimally adjusts to keep the crisis probability constant even under no program, and so any deterioration in the average fundamental is fully offset by correspondingly stronger adjustment. The same reasoning applies to the design of IMF-supported programs, suggesting no impact of ϕ on ΔP at the margin.

However, this invariance property should be qualified because it critically depends on the assumption that the adjustment cost is linear, and because it holds only for interior solutions in which neither the solvency constraint nor the resource constraint is binding. In general, the catalytic effect of an IMF-supported program would depend on the country's economic fundamentals, and would tend to diminish if program design is constrained by concerns on solvency. For instance, it can be easily proven that, for given A and L, $\Delta P \to 0$ and $\partial \Delta P / \partial A = \partial \Delta P / \partial L \to 0$ when $\phi \to \pm\infty$. In fact, no equilibrium solution exists for the model if the member country's economic fundamental is very poor ($\phi \to -\infty$).[16] In this case, the IMF

[15] The normality of θ is critical for this result. If θ is uniformly distributed, the catalytic effect would be invariant to h/C under interior solutions so that $\partial \Delta P / \partial (h/C) = 0$.

[16] The solvency constraint $A^S(L)$ will lie above the iso-cost curve $\tilde{A}(L)$ everywhere when $\phi \to -\infty$. Note that both the iso-cost curve and the solvency constraint shift upward as ϕ decreases, but the iso-cost curve will eventually be bounded from above due to the feasibility constraint ($A \leq A^{\max}$) while there is no such upper bound for $A^S(L)$.

would not intervene because the member country will almost surely default, and debt restructuring is necessary to restore solvency.

In the opposite case, where the member country's fundamental is very strong ($\phi \rightarrow +\infty$), not only ΔP but the crisis probability itself would converge to 0 for any finite A and L. In both limiting cases, therefore, IMF-supported programs would play little catalytic role in staving off financial crises. Consequently, the catalytic effect of the program for crisis prevention is most likely to be at work when the member country's economic fundamental is in an intermediate range.

It may be useful to distinguish between the policy channel and the lending channel in assessing the catalytic effect of IMF-supported programs in crisis prevention.[17] To this end, ΔP can be decomposed as:

$$\Delta P = \Delta P(A - \overline{A}) + \Delta P(L)$$

where the first term on the right-hand side refers to the policy channel that arises from programmed policy adjustment beyond the level to be chosen by the member country under no program, and the second term stands for the lending channel. Obviously, program design—the mix of policy adjustment and financing—directly affects the relative contribution of the policy channel as well as the average catalytic effect per unit of financing ($\Delta P / L$).

However, the distinction between the policy and lending channels, albeit operationally sensible, is blurred in the context of the model because adjustment and IMF lending are not independent of each other. IMF lending is essential in the sense that, with no lending, no adjustment can be supported in equilibrium beyond the level to be chosen by the member country under no program, and no catalytic effect can be obtained since $\Delta P = 0$ for $L = 0$ by construction. Program conditionality is equally essential to the catalytic effect of IMF-supported programs in crisis prevention because unconditional IMF support would have no catalytic effect due to possible debtor moral hazard. The role of program conditionality in this regard may be gauged by the vertical distance between point E and point D in Figures 1 and 2. Since it is increasing in L, conditionality contributes more to the catalytic effect in a program with larger financing.

IV. Comparative Statics

Before turning to the implications of the model, it is useful to examine how the interior solutions of the model change when the model's key parameters vary. To that end, comparative statics are undertaken for interior solutions with endogenous IMF lending with respect to three parameters of interest: the country's (average) economic fundamental ϕ and (political) tolerance for adjustment h / C, as well as the IMF's preference b / U.

[17] Hovaguimian (2003) makes similar distinction between the policy and lending channels in discussing the catalytic effect of IMF-supported programs.

Economic fundamental—ϕ

By using the fully specified interior solutions shown in Appendix II, it can be shown that

$$\partial A^* / \partial \phi = -1 \ < \ 0, \quad \partial L^* / \partial \phi = 0, \quad \partial P(A^*, L^*) / \partial \phi = 0$$

where asterisk denotes interior solutions of the model. The amount of IMF lending is at the margin invariant to the country's economic fundamental, whereas programmed adjustment varies one-for-one in the opposite direction. This result suggests that IMF-supported programs would envisage stronger adjustment for countries with weaker economic fundamental but not necessarily larger or smaller financing. The probability of a crisis remains unaltered as programmed adjustment counters in full the effect of the country's economic fundamental on the crisis probability.[18]

Tolerance for policy adjustment—h / C

The cost parameter h / C affects not only the position of the country's indifference curve but also its slope. The results of comparative statics with respect to h / C are given by,

$$\partial A^* / \partial (h / C) \ < \ 0, \quad \partial L^* / \partial (h / C) \ > \ 0, \quad \partial P(A^*, L^*) / \partial (h / C) \ > \ 0$$

Therefore, the less (more) tolerant the country is for adjustment, the weaker (stronger) is programmed adjustment and the larger (smaller) is IMF lending. The probability of a crisis is higher for a less tolerant country as the total size of program, defined by $A + L$, is smaller (i.e., $\partial (A^* + L^*) / \partial (h / C) \ < 0)$.

The IMF's preference—b / U

The IMF's preference parameter b / U affects the slope of the IMF's indifference curve. The IMF would be particularly concerned about a crisis (or program failure) if the member country is large in the sense that its potential for being a source of contagion is significant. In this case, b / U would be small. If the growing trend of financial globalization were to increase the risk of cross-country contagion, b / U would be expected to decline over time and remain relatively small for an increasingly larger set of countries with market access.

The results of comparative statics with respect to b / U are summarized as follows:

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[18] Appendix II shows that the crisis probability associated with interior solutions is given by $P(\overline{B} - R) = \Phi(-\sqrt{\alpha} \cdot \delta)$, which does not depend on ϕ.

$$\partial A^* / \partial(b/U) \ < \ 0, \quad \partial L^* / \partial(b/U) \ < \ 0, \quad \partial P(A^*, L^*) / \partial(b/U) \ > \ 0$$

According to these results, IMF-supported programs would envisage stronger adjustment supported by larger financing for countries with significant potential for being a source of crisis contagion. Therefore, the probability of a crisis implied by such programs would also be lower than otherwise.

Combined comparative statics—h/C and b/U

The results of comparative statics for individual parameters may usefully be combined to help explain the wide spectrum of IMF-supported programs in crisis prevention. For instance, suppose that two countries A and B are identical in every respect except for b/U and h/C: country A is larger but less tolerant for adjustment than country B so that $(b/U)_A < (b/U)_B$ and $(h/C)_A > (h/C)_B$. In this case, it is possible that the IMF-supported program for country A envisages weaker adjustment but nonetheless larger financing than that for country B.

V. Key Implications of the Model

In this section, we summarize the main features of the model, and discuss several testable implications that are broadly consistent with empirical findings.

First, the model can be used to explain how a capital account crisis could be triggered in the first place. Two potential trigger mechanisms, in addition to adverse shocks to the economic fundamental, could be identified from the model. The first mechanism is related to the unwinding of the "push" factor of capital inflows into emerging market countries. There is ample empirical evidence that emerging market crises have often been preceded by a rise in the world interest rate from a very low level that caused a surge in capital inflows in the first place. One may think of λ—the payoff to the creditor who forecloses—as representing the world risk-free interest rate. The model implies that the (expected) volume of net capital outflows and the probability of a crisis increase as λ rises, predicting that a rise in the world interest rate would likely increase capital outflows from emerging market countries.

The second mechanism relies on political uncertainty. In this regard, a crisis (or a near crisis) triggered by growing uncertainty surrounding the outcome of an election would be a case in point. One may view a political regime shift as a change in the parameter h/C. Under this view, a capital account crisis could be triggered by a regime shift that accompanies a discrete change in h/C (e.g., the inception of a new government with low tolerance for policy adjustment). According to the model, when a weak government is expected to come into office, creditors would reduce their exposure as they expect weaker policy adjustment.

The model also suggests that the size of short-term debt would matter for both trigger mechanisms. For given increases in the interest rate or adjustment costs, an increase in short-term debt would lead to a more-than-proportionate increase in the expected volume of net capital outflows in absolute dollar amount, making the IMF's resource constraint more likely to be binding in equilibrium. As a result, the country's vulnerability to crisis would increase at an increasing rate as short-term debt increases, and may help explain the relatively low debt tolerance of developing countries with market access.[19]

Second, the model implies that IMF financing, the country's policy adjustment, and the program conditionality required to enforce it are all complements in programs intended for crisis prevention with stronger policy adjustment being supported by larger financing.[20] As a result, IMF financing helps close the financing gap not only directly but also indirectly by reducing the (expected) volume of net capital outflows and supporting stronger policy adjustment. This feature of the model indicates that the IMF has an effective leverage for supporting stronger policy adjustment than otherwise, and thus ensuring a stronger post-program economic fundamental, which would benefit both the member country and the IMF.

As a corollary, both policy adjustment and IMF financing are essential for the IMF to contribute to crisis prevention. With no lending, no policy adjustment can be supported in equilibrium beyond the level to be chosen by the member country at no program. At the same time, unconditional IMF lending—unless extremely large—would have only limited or no effect on reducing the crisis probability as it is offset by weaker policy adjustment. This argument applies equally to precautionary arrangements because the insurance value of IMF access supports programmed policy adjustment even though no resources are expected to be drawn.

Third, the model shares with Morris and Shin (2006) and Bordo, Mody, and Oomes (2004) the implication that IMF support is most likely to be effective for crisis prevention when the member country's economic fundamental is weak but not hopelessly so. The model also implies that IMF support would have greater impact on lowering the likelihood of a crisis when the country faces particularly high costs of adjustment—for instance in the run-up to an election.

Fourth, the model provides sound rationale for phased disbursements combined with program conditionality. IMF disbursements conditioned on adjustment not only help safeguard IMF resources but also ensure program ownership by the member country. Program ownership is determined endogenously in the model, rather than exogenously assumed, on account of the

[19] Reinhart, Rogoff, and Savastano (2003) find that the risk of credit events starts to increase significantly when external debt exceeds 30 to 35 percent of GNP in a debt-intolerant country. IMF (2002) finds a benchmark threshold for external debt of 40 to 60 percent of GDP, above which the conditional probability of a debt crisis increases significantly.

[20] The complementarity of adjustment and financing implied by the model would be detected empirically in a cross-section of IMF-supported programs only if country characteristics are appropriately controlled for. Indeed, the results of comparative statics in Section IV suggest that adjustment and financing could be negatively correlated across IMF-supported programs without any control for country characteristics.

incentive compatibility conditions. Therefore, program design is constrained in terms of the mix of policy adjustment and financing.

Fifth, by explicitly modeling the preference of the member country and the IMF, the model is also able to shed light on how program ownership interacts with program success. It has often been argued that the catalytic effect of an IMF-supported program may arise from its role as a commitment device for good policy implementation supported by program conditionality.[21] According to the model, however, the mere presence of a program would not by itself render credibility to the country's commitment to policy adjustment. Rather, the credibility of policy adjustment is ensured by properly addressing the strategic incentives of the member country to renege ex post.

Finally, the model is capable of explaining the wide spectrum of the mix of policy adjustment and financing in a cross-section of IMF-supported programs by referring to country-characteristics and the IMF's preferences. The model suggests that programs for countries with significant potential for being a source of crisis contagion, high tolerance for adjustment and high costs of a crisis would envisage strong policy adjustment supported by large financing. As a result, for given realization of the underlying shock, such programs would likely be characterized by sizable current account adjustments owing to strong policy adjustment.

VI. Concluding Remarks

This paper presents a simple analytical framework for considering the role of IMF support in crisis prevention. By using the global game framework, the model establishes an analytically tractable link between program design and the (expected) volume of net private capital outflows and the associated probability of a crisis. This distinguishing feature of the model generates several testable implications of policy importantce, including when and how IMF support would be effective for crisis prevention, how the mix of policy adjustment and financing are determined, how conditionality sustains the agreed package of financing and adjustment, and how the parameters of IMF-supported programs may be expected to reflect country-specific characteristics, including political factors and the potential for crisis contagion.

The model can be usefully extended in several dimensions, including by incorporating incomplete information. Clearly, the model as it stands precludes any policy slippages or policy adjustment in excess of program expectation since the incentive compatibility conditions under complete information ensure full program ownership by the member country. Complete information also precludes at the outset any signaling role of IMF-supported programs. If extended to incorporate incomplete information with regard to the member country's political tolerance for policy adjustment, however, policy slippages emerge as a separating equilibrium

[21] See Marchesi and Thomas (1999), Dhonte (1997), and Fischer (1997). For other channels of catalytic effect of IMF-supported programs, see Cottarelli and Giannini (2002) and the references therein.

solution.[22] The model also generates richer implications for the signaling role of IMF-supported programs. For instance, if the IMF finds during program negotiation that the member country is politically committed to implement strong policies, the IMF has an incentive to front load its financial assistance for signaling purposes.

Another useful extension of the model would be to allow a more realistic timeline regarding the creditor's action and the country's adjustment. The model abstracts from the issue of time-to-adjust by assuming an instantaneous policy adjustment, but in reality policy adjustment takes longer than the time frame over which creditors take action. In the context of the model, the creditors who roll over their claims may face additional uncertainty with regard to whether the member country would adjust as programmed if policy adjustment were to take place over time. Such uncertainty would then affect the nature of equilibrium solutions in a complex way, a full treatment of which is beyond the scope of this paper. [23]

[22] Preliminary results for incomplete information are available upon request.

[23] A plausible conjecture would be that larger and more front-loaded financing would be required to support a given level of policy adjustment if policy adjustment takes places over time.

Equilibrium Solution of the Creditor Coordination Problem

This appendix derives the unique solution of the creditor coordination problem by applying the global game framework of Morris and Shin (2006).

Given the assumed information structure of the model, creditors update their belief on θ in a Bayesian fashion. When creditor *i* observes the realization of the signal $s_i = \theta + \varepsilon_i$, her posterior distribution of θ is normal with mean $\hat{\theta}_i$ and variance $1/(\alpha+\beta)$, where $\hat{\theta}_i$ is given by

$$\hat{\theta}_i = \psi\phi + (1-\psi)s_i, \quad \psi = \alpha/(\alpha+\beta)$$

If creditors use a switching strategy, they have a threshold level ξ (the switching point) such that they foreclose if and only if their updated estimate $\hat{\theta}_i$ is smaller than ξ, and roll over otherwise. This threshold ξ translates into another threshold for the observed signal s_i given by,

(A.I.1) $$\hat{\theta}_i \leq \xi \quad \Leftrightarrow \quad s_i \leq \bar{s} = (1-\psi)^{-1}(\xi - \psi\phi)$$

Let us denote by θ^* the critical state of θ below which the member country becomes illiquid and defaults. From (1), θ^* is determined by $x = \theta^* + A + L$. Since the incidence of creditors' foreclosure x is determined by the mass of creditors who have received a signal below the threshold $\bar{s}$, $x = \Phi\left(\sqrt{\beta}(\bar{s} - \theta^*)\right)$ where $\Phi(\cdot)$ stands for the cumulative distribution function for the standard normal. This leads to the first equilibrium condition in terms of ξ and θ^* given by,

(A.I.2)
$$\begin{aligned} \theta^* + R + A + L &= \Phi\left(\beta^{1/2}(\bar{s} - \theta^*)\right) \\ &= \Phi\left(\beta^{1/2}\left\{(1-\psi)^{-1}(\xi - \psi\phi) - \theta^*\right\}\right) \\ &= \Phi\left(\beta^{-1/2}\left\{\alpha(\xi - \phi) + \beta(\xi - \theta^*)\right\}\right) \end{aligned}$$

Note that the left-hand side of (A.I.2) is increasing in θ^* while the opposite is true for the right-hand side so that the liquidity condition (1) is satisfied and no default occurs if $\theta \geq \theta^*$.

The second equilibrium condition states that, at the switching point, creditors should be indifferent between rolling over and foreclosing. The assumed payoff structure indicates that the payoff from foreclosing is λ while the expected payoff from rolling over equals $1 - P(A, L)$. Since $P(A, L) = \Pr[\theta \leq \theta^*]$ and the posterior distribution of θ is normal with mean ξ and precision $\alpha + \beta$ at the switching point, this indifference condition requires the following equality, (A.I.3) $$1-\Phi\left(\sqrt{\alpha+\beta}(\theta^{*}-\xi)\right)=\lambda \quad \Leftrightarrow \quad \theta^{*}-\xi=\frac{\Phi^{-1}(1-\lambda)}{\sqrt{\alpha+\beta}}$$

Solving (A.I.2) and (A.I.3) together for θ^{*} yields,

(A.I.4) $$\theta^{*}+R+A+L \;=\; \Phi\left(\frac{\alpha}{\sqrt{\beta}}\left(\theta^{*}-\phi+\Phi^{-1}(\lambda)\frac{\sqrt{\alpha+\beta}}{\alpha}\right)\right)$$

There is a unique solution to (A.I.4) as long as $\alpha\,\beta^{-1/2} \leq \sqrt{2\pi}$. This condition—which is satisfied whenever β is arbitrarily large relative to α—is assumed to hold.

For tractability of the model, we focus on the limiting case where $\beta \to \infty$ so that the private signal becomes very precise. In this limiting case, the equilibrium value of θ^{*} satisfies

$$\theta^{*}+R+A+L \to \Phi(\Phi^{-1}(\lambda))=\lambda$$

so that, in the limit,

(A.I.5) $$\theta^{*}=\lambda-R-(A+L)$$

Note that when $\beta \to \infty$, $\theta^{*} \to \xi$ and $s_i \to \theta$ for all *i*, implying that all creditors receive effectively identical private signal, and formulate their switching strategy around $\xi=\theta^{*}$. Consequently, in equilibrium, *x* is either 0 if $\theta \geq \theta^{*}$, or 1 otherwise. The inspection of (A.I.4) suggests that in a more general case with $\beta < \infty$, *x* will be represented by a smooth logit function which is decreasing in A+L.

Interior Solutions of the Model

1. Optimal choice of the member country with unconditional IMF support

By using (3) and (5), the first-order condition for the expected cost minimization of the member country is given by

(A.II.1)
$$\frac{\partial Z(A,L)}{\partial A}=0 \quad \Leftrightarrow \quad \frac{\partial P(A,L)}{\partial A}+\frac{h}{C}=0$$

where

$$\frac{\partial P(A,L)}{\partial A}=-\frac{\sqrt{\alpha}}{\sqrt{2\pi}}\exp\left\{-\frac{1}{2}\alpha\left[(\lambda-\phi)-R-(A+L)\right]^2\right\}$$

Assuming that $h/C<\sqrt{\alpha/2\pi}$, there are in general two solutions for (A.II.1). But the second-order condition for cost minimization $\partial^2 Z/\partial A^2>0$ ensures the following unique solution given by

(A.II.2)
$$\hat{A}(L)=\begin{cases}\bar{A}-R-L & \mathit{for}\;\; 0\le L\le \bar{A}-R\\ 0 & \mathit{for}\;\; L\ge \bar{A}-R\end{cases}$$

where

$$\bar{A}=(\lambda-\phi)+\kappa,\quad \kappa=\sqrt{-\frac{2}{\alpha}\ln\left(\frac{h/C}{\sqrt{\alpha/2\pi}}\right)}\;>0$$

2. Indifference curve of the IMF

Totally differentiating $F(A,L)$ and solving $dF(A,L)=0$ for dA/dL results in

(A.II.3)
$$\left.\frac{dA}{dL}\right|_{dF=0} = A^{F\prime}(L) = -\frac{(\partial P/\partial L)+b/U}{(\partial P/\partial A)}=-1-\frac{b/U}{\partial P/\partial A}$$

where the last expression utilizes the fact that $\partial P/\partial A=\partial P/\partial L$ for all *A* and *L*. Since $\partial P/\partial A<0$ as shown in (A.II.1), $A^{F\prime}(L)$ is always greater than -1, and becomes positive if $b/U>-\partial P/\partial A$. Moreover, the indifference curve is flatter for smaller *b/U* since $\partial P/\partial A$ does not depend on *b/U*.

Given that $\partial P/\partial A\ge-\sqrt{\alpha/2\pi}$ as can be seen from (A.II.1), the slope of the indifference curve is strictly positive for all *A* and *L* if $(b/U)>\sqrt{\alpha/2\pi}$. If $(b/U)\le\sqrt{\alpha/2\pi}$, the slope of the indifference curve would change its sign depending on the value of $A+L$. Substituting into

(A.II.3) the expression for $\partial P / \partial A$ in (A.II.1) and solving $A^{F\prime}(L) = 0$ for $A + L$ results in two critical threshold values of $A + L$, denoted by T_1 and T_2, as given by

$$T_1 = (\lambda - \phi) - R - \tau \quad \text{and} \quad T_2 = (\lambda - \phi) - R + \tau, \quad \text{where} \quad \tau = \sqrt{-\frac{2}{\alpha} \ln\left(\frac{b/U}{\sqrt{\alpha / 2\pi}}\right)} > 0$$

According to these thresholds, $A^{F\prime}(L) < 0$ if $T_1 < A + L < T_2$, and $A^{F\prime}(L) \geq 0$ otherwise. Since A and L are assumed to take only nonnegative values, the slope of the IMF's indifference curve changes its sign twice if $T_1 > 0$, but only once if $T_1 < 0$ and $T_2 > 0$.

Further differentiation of $F(A, L)$ with respect to A and L results in

$$\text{(A.II.4)} \qquad \left.\frac{d^2 A}{dL^2}\right|_{dF=0} = \left.\frac{d^2 A}{dL\, dA}\right|_{dF=0} = \frac{b/U \cdot (\partial^2 P / \partial A \cdot \partial L)}{(\partial P / \partial A)^2} > 0$$

Therefore, the IMF's indifference curve is convex in L. Further, for given L such that $A + L > \overline{A} - R$, the indifference curve is steeper for larger A.

3. Indifference (iso-cost) curve of the member country

Totally differentiating $Z(A, L)$ and solving $dZ(A, L) = 0$ for dA / dL yields the slope of the country's indifference (iso-cost) curve $\tilde{A}(L)$ as given by,

$$\text{(A.II.5)} \qquad \left.\frac{dA}{dL}\right|_{dZ=0} = \tilde{A}'(L) = -\frac{(\partial P / \partial L)}{(\partial P / \partial A) + h / C} > 0$$

where the last inequality follows from $\partial P / \partial L = \partial P / \partial A < 0$, and from the second-order condition that $(\partial P / \partial A) + h / C \geq 0$ for all A and L such that $A + L \geq \overline{A} - R$. Clearly, $\tilde{A}'(L)$ is decreasing in h / C, suggesting that for any given $L \geq L_1$, the iso-cost curve $\tilde{A}(L)$ is flatter for higher h / C.

Further differentiation with respect to L yields,

$$\text{(A.II.6)} \qquad \left.\frac{d^2 A}{dL^2}\right|_{dZ=0} = \tilde{A}''(L) = -\frac{\left\{ \dfrac{\partial^2 P}{\partial L^2} \cdot \left(\dfrac{\partial P}{\partial A} + h / C\right) - \dfrac{\partial P}{\partial L} \cdot \dfrac{\partial^2 P}{\partial A \cdot \partial L} \right\}}{\left(\dfrac{\partial P}{\partial A} + h / C\right)^2} < 0$$

where

$$\frac{\partial^2 P}{\partial L^2} = \frac{\partial^2 P}{\partial A \cdot \partial L} = -\sqrt{\frac{\alpha}{2\pi}} \cdot \alpha \cdot \left[(\lambda - \phi) - R - (A + L)\right] \cdot \exp\left\{-\frac{1}{2}\alpha[(\lambda - \phi) - R - (A + L)]^2\right\} > 0$$

and the inequalities hold for all A and L such that $A + L > \overline{A} - R$.

Finally, since $\tilde{A}(L)$ represents the iso-cost curve associated with $Z(\overline{A} - R - L_1, L_1)$, the following equality should hold by construction for $L \geq L_1$:

$$Z(\tilde{A}(L), L) = Z(\overline{A} - R - L_1, L_1) \Leftrightarrow P(\tilde{A}(L), L) \cdot C + h \cdot \tilde{A}(L) = P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R - L_1)$$

where $P(\overline{A} - R)$ stands for the probability of a crisis when $A + L = \overline{A} - R$. By rearranging terms, this equality can be rewritten to yield,

$$\text{(A.II.7)} \qquad \tilde{A}(L) = \frac{C}{h}\left\{P(\overline{A} - R) - P(\tilde{A}(L), L)\right\} + (\overline{A} - R - L_1)$$

Taking limit with respect to $L \rightarrow \infty$ yields,

$$\lim_{L\rightarrow\infty} \tilde{A}(L) = \frac{C}{h}\left\{P(\overline{A} - R) - \lim_{L\rightarrow\infty} P(\tilde{A}(L), L)\right\} + (\overline{A} - R - L_1) = \overline{A} - R + \left(\frac{C}{h}P(\overline{A} - R) - L_1\right) > \overline{A} - R$$

since $\lim_{L\rightarrow\infty} P(\tilde{A}(L), L) = P(\tilde{A}(\infty), \infty) = 0$. The proof for the last inequality is given below.

4. Interior solutions of the IMF's optimization problem

Without loss of generality, the derivation of interior solutions focuses on the case in which the IMF's indifference curve is upward sloping by assuming that $h / C \leq b / U$.

Equating the slope of the iso-curve to that of the IMF's indifference curve, and solving for $A + L$ yields,

$$\text{(A.II.8)} \qquad A + L = \overline{B} - R$$

where

$$\overline{B} = (\lambda - \phi) + \delta, \qquad \delta = \sqrt{-\frac{2}{\alpha}\ln\left\{\left(\frac{h / C}{\sqrt{\alpha / 2\pi}}\right) \cdot \left(\frac{b / U}{h / C + b / U}\right)\right\}}$$

Note that $\overline{B}$ is strictly larger than $\overline{A}$ since $\delta > \kappa$. (A.II.8) indicates that any interior solution should lie on the locus that satisfies $A + L = \overline{B} - R$, where $\overline{B}$ may vary depending on the underlying parameters such as h/C and b/U. The probability of a crisis for given R is fully determined by $A + L$ in equilibrium. Therefore, all interior solutions on the locus of $A + L = \overline{B} - R$ are associated with the same crisis probability.

By using (A.II.7) and (A.II.8), interior solutions of the IMF's optimization problem can be specified as follows:

$$\text{(A.II.9)} \qquad \begin{aligned} A^* &= \overline{A} - R - L_1 + (h/C)^{-1} \cdot (P(\overline{A} - R) - P(\overline{B} - R)) \\ L^* &= (\overline{B} - \overline{A}) + L_1 - (h/C)^{-1} \cdot (P(\overline{A} - R) - P(\overline{B} - R)) \end{aligned}$$

where $P(\overline{A} - R) = \Phi(-\sqrt{\alpha} \cdot \kappa)$ and $P(\overline{B} - R) = \Phi(-\sqrt{\alpha} \cdot \delta)$ represents the probability of a crisis for $A + L = \overline{A} - R$ and $A + L = \overline{B} - R$, respectively.

Several important properties of the interior solution in (A.II.9) are worth noting:

- $P(\overline{B} - R) < P(\overline{A} - R)$ since $\overline{B} > \overline{A}$, implying that the probability of a crisis is strictly smaller with an IMF-supported program than with no program.
- Programmed policy adjustment is always stronger than what the member country would choose under no program (i.e., $A^* > \overline{A} - R$), the proof of which is given below.
- The crisis probability under an IMF-supported program $P(\overline{B} - R)$ is increasing in h/C and b/U, but independent of L_1 and ϕ.
- Programmed policy adjustment is decreasing in L_1 while the opposite holds for program financing.
- Program financing is independent of ϕ but policy adjustment is decreasing in ϕ.

5. The upper bound of L_1

The upper bound of L_1, denoted by $\overline{L}_1$, would be identified as an interior solution that is determined by the tangency point between the indifference (iso-cost) curve of the member country and the IMF's indifference curve $A^F(L)$. Denoting the tangency point by (A^T, L^T), (A.II.9) implies that $A^T + L^T = \overline{B} - R$. By construction, the expected cost of the member country and the IMF's expected utility at the tangency point (A^T, L^T) are given respectively by

$$Z(\hat{A}(\overline{L}_1), \overline{L}_1) = P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R - \overline{L}_1) \quad \text{and} \quad F(\overline{A} - R, 0) = (1 - P(\overline{A} - R)) \cdot U$$

Therefore, the following equalities should hold:

$$F(A^T, L^T) \equiv (1 - P(\overline{B} - R)) \cdot U \;-\; b \cdot L^T \;=\; (1 - P(\overline{A} - R)) \cdot U$$
$$Z(A^T, L^T) \equiv P(\overline{B} - R) \cdot C \;+\; h \cdot A^T \;=\; P(\overline{A} - R) \cdot C + h \cdot (\overline{A} - R - \overline{L}_1)$$

Solving these equalities for $\overline{L}_1$ using $A^T + L^T = \overline{B} - R$ yields,

(A.II.10) $$\overline{L}_1 \;=\; \overline{A} \;-\; \left\{ \overline{B} \;-\; (\frac{C}{h} + \frac{U}{b}) \cdot \{P(\overline{A} - R) - P(\overline{B} - R)\} \right\}$$

6. Proof of $A^* > \overline{A} - R$ and $\lim_{L \to \infty} \tilde{A}(L) > \overline{A} - R$

Since $\lim_{L \to \infty} \tilde{A}(L) > A^*$ by construction and A^* is strictly decreasing in L_1 as can be seen from (A.II.7) and (A.II.9), it is sufficient to prove $A^* > \overline{A} - R$ for $L_1 = \overline{L}_1$.

Substituting (A.II.10) into the expression for A^* in (A.II.9) yields,

(A.II.11) $$A^*(\overline{L}_1) \;-(\overline{A} - R) \;=\; (\overline{B} - \overline{A}) - \;(U/b) \cdot (P(\overline{A} - R) - P(\overline{B} - R))$$

By using the properties of the probability distribution and (A.II.1), it can be shown that the following relationship holds:

(A.II.12) $$P(\overline{A} - R) - P(\overline{B} - R) \;< (\overline{B} - \overline{A}) \cdot f(\overline{A} - R) = (\overline{B} - \overline{A}) \cdot (h/C)$$

where $f(\overline{A} - R)$ is the normal density function evaluated at $A + L = \overline{A} - R$, and the equality directly follows from (A.II.1). Substituting (A.II.12) into (A.II.11) yields,

$$A^*(\overline{L}_1) \;-(\overline{A} - R) \;>\; (\overline{B} - \overline{A}) \cdot \{1 - \;(U/b) \cdot (h/C)\} \;\geq\; 0$$

where the last inequality follows from the assumed parameter restriction $h/C \leq b/U$.

Convex Adjustment Cost and IMF Financing as a Loan

In this appendix, the model is extended by assuming a quadratic adjustment cost and introducing future adjustment cost in the country's objective function, while keeping all other aspects of the model. The extension, albeit very crude and simplistic, provides insight into how the country would react if unconditional IMF support is provided in the form of a (senior) loan, rather than grant.

To keep the analysis as simple as possible, we assume that there are two periods, denoted by $t = 0$ and 1, and that there is no possibility of a liquidity crisis or default in period 1 if the country does not default in period 0. The country's objective for period 1 is simply to repay the IMF by undertaking adjustment if necessary. Total repayment to the IMF is given by $(1+r_L)L$ where r_L is the interest rate charged on IMF lending. Without loss of generality, we normalize the country's own foreign reserves to 0 (i.e., $R = 0$).

Denoting by A_1 the country's adjustment in period 1, full repayment to the IMF requires the following condition given by

$$\text{(A.III.1)} \qquad Max[(\theta_0 + A_0 + L),\ 0] + A_1 \ \geq \ (1+r_L)L + I \cdot (1+r_D)D - \theta_1$$

where θ_j is the current account balance in period j, I is an indicator function that takes 0 if the country defaults in period 0, and 1 otherwise, and r_D is the interest rate on short-term debt. The left-hand side of the inequality represents the amount of liquid asset held by the country in period 1 while the right-hand side refers to the gross financing need. Note that the country does not repay private debt if it defaults in period 0, which is consistent with the assumption that private creditors get nothing upon default.

To further simplify the analysis, we assume that θ_1 is known a priori and given by

$$\theta_1 = I \cdot (1+r_D)D$$

so that the current account balance in period 1 is just enough to service short-term debt in full if no default occurs in period 0, and 0 otherwise. With this specification of θ_1 and assuming that adjustment is always nonnegative, (A.III.1) can be rewritten to yield,

$$\text{(A.III.2)} \qquad A_1 = \begin{cases} (1+r_L)L & \text{if } \theta_0 \leq \underline{\theta} \\ r_L L - (\theta_0 + A_0) & \text{if } \underline{\theta} < \theta_0 < \overline{\theta} \\ 0 & \text{otherwise} \end{cases}$$

where $\underline{\theta} = -L - A_0$ and $\overline{\theta} = r_L L - A_0$. Note that $A_1 = 0$ if $L = 0$ since $\underline{\theta} = \overline{\theta}$. Also note that A_1 is decreasing in A_0 but increasing in L for all states of θ_0:

$$\partial A_1 / \partial A_0 \leq 0 \quad \text{and} \quad \partial A_1 / \partial L \geq 0$$

The country's objective in period 0 is to minimize the expected cost given by

(A.III.3) $$Z(A_0, L) = P(A_0, L) \cdot C + \frac{h}{2} \cdot A_0^{\,2} + \delta E(\frac{h}{2} \cdot A_1^{\,2})$$

where $P(A_0, L) = \Pr[\theta_0 < \theta^* = \lambda - (A_0 + L)]$ is the probability of a liquidity crisis (and default) in period 0 as defined in the main text,[24] $\delta \in [0,\ 1)$ is the country's discount factor, and $E(\cdot)$ refers to the expectation taken with respect to θ_0 at the beginning of period 0. Since $A_1 = 0$ for all θ_0 if $L = 0$, (A.III.3) collapses in this case to a single-period objective function with no future adjustment cost being involved. Similarly, future adjustment cost does not enter the country's objective function if $\delta = 0$.

The first-order condition for the country's cost minimization is given by

(A.III.4) $$\frac{\partial Z(A_0, L)}{\partial A_0} = 0 \quad \Rightarrow \quad \frac{\partial P(A_0, L)}{\partial A_0} \cdot C + h \cdot A_0 + \frac{\delta h}{2} \cdot \frac{\partial E(A_1^{\,2})}{\partial A_0} = 0$$

After some algebra, it can be readily shown that for $L > 0$,

$$\frac{\partial E(A_1^{\,2})}{\partial A_0} < 0, \quad \frac{\partial E(A_1^{\,2})}{\partial L} > 0, \quad \frac{\partial^2 E(A_1^{\,2})}{\partial A_0 \partial L} < 0, \quad \text{and} \quad \frac{\partial^2 E(A_1^{\,2})}{\partial A_0^2} > \frac{\partial^2 E(A_1^{\,2})}{\partial A_0 \partial L}$$

We consider first the case in which $\delta = 0$ so that IMF support is a grant. Let us denote by A_0^* the country's optimal choice of A_0 when $\delta = 0$. It can be readily shown that A_0^* is always positive for any finite L and ϕ but may not be uniquely determined. There are at most two solutions, and we assume that the country will always choose the larger one as long as it is technically feasible.

Totally differentiating (A.III.4) with respect to A_0 and L yields

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[24] Recall that λ is the (gross) risk-free return relative to the (gross) return on short-term debt, which is also normalized to 1. Therefore, λ can be rewritten as $\lambda = (1 + r)/(1 + r_D)$ where r is the risk-free interest rate and r_D is the interest rate contracted for short-term debt.

(A.III.5) $$\frac{dA_0^*}{dL} = \frac{-f'(\theta^*)}{f'(\theta^*)+h/C} > -1$$

where $f(\theta^*)$ is the normal density of θ evaluated at the default threshold $\theta^* = \lambda - (A_0^* + L)$. The second-order condition for cost minimization ensures that the denominator be strictly positive. The inequality indicates that IMF financing partially offsets adjustment in period 0, and possibly reinforces it. After a lot of algebra, it can be shown that $dA_0^*/dL < 0$ if $\phi > \lambda - \sqrt{\alpha/2\pi}/(h/C)$. This condition would hold unless the country's fundamentals are so poor that it is insolvent—a case which can be ignored since the IMF would not enter into a program when the country is insolvent. Therefore, assuming a convex adjustment cost would not alter the conclusion of the model that adjustment and unconditional IMF financing are substitutes from the perspective of the country.

Now consider the case in which $\delta > 0$ so that IMF support is a loan that must be repaid. We denote by A_0^{**} the unique solution for the first-order condition (A.III.4) when $\delta > 0$. Since $\partial E(A_1^2)/\partial A_0 < 0$, it immediately follows that $A_0^{**} \geq A_0^*$ for any given *L*, which implies that $(dA_0^{**}/dL) \geq (dA_0^*/dL)$ and, hence, the offset is less pronounced when IMF support is a loan than when it is a grant. This result makes intuitive sense in light of the well-known result for optimal smoothing when adjustment cost is convex.

Totally differentiating (A.III.4) results in

(A.III.6) $$\frac{dA_0^{**}}{dL} = \frac{-[f'(\theta^{**}) + (\delta/2)(h/C)(\partial^2 E(A_1^2)/\partial A_0^{**}\partial L)]}{f'(\theta^{**}) + h/C + (\delta/2)(h/C)(\partial^2 E(A_1^2)/\partial A_0^{**2})} > -1$$

where $f(\theta^{**})$ is the normal density of θ evaluated at the default threshold $\theta^{**} = \lambda - (A_0^{**} + L)$. The inequality directly follows from the fact that $\partial^2 E(A_1^2)/\partial A_0^2 > \partial^2 E(A_1^2)/\partial A_0 \partial L$. The second-order condition for cost minimization ensures that the denominator is positive. The sign of the numerator is indeterminate, but it can be shown that it is negative if $dA_0^*/dL < 0$ and *L* is not too large, suggesting that adjustment and unconditional IMF lending (that must be repaid) would continue to be substitutes.[25]

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[25] Note that (A.III.6) converges to (A.III.5) as $L \to 0$ since $A_0^{**} \to A_0^*$, $\partial^2 E(A_1^2)/\partial A_0^2 \to 0$, and $\partial^2 E(A_1^2)/\partial A_0 \partial L \to 0$ when $L \to 0$.

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