Liquidity Facilities and Signaling

by

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Abstract

This dissertation studies the role of signaling concerns in discouraging access to liquidity facilities like the IMF contingent credit lines (CCL) and the Discount Window (DW).

In Chapter 1, I analyze the introduction of IMF CCL in an economy with asymmetric information and financial frictions. Countries have private information about the probability of a being hit by a negative aggregate shock. IMF insurance provides outside liquidity that partially alleviates financial frictions. In the absence of IMF CCL, weak countries face inefficient project termination when the economy is hit by the negative shock, but receive cheaper credit ex ante as they are pooled with strong countries. Once contingent credit lines are introduced, weak countries have to choose between reducing inefficient liquidation and losing the ex ante cross subsidy from pooling. Introducing the CCL leads to a Pareto improvement relative to the no-IMF benchmark only if the IMF can offer a sufficiently large amount of outside liquidity or if it can allow for cross subsidization from strong to weak countries.

Chapter 2 studies the role of eligibility requirements that make the CCL close to a rating agency. Risk-averse countries, with private information regarding the probability of being hit by an aggregate income shock, seek insurance in international capital markets. I focus on a No-IMF benchmark in which the target economies for the facility manage to separate from weaker countries by underinsuring. I model IMF CCL as the introduction of an imperfect stress test that countries may voluntarily take. If the stress test is good enough, the IMF generates a Pareto improvement by providing target economies with a cheaper way to separate from weaker economies. However, if the quality of the stress test is low enough, there exists an equilibrium in which no country chooses to take the exam. Provided that the cost of the exam is low enough, I show that forcing all countries to take the exam Pareto dominates the equilibrium in which no country takes the exam.

In Chapter 3, I study the role of the DW in the presence of competing liquidity facilities with market determined interest rates. There is stigma attached to borrowing at the DW. Stigma costs are assumed to be fixed costs and therefore banks borrow at the DW only when the fed funds market is severely tight. A more attractive discount window (lower discount rate or lower signaling costs) results in higher total DW borrowing and a higher fraction of banks borrowing from the facility. It is also accessed in more states of the world. I propose an empirical approach based on cross-district data to test for the stigma hypothesis.

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"Gente de un lado y del otro lado gente,
que ya no vive acá ni allá, sino en el puente.
De un lado el trabajo y del otro los parientes,
y ese cordón de luz que cruza continentes.
El puente es de aire, es incoloro, es transparente.
El puente que va, desde tu pecho al mío,
aunque no te tenga enfrente."
Jorge Drexler, Puente al sur (inédita).

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Chapter 1

Signaling Concerns and IMF Contingent Credit Lines

Abstract

Emerging market economies are exposed to significant macroeconomic risk. International reserves can be accumulated for self-insurance but this entails substantial costs. The IMF contingent credit line facility constitutes an attempt to provide a more efficient insurance mechanism. However, no country found the early versions of the facility attractive. This paper studies the role of signaling concerns in discouraging access to contingent credit lines. I analyze the introduction of IMF contingent credit lines in an economy with asymmetric information and financial frictions. Asymmetric information is present because countries differ in the probability of a negative aggregate shock, and this probability is private information. The financial frictions originate from the limited ability of lenders to commit future resources. IMF insurance provides outside liquidity that partially alleviates this commitment problem. In the absence of IMF credit lines, weak countries face inefficient project termination when the economy is hit by the negative shock, but receive cheaper credit ex ante as they are pooled with strong countries (cross subsidization). Once contingent credit lines are introduced, applying for a credit line can reveal information. Then weak countries have to choose between reducing inefficient liquidation and losing the ex ante cross subsidy from pooling. Introducing IMF credit lines leads to a Pareto improvement relative to the no-IMF benchmark only if the IMF can offer a sufficiently large amount of outside liquidity or if it can allow for cross subsidization from strong to weak countries.

1.1 Introduction

The IMF established the Contingent Credit Lines (CCL) in 1999 to "help countries with strong policies avoid contagion crises". The basic idea of the program was to increase ex ante eligibility requirements in exchange for reduced ex post conditionality, so that periods of exceptional financial pressure in the capital account could be met with higher "automaticity" of funds. However, the CCL expired in 2003 without having been used. The same fate was suffered by its successor, the Short Term Liquidity Facility (SLF) introduced in October 2008. It was not until the introduction of the Flexible Credit Lines in 2009 that the IMF managed to attract countries to join the program.

During the very same period, emerging economies (the target of this IMF facility) increasingly self-insured through the accumulation of international reserves. Cordella and Levy Yeyati (2005) report that reserve hoarding as a fraction of GDP increased from 8.9% in 1992 to 18.1% in 2002 in their sample of 35 emerging economies. Even when optimally managed, this option entails substantial costs (see Caballero and Panageas 2005a,b) and for this reason, external insurance arrangements have been advocated as more efficient insurance mechanisms against small probability events (such as large capital outflows). It has been argued that emerging economies lack access to hedging and insurance instruments to guard against macroeconomic shocks (aggregate uncertainty). The question addressed in this paper is: why did under-insured economies refuse to accept the IMF liquidity provision?

A lesson from the CCL experience is that the informational content of these liquidity agreements is vital. Quoting IMF reports: "*Potentially eligible countries were not confident that a CCL would be viewed as a sign of strength rather than weakness*", "*Such request could convey a signal of greater underlying vulnerabilities than the market had previously perceived (asymmetric information)*". This paper builds on the insight that whether countries decide to come to the IMF or not has a lot to do with the image they want foreign investors to have about them. Therefore, the underlying environment I consider has two crucial features: 1) borrowers desire to secure liquidity in advance; and 2) there is unobservable borrower heterogeneity.

The basic framework adds heterogeneity into a variation of Holmstrom and Tirole's 1998 liquidity model. Countries need to borrow to make investments that may be hit by random liquidity needs. Shocks are perfectly correlated, so there is macroeconomic uncertainty. A fundamental financial friction is assumed: lenders cannot commit their future resources. As a result, given limited pledgeability and the aggregate nature of the shock, in the absence of outside liquidity all projects are liquidated in case of a shock.

I model IMF CCLs as insurance that may not be provided by private capital markets. The idea is that the IMF is able to raise capital in situations in which capital markets cannot or do not want to, ex post.[1] In terms of the assumed financial friction, the provision of outside liquidity by the IMF solves the commitment problem of the lenders. I consider the case in which IMF outside liquidity provision is limited in size. In the setting of the model, allocations proposed by the IMF are implemented only if they Pareto dominate the no-IMF benchmark.

In a symmetric information scenario, in the absence of the IMF, liquidity shocks result in inefficient liquidation of the projects. Any amount of outside liquidity that the IMF may provide results in a Pareto improvement relative to the no-IMF situation.

The asymmetric information scenario consists of two types (strong, weak) that differ in the probability of a liquidity shock, which is private information. In the absence of IMF credit lines, contracts pool both types. Weak countries face inefficient project termination when the economy is hit by the negative shock, but receive cheaper credit ex-ante as they are pooled with the strong types (cross subsidization). I show that this pooling equilibrium maximizes utility for the strong type when both types are creditworthy.

Once IMF contingent credit lines are introduced, applying for a credit line can reveal information. Whether the introduction of IMF CCLs results in a Pareto improvement relative to the no-IMF benchmark (and therefore is implemented), depends crucially on two points: 1) the amount of outside liquidity the IMF is able to provide in case of a shock; and 2) whether insurance contracts with the IMF are required to break even type by type or in expectation. Pareto improvements relative to the no IMF equilibrium require IMF interventions to be either large in scale or to allow for cross subsidization from strong to weak countries.

The provision of outside liquidity by the IMF reduces the inefficiency associated with the liquidation of positive net present value projects that results from the lack of commitment of the lenders. The gain is proportional (in the relevant range) to the amount of outside liquidity

[1] For example, during the last global recession the leaders of the Group of 20 nations (G-20) announced a tripling of the lending power of the IMF to around $750 billion (April 2009).

that the IMF may provide. If the contracts signed with the IMF are required to break even type by type, it implies that weak types lose the benefits from cross subsidization when revealing their type. This loss for the weak types does not depend on the amount of outside liquidity the IMF provides. This is the key trade off driving the results. The informational content of insurance provision (signaling story), interacts with the terms (e.g. size) of the liquidity agreement. IMF insurance contracts that are required to break even type by type do not allow for a Pareto improvement (relative to the no IMF equilibrium) when the amount of outside liquidity is limited in size.

If contracts are required to break even in expectation instead of type by type, the introduction of the credit lines can generate a Pareto improvement relative to the no-IMF benchmark irrespective of the amount of outside liquidity provision. For limited supply of outside liquidity, cross subsidization in insurance contracts is strictly required.

I expand the basic setting in three directions. First I study the consequences of liquidity provision on crisis prevention effort by debtor countries. The size of the liquidity provision in case of a shock matters in two respects: it determines whether the IMF may induce separation of types or not, and conditional on separation it affects the optimal choice of effort. As a result, optimal crisis prevention effort has a non-monotone relationship with IMF liquidity provision. For intermediate size liquidity provision, effort choice increases relative to the no-IMF benchmark.

Second, I use the framework to discuss an alternative (and possibly complementary) signaling story. The model in this paper is centered around the "*upward*" concern that taking the CCL might reveal the country is not as good as the market had previously expected. The alternative signaling story focuses on the "*downward*" concern about being confused with a worse type. Not taking the contingent credit lines is a costly action that may enable the target economies of this facility to credibly signal they are better than other countries.

Finally, I introduce an inefficient storage technology in the basic setting in order to relate the model to the ongoing debate on inefficient reserve accumulation. I show that contingent credit lines that are too small, too narrow or not cross subsidized enough become less attractive relative to reserve hoarding, and might end up not being used if their signaling content is higher than the one of reserves.

The structure of the paper is as follows. In section 2 I introduce the model and review the symmetric information benchmark with and without the presence of the IMF. In section 3 I analyze the asymmetric information case without the IMF. Section 4 introduces the IMF in the asymmetric information context. I analyze the case in which IMF contracts are required to break even type by type and in expectation. In section 5 I use the model to analyze the effects of IMF intervention on crisis prevention effort by weak countries. Section 6 compares the results to an alternative signaling story. In section 7 I relate the model to the debate on inefficient international reserve hoarding by emerging countries; and section 8 concludes. All proofs are in the appendix.

1.1.1 Relation to the literature

There exists a large literature analyzing the consequences of financial frictions for economies facing macroeconomic risk (aggregate uncertainty). Following Holmstrom and Tirole (1996, 1998), and similar to Caballero and Krishnamurty (2002a-b), Caballero and Panageas (2005a-b) and Lorenzoni (2007), this paper assumes financial frictions both on the borrowers' (countries) and on the lenders' (international capital markets) side. Also in line with these papers, aggregate uncertainty is modeled as perfectly correlated exogenous shocks hitting investment projects. The main contribution of this paper to this strand of literature is the introduction of an informational friction at the contracting stage. This paper studies the challenges faced by a provider of outside liquidity (e.g. the IMF) under asymmetric information.

A number of papers study the role of the IMF when countries are heterogeneous and country types are private information. Marchesi and Thomas (1999) analyze IMF conditionality as a costly action that enables stronger countries to credibly signal their type. In Arregui (2008) the IMF has an advantage relative to the market in extracting private information from countries. As such, eligibility requirements are presented as an imperfect stress test that countries may voluntarily take or not. None of those papers focuses on the role of the IMF as a lending institution. More relatedly, this paper shares with Basu (2009) the idea that contracts signed with the IMF may reveal information to private capital markets and this should be incorporated in the mechanism design problem of the IMF. In Basu's paper there is no ex ante heterogeneity and the IMF advantage is to commit to redistributive transfers across types ex post. In this paper, it is crucial that there is heterogeneity at the contracting stage and the IMF may not be able to cross subsidize types.

This paper is also related to the strand of literature that analyzes the moral hazard consequences of IMF lending. The standard concern is that IMF lending, by making crisis scenarios less unattractive, may discourage crisis prevention effort by the debtor country. Several authors have considered settings under which the relationship between IMF lending and effort provision is not unambiguous. Jeanne and Zettlemeyer (2004) consider a setting in which the introduction of the IMF expands pledgeable income. Morris and Shin (2006) study the role of the IMF as a provider of catalytic finance. Basu (2009) concludes that IMF interventions can ameliorate the moral hazard problem ex ante. In line with those papers, in the setting I consider there is a non monotone relationship between country effort choice and IMF provision of outside liquidity.

Finally, this paper contributes to the literature on inefficient international reserve accumulation. Caballero and Panageas (2005b) stress the substantial costs associated with the use of reserve accumulation as a self insurance mechanism. In their paper, external insurance is hard to obtain because during sudden stops investors themselves are in distress. Caballero and Panageas (2005a) and Borensztein and Mauro (2003) propose ways of improving the self insurance strategy. In this paper, the IMF constitutes an alternative provider of external insurance that may hoard capital when private capital markets can not. I show how signaling concerns may favour the use of reserve accumulation in spite of the associated efficiency costs.

1.2 The Model

The basic environment is similar to Holmstrom and Tirole's (1998) liquidity model. There are two agents: the country and the international lenders (the IMF will be introduced later). There are 3 periods $t = 0, 1, 2$. At date 0 the country has access to a continuum of projects of fixed size I, has wealth $A < I$, and must borrow $I - A$.

At date 1, an additional, uncertain reinvestment $\hat{\rho}$ is required in order to continue the project and realize the final payoffs. If the amount is not paid the project terminates and yields nothing (i.e. the liquidation value of the project is zero). The reinvestment need $\hat{\rho}$ follows

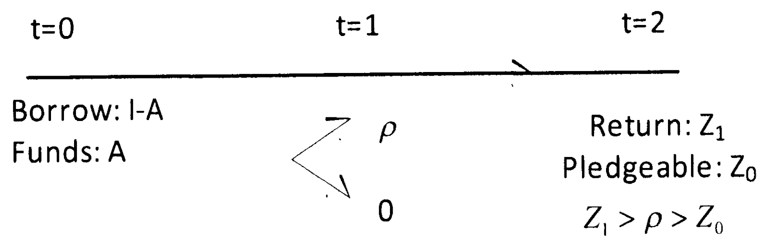

Figure 1-1: Timeline.

a binomial distribution: with probability λ continuation requires reinvesting $\rho > 0$ and with probability $1 - \lambda$ there is no reinvestment requirement (no shock). The shock $\hat{\rho}$ is perfectly correlated across projects (macroeconomic uncertainty) and is observable and verifiable.

At date 2 , if the project gets to completion it yields Z_1. A financial friction on the borrowers' side is assumed: borrowers are unable to pledge all the benefits from investment to investors. Only a fraction of the project can be valued and seized in default, generating a wedge between the total returns to the project Z_1 and what can be pledged to investors Z_0. I call Z_0 "pledgeable income". Assume $Z_1 > \rho > Z_0$, that is, continuation in case of a shock has negative net present value (NPV) from the point of view of the lenders but positive NPV for the country. Countries are assumed to be risk neutral.

Lenders are risk neutral and require a zero rate of return. A financial friction on the lenders' side is assumed: lenders cannot commit their future resources. There is no storage technology from period 0 to 1. These two assumptions limit the ability of the country to insure ex ante against aggregate shocks.

Assume each project has positive present value even if it is terminated every time it is hit by a shock, i.e. $(1 - \lambda) Z_1 > I$. Also, assume that lenders would be willing to finance each project even with certain continuation (if they could commit their future income): $Z_0 - \lambda\rho \geq I - A$.

Condition 1 *Assume* $(1 - \lambda) Z_1 > I$.

Condition 2 *Assume* $Z_0 - \lambda\rho \geq I - A$.

Under the proposed setting, liquidity shocks must result in liquidation of the projects. The reason for liquidation is that when funds ρ are required, the country does not have the funds (no storage technology between 0 and 1) and the projects have negative net present value from the point of view of the lenders ($\rho > Z_0$). The aggregate nature of the shock implies there are no assets to back up investors' promises to cover a liquidity shock. The only option is for all projects to shut down.

Ideally, the country would like to pledge additional funds in the good state to compensate for the negative net present value reinvestments by the lenders in case of a shock, and allow for some continuation. Given our second assumption, there is enough pledgeable income in expectation to attain full continuation in case of a shock. However, such agreements are not possible because the lenders cannot commit to provide the funds ex post.

1.2.1 What can the IMF do that private capital markets cannot?

I assume that the IMF is able to commit resources up-to $\bar{L}$ in case of a shock. In this way I intend to capture the idea that the IMF may be able to raise funds in situations in which private capital markets cannot or do not want to, ex post. I do not go into the detailed mechanics of how the IMF raises liquidity, but acknowledging it is a complicated process I parameterize the scope of insurance that the IMF may provide by the parameter $\bar{L}$ (the most the IMF may commit to pay in case of a shock).

In terms of the model, the IMF (partially) solves the commitment problem of the lenders that lies at the heart of the inefficient liquidation of projects. It allows the country to insure against aggregate liquidity shocks across states of nature, allowing for some projects not to be liquidated in case of a shock. Note that the IMF is not assumed to expand pledgeable income as in Jeanne and Zettlemeyer (2004). In this paper, the IMF relaxes the financial friction on the lender's side, not on the borrower's side.

The emerging economies that were the target of the CCL facility have been vastly argued to be under-insured as a result of lacking hedging and insurance instruments (e.g. see Caballero 2003). In this paper, I model IMF CCLs as insurance instruments that countries may not access in private capital markets. It is not the purpose of this paper to argue the reasons why the IMF has such an advantage over private capital markets.[2] This stark characterization of the

[2] For example. Holmstrom and Tirole 1998 argue that the ability of governments to commit future income of unborn citizens using taxation represents a clear advantage over private capital markets. We may think of the IMF as coordinated government intervention.

role of the IMF makes it challenging to explain why emerging economies did not take on the liquidity provision by the IMF.

1.2.2 Symmetric Information benchmark

In this section I consider the symmetric information scenario. There are three main features that should be held in mind: the liquidity shock is aggregate (macroeconomic uncertainty), reinvestments are not self financing ($\rho > Z_0$) and lenders cannot commit their future income. The IMF is interpreted as a provider of outside liquidity, that (partially) solves the lack of commitment problem by the lenders.[3]

Call $\bar{L}$ the maximum amount the IMF can commit to deliver in case of a shock. The case $\bar{L} = 0$ corresponds to the no-IMF scenario.

Without loss of generality, let contracts specify a payment to the lenders in case of shock and no shock (P_s and P_{ns} respectively) and a probability of continuation in case of a shock x (which may also be interpreted as a downsizing of the project) and liquidity provision in case of a shock L. The optimal contract for the country maximizes utility

$$(1 - \lambda)(Z_1 - P_{ns}) + \lambda x (Z_1 - P_s) - A \tag{1.1}$$

subject to the break even constraint for the lenders,

$$(1 - \lambda) P_{ns} + \lambda x (P_s - \rho) \geq I - A \tag{1.2}$$

the continuation constraint,

$$x(\rho - P_s) \leq L \tag{1.3}$$

the limited outside liquidity constraint,

$$L \leq \bar{L} \tag{1.4}$$

[3]Equivalently we may think of the IMF as the introduction of a storage technology that delivers one unit at $t = 1$ for each unit purchased at $t = 0$. The storage technology has a maximum of $\bar{L}$.

and limited pledgeability and feasibility of the liquidation policy constraints,

$$\begin{aligned} P_i &\leq Z_0 \quad i = s, ns \\ 0 &\leq x \leq 1 \end{aligned} \tag{1.5}$$

As it is shown in the appendix, lenders will just break even and countries will earn the net present value of the project. The net present value of the project is increasing in the probability of continuation in case of a shock.[4] Countries will choose the highest x subject to the rest of constraints.

Given the assumption that $Z_0 - \lambda\rho \geq I - A$ (condition 2), in case there is sufficient outside liquidity $\bar{L} \geq \rho - Z_0$ it will allow for full continuation in case of a shock $x = 1$ and the payments to the lender $P_i \leq Z_0$ $i = s, ns$ will be such that it just breaks even.

$$(1 - \lambda) P_{ns} + \lambda x (P_s - \rho) = I - A$$

The country gets the NPV of the project

$$U_b = Z_1 - \lambda\rho - I$$

However, if outside liquidity provision is insufficient $\bar{L} < \rho - Z_0$, there will be inefficient liquidation of projects.

Proposition 3 *If $\bar{L} < \rho - Z_0$, the optimal contract for the country involves liquidation of projects given by*

$$x = \frac{\bar{L}}{\rho - Z_0} < 1$$

The payments to the lender are $P_s = Z_0$, and $P_{ns} = \frac{I - A + \lambda\bar{L}}{1 - \lambda} \leq Z_0$. The case $\bar{L} = 0$ corresponds to the no-IMF scenario.

Lenders break even and countries get the net present value of the project, which is affected

[4] Here I present the results for the case $\lambda > 0$. If $\lambda = 0$, outside liquidity provision is irrelevant. The payment to the lender is $P_s = I - A$ and the country gets the net present value of the project $Z_1 - I$.

by inefficient liquidation

$$U_b = (1 - \lambda) Z_1 + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_1 - \rho) - I$$

There are several ways to implement this allocation. For instance, countries may sign a funding contract with capital markets that provides $I - A$ in exchange for a payment $\frac{I-A}{1-\lambda}$ in case of no shock. And an insurance contract with the IMF that provides $\frac{\lambda \bar{L}}{1-\lambda}$ if there is no shock, in exchange for liquidity provision $\bar{L}$ if there is a shock. If there is a shock, the country will commit pledgeable income Z_0 to maximize continuation.

In the no-IMF scenario ($\bar{L} = 0$) all projects are liquidated in case of a shock. The introduction of the IMF ($0 < \bar{L} \leq \rho - Z_0$) results in a strict Pareto improvement relative to the no IMF situation ($\bar{L} = 0$), since it reduces inefficient liquidation and increases the value of the project (note the probability of continuation x and the NPV of the project are increasing in $\bar{L}$ in the range $[0, \rho - Z_0]$). It should be noted that this inefficient liquidation is a consequence of the limited outside liquidity. As it is shown in the appendix, in the case expected pledgeable income does not allow for full continuation in case of a shock[5] ($Z_0 - \lambda\rho < I - A \leq (1 - \lambda) Z_0$) there is an extra source of inefficiency arising from limited pledgeability that makes countries reduce scale (lower x) to get funding.

1.3 Country types

Assume there are two types of countries $\theta_i \in \{g - ood, b - ad\}$. Types are unobservable. Let γ be the fraction of good types. Good and bad countries differ in the probability of a liquidity shock: $\lambda^g < \lambda^b < 1$. Furthermore, I make the extreme assumption that good types do not suffer liquidity shocks $\lambda^g = 0$. This implies that these types do not benefit directly from IMF liquidity provision.

The asymmetric information scenario requires us to specify many more details than in the symmetric information case. In particular, we need to specify what the benchmark is in the absence of the IMF, we need to specify if the break even constraint is required to hold type

[5] Note that condition 2 rules this case out.

by type or in expectation, and we need to specify the conditions under which an allocation proposed by the IMF is implemented or not.

In this section I characterize the no-IMF benchmark. I focus initially on financial contracts that specify a payment P to the lender in case of completion (notice that in the absence of IMF liquidity, completion happens only when there is no shock).[6] I consider richer contracts later in the section. In the next section I introduce the IMF into the asymmetric information setting.

1.3.1 No IMF benchmark

For the same reasons explained in the symmetric information case, in the absence of the IMF, liquidity shocks result in liquidation of the projects.[7] Assume that the only feasible financial contracts are contracts that specify a payment P to the lender in case of completion in exchange for initial funds $I - A$. By inspection of the incentive compatibility constraints,

$$\begin{aligned} Z_1 - P_g - A &\geq Z_1 - P_b - A \\ (1-\lambda)(Z_1 - P_b) - A &\geq (1-\lambda)(Z_1 - P_g) - A \end{aligned}$$

we conclude that the considered contracts necessarily pool the 2 types ($P_g = P_b = P$). Each type prefers financing to no financing and conditional on funding, a lower value for P. I require P to just break even for the lenders and to satisfy limited pledgeability $P \leq Z_0$.

I take this allocation to be the no IMF benchmark (or equilibrium). This allocation is the only (PBE) equilibrium contract that just breaks even in the following two stage game: in the first stage, the borrower proposes a contract P; in the second stage, the lender updates beliefs based on the observed proposal and accepts if and only if $P \leq Z_0$ and the expected value of the payment P given the updated beliefs is at least $I - A$.[8]

Proposition 4 *Under asymmetric information, the no-IMF equilibrium is characterized by*

[6] More generally a contract could specify a probability of financing, a payment to the lender in case of financing and completion, a payment to the lender in case of financing and not completion, a payment to the lender in case of not financing (could be positive or negative, positive requires $A > 0$).

[7] This results follows from the fact that there is only one country with two types, i.e. types do not coexist. Otherwise, the shock would not be an aggregate shock and weak types could attain some continuation by holding stock in the good type's project (as in Holmstrom and Tirole 1996).

[8] This game has no separating equilibrium and multiple pooling equilibria $P_g = P_b = P$ with $\frac{I-A}{\gamma+(1-\gamma)(1-\lambda)} \leq P \leq \frac{I-A}{1-\lambda}$. Only when $P = \frac{I-A}{\gamma+(1-\gamma)(1-\lambda)}$ lenders do not make positive profits in expectation.

$P_g = P_b = P,$

$$I - A < P = \frac{I - A}{\gamma + (1-\gamma)(1-\lambda)} < \frac{I - A}{(1-\lambda)}$$

Ex post there is cross subsidization, lenders make money on the good types and lose money on the bad types. In the pooling equilibrium, the good type pays more to lenders than what he would under symmetric information. The opposite is true for the weak type. The size of the cross subsidy to the bad type is increasing in the proportion of good types γ.

From the point of view of the bad countries, the absence of outside liquidity results in inefficient project termination when a shock occurs; however, it results in a pooling equilibrium that entails cross subsidies from the strong types. This cross subsidization will be at the core of the results in the next section.

I will work under the assumption that $Z_1 - \rho > I - A$. This means that the utility for the weak type when pooling with the strong type for any γ is lower than what he would obtain in the symmetric information case with sufficient liquidity provision ($\bar{L} \geq \rho - Z_0$). [9]

Condition 5 *Assume* $Z_1 - \rho > I - A$.

1.3.2 Richer contracts

So far we have restricted attention to contracts that specify a payment to the lender in case of completion (no liquidity shock). Could the countries do better by signing more general contracts? In more generality a contract may specify a probability of financing x_i, a payment to the lender in case of financing and no shock R_i^s and a payment to the borrower in case of no financing $-R_i^0$. Note that given the aggregate nature of the shocks and the requirement that international lenders must back their promises by assets (and assuming no outside liquidity) contracts may not specify a probability of continuation in case of a liquidity shock, nor a payment to the lenders in such case (since shock implies liquidation and there is limited liability).

Proposition 6 *Assuming that both types are creditworthy* ($(1-\lambda) Z_1 > I$ *and* $Z_0 - \lambda\rho \geq I - A$) *the pooling equilibrium maximizes utility for the good type out of the incentive compatible*

[9] If they are granted access to enough outside liquidity $\left(\bar{L} \geq \rho - Z_0\right)$, there will be an efficiency gain of $\lambda (Z_1 - \rho)$, since projects now survive the liquidity shock with certainty. The maximum loss in cross subsidies is given by $(1-\lambda)\left[\frac{I-A}{1-\lambda} - (I - A)\right] = \lambda (I - A)$.

allocations that break even in expectation and satisfy limited pledgeability.

That is, the best allocation for the strong type entails cross subsidies to the weak type. The intuition is that when both types are creditworthy, lending is efficient and any other (reasonable) contract we consider will amount to a redistribution of wealth between the good and bad types. A contract that pays only in case of no shock minimizes the cross subsidy to the weak type, since it best reflects the comparative advantage of the good type.

1.4 Asymmetric information and the IMF

I now analyze the introduction of the IMF in the context of asymmetric information. The IMF is able to commit funds up-to $\bar{L}$ in case of a shock. This advantage over private capital markets could in principle allow for allocations that were not attainable in the absence of the IMF. I study the behavior of the IMF as a mechanism design problem. I show that the introduction of IMF CCLs may generate a Pareto improvement relative to the no-IMF equilibrium only if the IMF can commit a sufficiently large amount of outside liquidity or if it can allow for cross subsidization from strong to weak countries.

The IMF offers a pair of contracts $\left(c^g, c^b\right)$ that satisfy limited pledgeability, continuation and limited outside liquidity constraints. Without loss of generality, I restrict attention to incentive compatible contracts. The mechanism design problem has two extra set of constraints: participation and break even constraints. I turn in detail to each of these next.

A type that rejects the allocation proposed by the IMF may still go to the private capital markets for funding. I assume that private capital markets do not find out about the IMF meeting (in case of rejection) and therefore, the country may always obtain its no-IMF benchmark allocation. In terms of the mechanism design problem, this means that an allocation will be implemented as long as it generates a Pareto improvement relative to the no-IMF equilibrium described in the previous section. There will be a participation constraint for each type.

How realistic is this assumption? Even when the formal procedure requires a country to make the request for a CCL, it has been common practice for IMF officials to have informal and confidential meetings with country representatives, out of which private markets do not seem to learn much. For example, in the year 2000, the IMF staff conducted in depth assessments for 15 countries against the eligibility criteria. 7 countries were identified as potentially eligible and conversations between the candidates and IMF staff were held. This procedure was entirely confidential, the results were not even shared with the IMF Board.[10]

Given that the IMF may commit funds (up-to $\bar{L}$) in case of a shock, it is allowed to provide insurance across states of the world. In the following subsections I consider two cases in turn : in the first case contracts offered by the IMF $\left(c^g, c^b\right)$ are required to break even type by type. This means that contracts may shift resources across states of the world but not across different types (unless $c^g = c^b$) . In the second case, I require contracts offered by the IMF to break even in expectation, that is, it may entail redistributions across types.

It is important to have in mind the kind of settings that would require contracts to break even type by type versus in expectation. For simplicity, I have unified in the IMF the role of funding and insurance provider. However, a natural division of tasks would be to have the IMF providing insurance and capital markets providing funding.[11] To highlight the fact that insurance contracts signed with the IMF may reveal information to capital markets, consider the timing: initially countries arrange liquidity provision with the IMF, the liquidity provision arrangement is observable by private capital markets that provide funding for the projects. If the insurance contract menu offered by the IMF has $c^g \neq c^b$, private capital markets will learn types before contracting for funding. If insurance contracts do not redistribute resources across types and capital markets learn from the insurance agreement, cross subsidization across types is shut down whenever $c^g \neq c^b$. As in Basu (2009), the IMF mechanism design problem takes into account that its policies affect information revelation in equilibrium.

The break even in expectation case requires insurance contracts to allow for resource redistribution across types or require a higher degree of commitment from capital markets to break even in expectation in the funding contracts once types have been revealed $c^g \neq c^b$.[12]

[10] The refusal to adopt a pure rules-based framework to assess eligibility (keep discretionality) and the refusal to adopt systematic public assessments by the IMF Board of CCL eligibility, are other examples of practices that make inference (at capital markets) when an agreement with the IMF is not reached more difficult.

[11] The task division is based on the previous observation that the IMF CCLs are a sort of insurance that is not available in private capital markets and on the fact that "The IMF lends to countries with balance of payments difficulties. Unlike development banks, *the IMF does not lend for specific projects*". As a result, countries have to deal with institutions other than the IMF to finance investment projects.

[12] It could also be attained by making insurance contracting with the IMF non transparent. Either by keeping it confidential or, following Maskin and Tirole 1992, by offering each country a menu of contracts and having the country to choose from the menu after signing funding contracts with Capital Markets. I find those alternatives

I identify the conditions under which the IMF may offer a pair of insurance contracts that generates a Pareto improvement relative to the no-IMF equilibrium described in the previous section. First, I solve the mechanism design problem when insurance contracts offered by the IMF are required to break even type by type. Then I relax the requirement and allow them to break even in expectation.

1.4.1 Type by type

Consider the case in which the insurance contracts offered by the IMF are required to break even type by type. IMF contracts $c^i = \left(P_{ns}^i, P_s^i, x^i, L^i\right)$ specify for each type i a payment P_{ns}^i in case of no shock, a payment P_s^i, a probability of continuation x^i and liquidity provision L^i in case of a shock. No cross subsidization across types is allowed if $c^g \neq c^b$. The IMF maximizes its objective function subject to:

1. incentive compatibility constraints

$$\begin{aligned} Z_1 - P_{ns}^g - A &\geq Z_1 - P_{ns}^b - A \\ (1-\lambda)\left(Z_1 - P_{ns}^b\right) + \lambda x^b \left(Z_1 - P_s^b\right) - A &\geq (1-\lambda)\left(Z_1 - P_{ns}^g\right) + \lambda x^g \left(Z_1 - P_s^g\right) - A \end{aligned}$$

2. break even constraint. If $c^g \neq c^b$

$$\begin{aligned} I - A &\leq P_{ns}^g \\ I - A &\leq (1-\lambda) P_{ns}^b + \lambda x^b \left(P_s^b - \rho\right) \end{aligned}$$

If $c^g = c^b$

$$I - A \leq \gamma P_{ns} + (1-\gamma)\left[(1-\lambda) P_{ns} + \lambda x \left(P_s - \rho\right)\right]$$

attractive from a theoretical point of view, but it is not clear they constitute feasible policies for an institution like the IMF.

3. limited pledgeability and feasibility of the liquidation policy constraints (for $i = g, b$)

$$\begin{aligned} P^i_{ns}, P^i_s &\leq Z_0; \\ 0 &\leq x^i \leq 1 \end{aligned}$$

4. continuation constraint

$$x^i \left(\rho - P^i_s\right) \leq L^i$$

5. limited outside liquidity constraint

$$L^i \leq \bar{L}$$

6. Pareto improving relative to "no-IMF" equilibrium.

In the appendix I show how these constraints are obtained from the decentralized problem in which countries agree first on liquidity provision from the IMF and later face private capital markets to get funding.

I first restrict attention to pooling contracts. Clearly, the no-IMF equilibrium allocation is still attainable. Any pooling contract specifying a positive probability of continuation will require a higher payment in case of no shock. As a result, the good type's utility is maximized by the pooling contract that allows for no continuation in case of a shock.

Proposition 7 *No pooling contract $c = c^g = c^b$ Pareto dominates the original no-IMF (pooling) equilibrium.*

Therefore, if there exists a contract that results in a Pareto improvement relative to the no-IMF equilibrium, it has to induce separation of types. I turn now to separating contracts.

Consider the case in which outside liquidity provision is abundant $\left(\bar{L} = \rho - Z_0\right)$ so we may ignore the continuation and limited outside liquidity constraints. As we have assumed $1 > \lambda^b > \lambda^g = 0$, giving each type its symmetric information payoff is incentive compatible and breaks even type by type. Such allocation is the best separating allocation for the good type, who is strictly better compared to the no-IMF benchmark. Also, under the assumption $Z_1 - \rho > I - A$, the weak type prefers receiving the symmetric information benchmark allocation with abundant liquidity $\left(\bar{L} = \rho - Z_0\right)$ to the no-IMF benchmark for any value of γ (which indexes the size of the cross subsidy).[13]

Therefore, for $\bar{L} = \rho - Z_0$, the best separating allocation for the good type strictly (which gives each type its symmetric information benchmark) Pareto dominates the no-IMF equilibrium. The basic idea is that there is enough outside liquidity to compensate the bad type (with continuation in case of a shock) for the loss in cross subsidies. However, this is no longer the case when outside liquidity is limited.

Proposition 8 *Given that $Z_1 - \rho > I - A$, and the requirement for contracts to break even type by type,*

- *For not enough outside liquidity provision $\bar{L} \in \left[0, \bar{L}^{\min}\right]$ the introduction of the IMF does not allow for allocations that Pareto dominate the original no-IMF (pooling) equilibrium.*
- *For sufficient outside liquidity provision $\bar{L} \in (\bar{L}^{\min}, \rho - Z_0]$ the introduction of the IMF allows for separating allocations that Pareto dominate the original no-IMF (pooling) equilibrium.*
- *The cutoff level of outside liquidity $\bar{L}^{\min}$ is given by*

$$\bar{L}^{\min} = \frac{\gamma}{\gamma + (1-\gamma)(1-\lambda)} \frac{I - A}{Z_1 - \rho} (\rho - Z_0)$$

Consider first the subset of the restrictions faced by the IMF that include: the break even constraint, the continuation constraint and the limited pledgeability constraints for the bad type together with the limited outside liquidity constraint given by:

$$x^b \left(\rho - P_s^b\right) \leq \bar{L}$$

The maximum level of utility that may be granted to the bad type subject to this group of constraints was derived in section 2 and is given by

$$U_b^b\left(\bar{L}\right) = (1-\lambda) Z_1 + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_1 - \rho) - I$$

[13] If the assumption $Z_1 - \rho > I - A$ did not hold, the statement would still be true but only for a range of values of γ.

Whenever $\bar{L} < \bar{L}^{\min} = \frac{\gamma}{\gamma+(1-\gamma)(1-\lambda)} \frac{I-A}{Z_1-\rho} (\rho - Z_0)$ the maximum utility that can be granted to the bad type is less than what he obtains under the no-IMF equilibrium, and therefore, it is impossible for the IMF to find a Pareto improvement.

The minimum level of liquidity required to generate a Pareto improvement relative to the no-IMF benchmark $\left(L^{\min}\right)$ is increasing in γ. The reason is that the cross subsidy when pooling for the weak type is increasing in γ (and his symmetric information payoff is independent of γ). The "proximity" of a crisis in the developed economies, captured by lower cross subsidies to the weak type (lower γ) makes it easier to separate types. Also, $L^{\min}$ is increasing in the size of the shock ρ and in the probability of the shock λ. This is a consequence of the fact that in this particular setting every shock results in liquidation in the absence of the IMF. In this setting, the "proximity" of a crisis in the emerging economies (higher λ or ρ) makes it harder to separate types.

To complete the proof, we still have to show that for every $\bar{L} \in (\bar{L}^{\min}, \rho - Z_0]$ the IMF can find contracts that Pareto dominate the no-IMF benchmark. Consider assigning all the liquidity to the bad type and giving the bad type its symmetric information allocation (given $\bar{L} \in [0, \rho - Z_0]$). The bad type will then have continuation probability $x^b = \frac{\bar{L}}{\rho - Z_0}$ and payments $P_s^b = Z_0, P_{ns}^b = \frac{I-A}{1-\lambda} + \frac{\lambda}{1-\lambda}\bar{L}$ that yield utility level $U_b^b\left(\bar{L}\right) = (1-\lambda) Z_1 + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_1 - \rho) - I$.

We choose the allocation for the good type that maximizes his utility $Z_1 - P_{ns}^g - A$ subject to the break even constraint for the good type

$$P_{ns}^g \geq I - A$$

the incentive compatibility constraint for the good type

$$(1-\lambda)\left(Z_1 - P_{ns}^g\right) + \lambda x^g \left(Z_1 - P_s^g\right) - A \leq U_b^b\left(\bar{L}\right)$$

and the limited pledgeability constraints for the good type $P_{ns}^g, P_{ns}^g \leq Z_0; 0 \leq x^g \leq 1$.

The solution is given by $x^g = 0$ and $P^g_{ns} = \max\left\{I - A, \frac{I-A}{1-\lambda} - \frac{\lambda}{1-\lambda}\frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho)\right\}$ which satisfies the limited pledgeability constraint $P^g_{ns} \leq Z_0$. So

$$P^g_{ns} = \begin{cases} \frac{I-A}{1-\lambda} - \frac{\lambda}{1-\lambda}\frac{\bar{L}}{\rho-Z_0}(Z_1 - \rho) \text{ if } \bar{L} \in \left[0, \tilde{L}\right] \\ I - A \text{ if } \bar{L} \in \left[\tilde{L}, \rho - Z_0\right] \end{cases}$$

where $\tilde{L}$ is given by

$$\tilde{L} = \frac{I - A}{Z_1 - \rho}(\rho - Z_0) < \rho - Z_0$$

For each region, we need to verify if the proposed allocations satisfy the incentive compatibility constraint for the good type and if it yields a Pareto improvement relative to the no-IMF equilibrium.

In the region $\left[\tilde{L}, \rho - Z_0\right]$, the IC for the weak type is satisfied since

$$P^g_{ns} = I - A \leq P^b_{ns} = \frac{I - A}{1 - \lambda} + \frac{\lambda}{1 - \lambda}\bar{L}$$

The allocations yield a higher payoff (than in the no-IMF equilibrium) to the good type provided that

$$Z_1 - I \geq Z_1 - \frac{I - A}{\gamma + (1 - \gamma)(1 - \lambda)} - A$$

which is always satisfied. The allocations yield a higher payoff (than in the no-IMF equilibrium) to the bad type provided that $\bar{L} \geq \frac{\gamma}{\gamma+(1-\gamma)(1-\lambda)}\frac{I-A}{Z_1-\rho}(\rho - Z_0)$ as was previously shown.

In the region $\left[0, \tilde{L}\right]$, the IC for the weak type is satisfied since

$$P^g_{ns} = \frac{I - A}{1 - \lambda} - \frac{\lambda}{1 - \lambda}\frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho) \leq P^b_{ns} = \frac{I - A}{1 - \lambda} + \frac{\lambda}{1 - \lambda}\bar{L}$$

The allocations yield a higher payoff (than in the no-IMF equilibrium) to the good type provided that

$$Z_1 - \left(\frac{I - A}{1 - \lambda} - \frac{\lambda}{1 - \lambda}\frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho)\right) - A \geq Z_1 - \frac{I - A}{\gamma + (1 - \gamma)(1 - \lambda)} - A$$

which is satisfied as long as $\bar{L} \geq \frac{I-A}{Z_1-\rho} \frac{\gamma}{\gamma+(1-\gamma)(1-\lambda)} (\rho - Z_0)$, the same condition necessary for the bad type to get more than under the no-IMF equilibrium.

Notice that in this region the break even constraint for the strong type is not binding ($P_{ns}^g > I - A$). To achieve separation it is required that the good types leave some money on the table. This is a costly action by the strong types to credibly signal their credentials.

1.4.2 In expectation

When contracts are required to break even in expectation instead of type by type, the mechanism design problem for the IMF remains the same except for the break even constraint, that is now given by

$$\gamma\left[I - A - P_{ns}^g\right] + (1-\gamma)\left[I - A - (1-\lambda) P_{ns}^b - \lambda x^b \left(P_s^b - \rho\right)\right] \leq 0$$

Irrespective of the size of outside liquidity $\bar{L}$ the introduction of the IMF generates a Pareto improvement relative to the no-IMF benchmark. Consider, for example, contracts that keep the same cross subsidy from strong to weak types but also allow the weak type to purchase insurance

$$\begin{aligned} P_{ns}^g &= \frac{I-A}{\gamma+(1-\gamma)(1-\lambda)} < P_{ns}^b = P_{ns}^g + \frac{\lambda}{1-\lambda}\bar{L} \\ x^g &= 0 < x^b = \frac{\bar{L}}{\rho - Z_0}; P_s^b = Z_0 \end{aligned}$$

Such contracts are incentive compatible and break even in expectation, leave the strong types indifferent relative to the no-IMF benchmark and leave the weak types strictly better (if $\bar{L} > 0$).

Proposition 9 *when contracts are required to break even in expectation, any $\bar{L} > 0$ allows the IMF to make a Pareto improvement relative to the no-IMF equilibrium. In cases of limited outside liquidity provision ($\bar{L} < L^{\min}$) some cross subsidization from good to bad types is required.*

When there is abundant liquidity ($\bar{L} \geq L^{\min}$), the previous Proposition follows from the results for contracts that break even type by type. When $\bar{L}$ is limited ($\bar{L} < L^{\min}$), the fact that contracts have to break even in expectation does not eliminate all cross subsidization. Actually, some cross subsidization is strictly required.

1.4.3 CCLs in practice

Since 1999 three different contingent lending facilities have been introduced by the IMF: the Contingent Credit Lines (CCL), the Short Term Liquidity facility (SLF) and the Flexible Credit Lines (FCL). They all shared the same basic premise: increase eligibility requirements ex ante in order to provide reduced conditionality ex post. The CCL was allowed to expire in 2003 and the SLF introduced in October 2008 was replaced by the FCL in March 2009. Both the CCL and the SLF failed to attract a single borrower request.

The reluctance of the targeted emerging economies to join these facilities resulted in consecutive re-designs to provide more appealing terms. In November 2000 the CCL's conditions for activation were simplified to enhance automaticity, also the rate of charge and the commitment fee were reduced. Under the SLF ex-post conditionality was further reduced. The FCL increased the size of the committed resources to 10 times the quota (compared to 3-5 under the CCL and SLF) and extended the repayment period to 3.5 to 5 years (compared to 3 months under the SLF). Mexico (47bn), Poland (21bn) and Colombia (11bn) are currently enrolled in the FCL.

This sequence of re-designs in the facility does not provide direct evidence in favour of the signaling story in this paper. However, it is interesting to read the sequence of events through the lens of the model. The contingent credit lines are associated with a signaling cost and with a benefit resulting from reduced inefficient liquidation of the projects. Holding everything else constant, re-designs improving the terms of IMF external insurance help overcome the signaling costs.

So far we have used the parameter $\bar{L}$ to index the level of liquidity the IMF may provide in case of a shock. As such, $\bar{L}$ is a measure of how good the IMF contingent lines are at providing insurance. Of course, there are many dimensions other than the size that determine how good an insurance contract is. Take, for example, a context where the bad type faces a variety of liquidity shocks, some of which are contractible with the IMF and some of which are not. All shocks are identical in the sense that they require a reinvestment ρ for continuation. Only a fraction Φ of the shocks is insurable by the IMF, meaning that the IMF can commit to provide funds up to $\bar{L}$ in those states of the world. Under our assumptions, weak countries optimally choose continuation $\frac{\bar{L}}{\rho - Z_0}$ in each of the insurable states, yielding utility

$$U^b_{symm}\left(\bar{L}, \Phi\right) = (1-\lambda) Z_1 - I + \lambda \Phi \frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho)$$

The symmetric information payoff for the bad type depends on Φ in the same way as it depends on $\bar{L}$. Even if I have presented the results in terms of the size of liquidity provision, it should be understood more generally as how attractive the terms of IMF insurance are (e.g. size, maturity, automaticity).

1.5 Endogenous effort choice

The possibility that liquidity provision by the IMF may induce debtor moral hazard has been a concern for the design of the Contingent Credit Lines. Insurance across states of nature makes bad states less unattractive and therefore may discourage governments' costly actions that reduce the probability of adverse macroeconomic shocks. This is one of the concerns that the inclusion of ex-ante eligibility criteria has been designed to address (at least partially). In this section, I analyze the effect of liquidity provision by the IMF on crisis prevention effort in the setting of my model. I show that optimal crisis prevention effort has a non-monotone relationship with IMF liquidity provision.

The relationship between IMF interventions and debtor moral hazard has been theoretically analyzed under different settings. Jeanne and Zettlemeyer (2004) consider a case in which borrowers may pledge more income to the IMF than to the private lenders. They show that IMF intervention may increase or decrease domestic efforts to avoid a crisis, although this is not moral hazard in strict sense if the IMF lends at actuarially fair rates. Morris and Shin (2006) study the catalytic finance role of the IMF. In their setting the IMF reduces an ex-post inefficiency by solving creditor coordination failure. Adjustment effort (as a function of underlying fundamentals) with and without IMF cannot be unambiguously ranked. Basu (2009) explores a setting with moral hazard followed by adverse selection in which the IMF allows for redistributive transfers ex post. He concludes that IMF intervention can ameliorate the moral hazard problem ex ante.

I analyze the effect of liquidity provision by the IMF on crisis prevention effort by the bad type. In particular, I restrict attention to the case in which the bad type receives the maximum of the pooling equilibrium without the IMF and his symmetric information payoff given liquidity $\bar{L}$ (as in the case in which contracts are required to break even type by type). I do not consider the case in which contracts are redesigned to elicit effort.

Assume that the bad type may exert some effort e to reduce the probability of a liquidity shock $\lambda(e)$ at a cost $c(e)$. In particular, assume $\lambda(e) = \lambda - e$ and $c(e) = b\frac{e^2}{2}$. I choose the parameter b to obtain interior solutions. For e to belong to $[0, a < \lambda]$ I require $b > Z_1/\lambda$.

Given outside liquidity $\bar{L}$, the bad type's utility level is given by

$$\max \left\{ \begin{array}{c} \max_e (1-\lambda+e)\left(Z_1 - \frac{I-A}{\gamma+(1-\gamma)(1-\lambda+e)}\right) - A - b\frac{e^2}{2}; \\ \max_e (1-\lambda+e) Z_1 + (\lambda - e)\frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho) - I - b\frac{e^2}{2} \end{array} \right\}$$

For low levels of outside liquidity $\bar{L}$, the types will remain pooled. The optimal effort choice $\tilde{e}$ while types remain pooled is independent of $\bar{L}$ and solves the first order condition

$$Z_1 - \frac{\gamma}{[\gamma + (1-\gamma)(1-\lambda+\tilde{e})]^2}(I - A) = b\tilde{e}$$

When $\bar{L}$ is large enough to attain separation of types, the optimal effort level $e^*(\bar{L})$ is given by

$$e^*(\bar{L}) = \frac{1}{b}\left[Z_1 - \frac{\bar{L}}{\rho - z_0}(Z_1 - \rho)\right]$$

Effort provision is decreasing in $\bar{L}$, ranging from $e^*(0) = Z_1/b$ to $e^*(\rho - Z_0) = \rho/b$.

The minimum size of outside liquidity required for the IMF to attain separation of types is denoted $\tilde{L}$ when effort is chosen optimally and $L^{\min}(\tilde{e})$ when effort is fixed at the pooling level $\tilde{e}$. The following Proposition summarizes the results:

Proposition 10

- *Small size interventions ($\bar{L}$ in $[0, \tilde{L})$) will not be accepted by the weak type and therefore do not affect effort choice relative to the no-IMF benchmark.*
- *Intermediate size interventions ($\bar{L}$ in $[\tilde{L}, L^{\min}(\tilde{e}))$) strictly increase effort choice by the weak country relative to the no-IMF benchmark.*

- *Large size interventions ($\bar{L}$ in $[L^{\min}(\tilde{e}), \rho - Z_0]$) may increase or decrease crisis prevention effort relative to the no-IMF benchmark.*
- *In the range* $\left[\tilde{L}, \rho - Z_0\right]$ *, effort choice is decreasing in liquidity provision.*

The size of the liquidity provision in case of a shock $\bar{L}$ matters in two respects: it determines whether the IMF may induce separation of types or not, and conditional on separation it affects the optimal choice of effort. While countries remain pooled the bad type does not receive the entire marginal payoff for increasing his effort choice. As a result, in the no-IMF benchmark, effort provision is lower than in the symmetric information setting.

Once liquidity is large enough to attain separation, the bad type receives the marginal return on its effort choice. The effect of internalizing the full returns in the separation determines the existence of a region in which crisis prevention effort increases relative to the no-IMF benchmark. Conditional on separation, liquidity provision prevents inefficient liquidation in case of a shock, making the shock scenario less unattractive and the optimal effort provision declines.

The possibility that liquidity provision by the IMF may reduce crisis prevention effort by debtor countries has been a concern for the design of the Contingent Credit Lines. In the setting of my model, the relationship between the two variables is non-monotone. Optimal crisis prevention effort increases (relative to the no-IMF benchmark) for intermediate size liquidity interventions. The reason behind the result is the existence of a minimum intervention scale for the weak type to take on the IMF liquidity provision and therefore, internalize the full return on an extra unit of effort.

1.6 Additional country types

An alternative signaling story is that the target economies of this IMF facility may take a costly action (i.e. not taking the contingent credit line) to credibly signal their type.[14] This story is possibly complementary to the one in the basic framework considered so far, but it is important to understand the differences between them. Consider a setting with 3 types of countries: good, medium and bad. Take the target economy of the IMF to be the medium

[14] Although in a different setting, such story is in line with Marchesi and Thomas (1999). In their paper the costly action that enables stronger countries to credibly signal their type is given by costly IMF conditionality.

type. The medium type may benefit from being taken for a strong type and is concerned about being confused with a weak type. We could expect the target economies to take actions to mimic stronger types and to differentiate themselves from worse types. These represent two different kinds of signaling concerns. The discussion in the previous sections is centered around the ("upward") concern that taking the CCL might reveal the country is not as good as the market had previously expected (losing cross subsidies). In this section I reinterpret the setting of the model to illustrate the ("downward") concern about being confused with a worse type.

Assume both types face liquidity shocks with positive probability ($\lambda^b > \lambda^g > 0$). I focus on the best separating allocation for the strong(er) type. The bad types impose an externality on the good types, and as it is standard in information theory, good types may take some costly action as a means of separation. In the setting of the model, the costly action takes the form of lower continuation in case of a crisis, or even no continuation at all. The reason is that good types face liquidity shocks with lower probability and therefore a lower probability of continuation is more costly to the bad types.

Proposition 11 *Provided that* $0 \leq \bar{L} \leq L' = \frac{I-A}{Z_1-\rho}\frac{\lambda^b-\lambda^g}{\lambda^b(1-\lambda^g)}(\rho - Z_0)$, *the best separating allocation for the strong(er) type involves no continuation for the strong type in case of a shock* ($x^g = 0$)*. Weak(er) types continue with probability* $x^g = \frac{\bar{L}}{\rho - Z_0}$.

Proposition 12 *Provided that* $L' = \frac{I-A}{Z_1-\rho}\frac{\lambda^b-\lambda^g}{\lambda^b(1-\lambda^g)}(\rho - Z_0) \leq \bar{L} \leq (\rho - Z_0)$, *the best separating allocation for the strong(er) type involves continuation with probability* $0 < x^g = \frac{(1-\lambda^g)\lambda^b\frac{\bar{L}}{\rho-Z_0}(Z_1-\rho)-(I-A)(\lambda^b-\lambda^g)}{(1-\lambda^g)\lambda^b(Z_1-Z_0)-(1-\lambda^b)\lambda^g(\rho-Z_0)} < 1$ *for the strong type in case of a shock. Weak(er) types continue with probability* $x^g = \frac{\bar{L}}{\rho-Z_0}$.

The good types choose lower continuation than they would under symmetric information. For low liquidity levels $(\bar{L} \leq L')$, the result is extreme, they choose not to insure the shock at all $(x^g = 0)$. Even if the IMF could hoard enough liquidity to separate types[15], the good types

[15] Assuming that $\lambda^g\left[\gamma(1-\lambda^g)+(1-\gamma)(1-\lambda^b)\right]Z_1 + (1-\gamma)(\lambda^b - \lambda^g)Z_0 < (1-\lambda^g)\left[\gamma\lambda^g + (1-\gamma)\lambda^b\right]\rho$ the following propositions follow:

Proposition 13 *No pooling allocation provides a Pareto improvement relative to the No IMF benchmark.*

Proposition 14 *Provided that* $0 \leq \bar{L} < \bar{L}^{\min} = \frac{\gamma}{\lambda^b}\frac{I-A}{Z_1-\rho}\frac{\lambda^b-\lambda^g}{\gamma(1-\lambda^g)+(1-\gamma)(1-\lambda^b)}(\rho - Z_0)$ *the IMF cannot generate a Pareto improvement relative to the No IMF benchmark (nor pooling nor separating).*

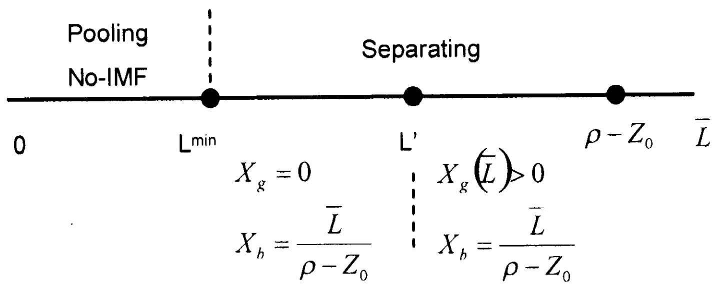

Figure 1-2: Best separating allocation for strong(er) type.

(that would benefit from insurance contracts under symmetric information), do not take the contingent credit lines to signal their type (provided $\bar{L} \leq L'$). That is, the fact that a country is "under-insuring" by not taking the CCL does not necessarily imply that the facility is not playing a role, as it was the case in the basic setting.

Note that in this reinterpretation of the model, I have shifted attention from weak types not taking the contingent lines to strong types not taking the contingent lines. The reason is that I am using reinterpretations of a 2 type model to understand a story that involves 3 types. The target economy for the IMF is the medium type. When I focus on the "upward" concern in a 2 type model, the target economy is the weaker country. When I focus on the "downward" concern, it is the stronger one.

A "*critical feature of the [IMF] CCL*" that I have abstracted from so far is given by the inclusion of eligibility criteria.[16] Pre-qualification requirements were included for a number of reasons. Firstly, to safeguard IMF resources when providing large sums with reduced conditionality. Secondly, to reduce moral hazard by shifting from ex post to ex ante conditionality. And finally, to provide signaling. The eligibility criteria could be used to "*..signal Fund's confidence in member's economic policy*". The objective was to "(set) *threshold for eligibility at an appropriately high level to avoid the risk of validating a policy framework that proved fragile.*" Based on this last point, it could be argued that the inclusion of the eligibility criteria is, at least in part, oriented towards ameliorating the "downward" concern.

Proposition 15 $\bar{L}^{\min} = \frac{\gamma}{\lambda^b} \frac{I-A}{Z_1-\rho} \frac{\lambda^b-\lambda^g}{\gamma(1-\lambda^g)+(1-\gamma)(1-\lambda^b)} (\rho - Z_0) < \frac{I-A}{Z_1-\rho} \frac{\lambda^b-\lambda^g}{\lambda^b(1-\lambda^g)} (\rho - Z_0)$.

[16] See Arregui 2008 for an analysis of the eligibility criteria in a context of 3 types.

1.7 Reserve accumulation

In reality, countries have access to a variety of insurance mechanisms other than IMF packages.[17] In particular, during the last decade, emerging economies have increasingly self-insured through the accumulation of international reserves. Even when optimally managed, this option entails substantial costs (see Caballero and Panageas 05a,b) and this is the reason why external insurance arrangements have been advocated as more efficient insurance mechanisms against small probability events (such as large capital outflows). The IMF challenge has been to provide the right facility for state contingent liquidity provision.[18]

In this section I connect my model with the ongoing debate about excessive reserve hoarding. Countries accumulate reserves for self insurance and for a variety of other reasons (e.g. by product of export led growth). Their use for self insurance is likely to remain as long as the state contingent alternatives are limited in the types of shock they may insure. Also, the fact that countries accumulate reserves for reasons other than self insurance influences their use for self insurance. The idea is that the signaling content (information revealing) of reserve hoarding is lower than that of IMF insurance.

In the setting of the previous sections, given the absence of a storage technology, the inability by the lenders to commit future resources implies that every macroeconomic shock inevitably results in project liquidation. IMF provision of outside liquidity was assumed to be the only source of insurance available to the countries. Consider now the introduction of reserves in the symmetric information setting. Access to a storage technology that yields one unit at $t = 1$ for each unit invested at $t = 0$ allows for full continuation in case of a shock. That is, the storage technology gets around the lenders' commitment problem by allowing lenders to hand in at $t = 0$ the resources needed at $t = 1$. If the storage technology is efficient, the IMF provides no advantage relative to the no-IMF benchmark.

However, if the storage technology is inefficient (e.g. it yields $\theta < 1$ units at $t = 1$ for each unit invested at $t = 0$) the introduction of the IMF still provides an efficiency gain relative to the no-IMF benchmark. By (partially) solving the commitment problem of the lenders, the IMF provides state contingent liquidity which is less costly than the use of the unconditional

[17] See Cordella and Levy Yeyati 2005 for an overview of available alternatives.
[18] See Holmstrom and Tirole 1998 for a discussion on the advantages of state contingent liquidity provision.

storage technology.

Consider the same setting as the one in the main section with the following variation, each type $i \in \{g, b\}$ has access to a storage technology that delivers θ^i units at $t = 1$ per unit invested at $t = 0$. For simplicity, the returns on the short term investment are assumed to be non pledgeable and initials funds are set to zero $A = 0$. The only source of pledgeable income is still the fixed size project.

Assume that $\theta^b < 1$, so that the storage technology for the weak country is inefficient. Provided that reserves hoarding is not too inefficient ($\theta^b > \frac{\rho - Z_0}{\rho - Z_0 + \lambda[Z_1 - \rho]}$), the bad type optimally chooses to hoard reserves in order to allow for project continuation in case of a shock. The utility level is given by

$$\begin{aligned} U^b_{symm,non\_contingent} &= (1-\lambda) Z_1 - I + \left[\left(\theta^b - 1 \right) + \lambda \theta^b \frac{Z_1 - \rho}{\rho - Z_0} \right] a^b_{symm,non\_contingent} \\ a^b_{symm,non\_contingent} &= \min \left\{ (1-\lambda) Z_0 - I ; \frac{\rho - Z_0}{\theta^b} \right\} \end{aligned}$$

Non contingent reserves make a loss $\theta^b - 1$ in every state, but they allow the project to survive with positive probability when it is hit by a shock. The amount of reserves is determined by the minimum between the amount required to achieve full continuation and what pledgeable income allows to borrow (recall that the fixed size project is the only source of pledgeable income).

Suppose instead that the country may purchase at a (actuarially fair) price λ a unit of good delivered at $t = 1$ in case of a shock. In this case, the uncontingent storage technology will not be used. The utility level is given by

$$\begin{aligned} U^b_{symm,contingent} &= (1-\lambda) Z_1 - I + \left[\lambda \left(\theta^b - 1 \right) + \lambda \theta^b \frac{Z_1 - \rho}{\rho - Z_0} \right] a^b_{symm,contingent} \\ a^b_{symm,contingent} &= \min \left\{ \frac{(1-\lambda) Z_0 - I}{\lambda} ; \frac{\rho - Z_0}{\theta^b} \right\} \end{aligned}$$

Contingent liquidity provision incurs the loss $\theta^b - 1$ only in case of a shock and allows for continuation of the project in such a case. This is exactly the sense in which state contingent provision of liquidity dominates uncontingent reserves. As before, the amount of reserves is determined by the minimum between the amount required to achieve full continuation and what pledgeable income allows the country to borrow. The efficiency gains generated by the use of contingent liquidity relax the credit constraints, potentially providing an extra channel to increase utility levels, i.e. $a^b_{symm,contingent} \geq a^b_{symm,non\_contingent}$.

When state contingent liquidity provision spans the entire liquidity shock space, it dominates reserves hoarding as an insurance mechanism. Consider instead a setting with multiple liquidity shocks some of which are contractible and some of which are not. An extra unit of reserves loses ex post when there is no crisis and pays off in case of any shock. An extra unit of IMF insurance does not lose if there is no crisis, loses if there is an uninsurable shock and pays off only if the shock that it insures happens. The narrower the circumstances under which the CCL can be withdrawn limits the usefulness of the facility vis a vis reserves accumulation.

Such an environment with un-contractible shocks is natural given that liquidity crises are very hard to define in an uncontroversial way ex ante and also ex post. For example, under the original CCL facility, drawings were available only in response to contagion crises, i.e. "*difficulties [that] are judged to be largely beyond the members' control and to be primarily from adverse developments in international capital markets*". The purpose of this provision was to safeguard IMF resources by limiting moral hazard. Several IMF members raised their concern regarding the narrow use of the facility and the uncertainty generated by the ambiguous definition of the states of nature in which IMF resources would be available.

Let us now compare reserves hoarding with state contingent liquidity provision in a setting with asymmetric information. Given the assumption that only bad types face liquidity shocks with positive probability, accumulation of reserves would in principle be subject to the same signaling concerns that the IMF CCL have. To provide an explanation for the use of inefficient self-insurance instead of IMF liquidity along the lines of the model in this paper, it is required that the signaling content in hoarding reserves to be lower than the one in signing insurance agreements with the IMF. The fact that countries accumulate reserves for many reasons other than insurance (for example, reserve accumulation can be a by-product of export led growth) provides a possible explanation for this.

A way to capture this idea in the model is to assume that the short term investment for the good types is not inefficient i.e. $\theta^g > 1$. This assumption is only intended as a shortcut to make reserves hoarding less revealing than state contingent insurance.[19] Given that $\theta^g > 1$

[19] Alternatively, I have solved for the case in which economies are hit by exogenous random reserves require-

and $(1-\lambda) Z_0 - I < \frac{\rho - Z_0}{\theta^b}$ both good and bad types would like to invest as much as their pledgeable income permits in the short term technology. The good types because their short term technology is profitable, the bad types because (even if inefficient) it allows for project continuation in case of a shock. The benchmark in the absence of the IMF is given by a pooling allocation in which the bad types receive cross subsidies from the good types[20]

$$\begin{aligned} P_{pool} &= Z_0 \\ a_{pool} &= [\gamma + (1-\gamma)(1-\lambda)] Z_0 - I \end{aligned}$$

The interesting case, in line with the model in the previous sections, is when the bad type obtains higher utility by pooling than by revealing his type to obtain state contingent liquidity provision, i.e. $U^b_{pool} > U^b_{symm,contingent}$. IMF insurance provides efficiency gains relative to reserve hoarding. However, if contracts are required to break even type by type, they would not provide a Pareto improvement to the bad types relative to the no-IMF benchmark. As a result, IMF insurance might not be implemented.

Contingent credit lines that are too small, too narrow or not cross subsidized enough become less attractive relative to reserves hoarding, and might end up not being used if their signaling content is higher than the one of reserves.

1.8 Conclusions

During the last decade, emerging economies have increasingly self-insured through the accumulation of international reserves. Even when optimally managed, this option entails substantial costs and for this reason, external insurance arrangements have been advocated as more efficient insurance mechanisms against small probability events (such as large capital outflows). The IMF challenge has been to provide the right facility for state contingent liquidity provision.

Since 1999 three different contingent lending facilities have been introduced by the IMF: the Contingent Credit Lines (CCL), the Short Term Liquidity facility (SLF) and the Flexible

ments. However, this is not included in these notes.

[20] I assume $[\gamma + (1-\gamma)(1-\lambda)] Z_0 - I < \frac{\rho - Z_0}{\theta^b}$ and $\theta^g > \theta^b \left[1 + \frac{\lambda}{1-\lambda} \frac{Z_1 - Z_0}{\rho - Z_0}\right]$. The pooling allocation dominates the best separating allocation for the strong type.

Credit Lines (FCL). They all shared the same basic premise: increase eligibility requirements ex ante in order to provide reduced conditionality ex post. The CCL was allowed to expire in 2003 and the SLF introduced in October 2008 was replaced by the FCL in March 2009. Both the CCL and the SLF failed to attract a single borrower request.

A lesson from the CCL experience is that the informational content of these liquidity agreements is vital. If the IMF is going to advocate a shift from ex-post to ex-ante conditionality it is crucial that we understand the consequences in contexts of asymmetric information. This paper provides a tractable simple model to understand the role of signaling concerns in discouraging access to contingent credit lines. I show that in order to be implemented, contingent credit lines are required to be either large in scale or to allow for cross subsidization across countries. Also, optimal crisis prevention effort has a non-monotone relationship with IMF liquidity provision. For intermediate size liquidity provision, effort choice increases relative to the no-IMF benchmark.

In the construction of the model many simplifications were made to isolate the role of signaling concerns. In particular, there are two dimensions that I believe should be further explored to enrich the conclusions of this paper. Firstly, it is important to understand the process of creation of outside liquidity by the IMF. In terms of the model, what are the determinants of $\bar{L}$? What are the costs of liquidity provision and how can it be enhanced?

Secondly, I have modeled the liquidity shocks as an exogenous random process. A large literature has explored the coordination origin of such shocks (e.g. Chang and Velasco 1998-99). Moreover, even if not stated explicitly, part of the goal of IMF contingent credit lines is crisis prevention. It would be interesting to understand how the relationship between expectation coordination and signaling concerns works.

Bibliography

[1] Arregui, N., "IMF Contingent Credit Lines and Eligibility Criteria", work in progress, 2009.

[2] Borensztein, E. and P. Mauro, "The Case for GDP-Indexed Bonds", Economic Policy, 2004, Vol. 19, pp 165-216.

[3] Cordella, T. and E. Levy Yeyati, "A (New) Country Insurance Facility", IMF Working Papers 05/23, International Monetary Fund, 2005.

[4] Basu, S., "Optimal IMF Policy with Private Capital Flows", Chapter 3, PhD Dissertation, MIT, 2009.

[5] Broda, C., and E. Levy-Yeyati, "Dollarization and the Lender of Last resort," in Dollarization: Debates and Policy Alternatives, ed. by E. Levy-Yeyati and F. Sturzenegger, (Cambridge, Massachusetts: MIT Press), 2003.

[6] Caballero, R.J., "The Future of the IMF," MIT mimeo, January 2003.

[7] Caballero, R.J., and A. Krishnamurty, "A Vertical Analysis of Monetary Policy in Emerging Markets," MIT mimeo, March 2002a.

[8] Caballero, R.J., and A. Krishnamurty, "A Dual Liquidity Model for Emerging Markets," American Economic Review, Papers and Proceedings, May 2002b.

[9] Caballero, R.J., and S. Panageas, "Hedging Sudden Stops and Precautionary Recessions: A Quantitative Framework," NBER Working paper No. 9778 (Cambridge, Massachusetts: National Bureau of Economic Research), 2003.

[10] Caballero, R.J., and S. Panageas, "Contingent Reserves Management: An Applied Framework," NBER Working paper No.10786 (Cambridge, Massachusetts: National Bureau of Economic Research), 2004.

[11] Chang, R. and A. Velasco, "Financial Crises in Emerging Markets: A Canonical Model," Federal Reserve Bank of Atlanta, WP98-10, July 1998.

[12] Chang, R. and A. Velasco, "Financial Crises in Emerging Markets: Theory and Policy", Federal Reserve Bank of Atlanta, WP99-15, October 1999.

[13] Farhi, E., and J. Tirole , "Collective Moral Hazard, Maturity Mismatch and Systemic Bailouts," NBER Working Papers 15138, NBER, 2009.

[14] Holmstrom, B., and J. Tirole, "Private and Public Supply of Liquidity," Journal of Political Economy 106-1, February 1998, pp. 1-40.

[15] Holmstrom, B., and J. Tirole, "Modeling Aggregate Liquidity", The American Economic Review, Vol. 86, No. 2, May 1996, pp. 187-191

[16] IMF, 2003, Review of Contingent Credit Lines (IMF SM/03/64) available online at : http://www.imf.org/external/np/pdr/fac/2003/021103.htm

[17] Jeanne, O., and J. Zettelmeyer, "The Mussa Theorem: and Other Results on IMF Induced Moral Hazard," IMF Working Papers 04/192, International Monetary Fund, 2004.

[18] Lorenzoni, G., "Inefficient Credit Booms," Review of Economic Studies, 75 (3), July 2008, 809-833.

[19] Marchesi, S. and J. Thomas, "IMF Conditionality as a Screening Device", The Economic Journal, Vol. 109, N0. 454, Mar. 1999.

[20] Maskin, E. and J. Tirole, "The Principal-Agent Relationship with an Informed Principal, II: Common Values", Econometrica, Vol. 60, No. 1, 1992, pp1-42.

[21] Morris, S., and H.S. Shin, "Catalytic Finance: When Does It Work?" Journal of International Economics 70 (2006), 161-177.

[22] Tirole, J., "Financial Crises, Liquidity and the International Monetary System", Princeton University Press, 2002.

[23] Tirole, J., "The Theory of Corporate Finance", Chap 6, Princeton University Press, 2006.

1.9 Appendix

1.9.1 Symmetric information benchmark (proof of prop. 3)

The IMF offers contracts $c = (P_{ns}, P_s, x, L)$ that specify payments to the lender in case of no shock and in case of a shock and completion, a probability of continuation x and liquidity provision L in case of a shock. There is an exogenous supply of "outside" liquidity $\bar{L}$. The optimal contract for the country solves

$$\max_{L,P_s,P_{ns},x} (1-\lambda)(Z_1 - P_{ns}) + \lambda x (Z_1 - P_s) - A \quad \text{s.t.}$$

$$\begin{aligned} (1-\lambda) P_{ns} + \lambda x (P_s - \rho) &\geq I - A \\ P_{ns}, P_s &\leq Z_0; 0 \leq x \leq 1 \\ x(\rho - P_s) &\leq L \\ L &\leq \bar{L} \end{aligned}$$

Given condition 2 $(Z_0 \geq I - A + \lambda\rho)$, in the absence of the limited outside liquidity constraint $(L \leq \bar{L})$ the optimal allocation is given by $x = 1$ and (P_{ns}, P_s) such that

$$\begin{aligned} (1-\lambda) P_{ns} + \lambda x (P_s - \rho) &= I - A \\ P_s &\leq Z_0 \\ P_{ns} &\leq Z_0 \end{aligned}$$

If $(\rho - Z_0) \leq \bar{L}$ the outside liquidity constraint is not binding (no problem with ignoring it).

$$U_b = Z_1 - \lambda\rho - I$$

If $(\rho - Z_0) > \bar{L}$, then the outside liquidity constraint is binding. Then $P_s = Z_0$,

$$x = \frac{\bar{L}}{\rho - Z_0}$$

and P_{ns} such that $(1-\lambda) P_{ns} + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_0 - \rho) = I - A$

$$P_{ns} = \frac{I - A + \lambda \bar{L}}{1 - \lambda}$$

(note that $P_{ns} \leq Z_0$ given condition 2. The utility level is given by

$$U_b = (1-\lambda) Z_1 + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_1 - \rho) - I$$

which is increasing in $\bar{L}$ in $[0, \rho - Z_0]$.

Consider the case in which $(1-\lambda) Z_0 + \lambda (Z_0 - \rho) < I - A$ (which violates condition 2). In the absence of the limited outside liquidity constraint $(L \leq \bar{L})$ the optimal allocation is given by $P_s = P_{ns} = Z_0$ and

$$x = \frac{(1-\lambda) Z_0 - (I - A)}{\lambda (\rho - Z_0)} < 1$$

If $\frac{(1-\lambda)Z_0 - (I-A)}{\lambda} \leq \bar{L}$ the outside liquidity constraint is not binding (no problem with ignoring it).

If $\frac{(1-\lambda)Z_0 - (I-A)}{\lambda} > \bar{L}$ the outside liquidity constraint is binding. Then $P_s = Z_0$,

$$x = \frac{\bar{L}}{\rho - Z_0}$$

and P_{ns} such that $(1-\lambda) P_{ns} + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_0 - \rho) = I - A$

$$P_{ns} = \frac{I - A + \lambda \bar{L}}{1 - \lambda}$$

The utility level is given by

$$U_b = (1-\lambda) Z_1 + \lambda \frac{\bar{L}}{\rho - Z_0} (Z_1 - \rho) - I$$

which is increasing in $\bar{L}$ in $\left[0, \frac{(1-\lambda)Z_0 - (I-A)}{\lambda}\right]$.

1.9.2 Asymmetric information - No IMF (proof of prop. 6)

More generally a contract could specify a probability of financing x, a payment to the lender in case of financing and no shock P_{ns}, a payment to the lender in case of financing and shock, and an initial transfer from the borrower to the lender $\tilde{A}$ (the borrower keeps $A - \tilde{A}$). Note $\tilde{A} < 0$ is allowed, it would be an initial transfer from the lender to the borrower. Note that contracts may not specify continuation probabilities in the absence of the IMF.

Define

$$\begin{aligned} u_b^i &= x^i \left[\left(1-\lambda^i\right) \left(Z_1 - P_{ns}^i\right) + \lambda^i \left(-P_s^i\right) \right] - \tilde{A}^i \\ u_l^i &= x^i \left[\left(1-\lambda^i\right) P_{ns}^i + \lambda^i P_s^i - I \right] + \tilde{A}^i \end{aligned}$$

Note

$$u_b^i + u_l^i = x^i \left[\left(1-\lambda^i\right) Z_1 - I \right]$$

We want to find the best allocation for the strong type out of those that break even in expectation, are incentive compatible and satisfy the limited pledgeability constraints. That is,

$$\max x^g \left[Z_1 - P_{ns}^g\right] - \tilde{A}^g \quad \text{s.t.}$$

IC constraints for the good and for the bad type

$$\begin{aligned} x^g \left[Z_1 - P_{ns}^g\right] - \tilde{A}^g &\geq x^b \left[Z_1 - P_{ns}^b\right] - \tilde{A}^b \\ x^b \left[(1-\lambda)\left(Z_1 - P_{ns}^b\right) + \lambda\left(-P_s^b\right)\right] - \tilde{A}^b &\geq x^g \left[(1-\lambda)\left(Z_1 - P_{ns}^g\right) + \lambda\left(-P_s^g\right)\right] - \tilde{A}^g \end{aligned}$$

limited pledgeability constraints for $i = g, b$

$$\begin{aligned} P^i_{ns} &\leq Z_0 \\ P^i_{ns} &\leq 0 \\ \tilde{A}^i &\leq A \\ 0 &\leq x^i \leq 1 \end{aligned}$$

break even constraint in expectation constraint

$$\gamma \left[x^g \left[P^g_{ns} - I\right] + \tilde{A}^g\right] + (1-\gamma)\left[x^b \left[(1-\lambda) P^b_{ns} + \lambda P^b_s - I\right] + \tilde{A}^b\right] \geq 0$$

Note first that setting $P^g_s = 0$ just relaxes the IC constraint for the weak type. The incentive compatibility constraint for the weak type may be written as

$$u^b_b \geq u^b_b - \lambda x^g \left(Z_1 - P^g_{ns}\right)$$

and the break even constraint as

$$\gamma \left[x^g \left[Z_1 - I\right] - u^g_b\right] + (1-\gamma)\left[x^b \left[(1-\lambda) Z_1 - I\right] - u^b_b\right] \geq 0$$

Ignore for now the IC constraint for the good type (will verify later). Note the IC constraint for the bad type must bind $\left(u^b_b = u^b_b - \lambda x^g \left(Z_1 - P^g_{ns}\right)\right)$. We may rewrite the program as

$$\max_{x^b, x^g, P^g_s, \tilde{A}^g} u^g_b \text{ s.t.}$$

$$\gamma \left[x^g \left[Z_1 - I\right]\right] + (1-\gamma) x^b \left[(1-\lambda) Z_1 - I\right] + (1-\gamma) \lambda x^g \left(Z_1 - P^g_{ns}\right) \geq u^g_b$$

$$
\begin{aligned}
P_{ns}^{g} &\leq Z_0 \\
\tilde{A}^{g} &\leq A \\
0 &\leq x^{g}, x^{b} \leq 1
\end{aligned}
$$

$\left(P_s^b, P_{ns}^b, \tilde{A}^b\right)$ may be recovered using $u_b^g = u_b^b - \lambda x^g \left(Z_1 - P_{ns}^g\right).$

Given that $(1-\lambda) Z_1 - I > 0$, we set $x^b = 1$.

For $x^g = 0$ the maximum level of utility that the good type may obtain solves

$$\max_{x^b, x^g, P_s^g, \tilde{A}^g} -\tilde{A}^g \text{ s.t.}$$

$$(1-\gamma)\left[(1-\lambda) Z_1 - I\right] \geq -\tilde{A}^g$$

$$
\begin{aligned}
P_{ns}^{g} &\leq Z_0 \\
\tilde{A}^{g} &\leq A \\
0 &\leq x^{g} \leq 1
\end{aligned}
$$

that is, we set $(1-\gamma)\left[(1-\lambda) Z_1 - I\right] = -\tilde{A}^g$ which gives $(1-\gamma)\left[(1-\lambda) Z_1 - I\right]$ to the good type.

For $x^g = 1$ the maximum level of utility that the good type may obtain solves

$$\max_{x^b, x^g, P_s^g, \tilde{A}^g} Z_1 - \left(P_{ns}^g + \tilde{A}^g\right) \text{ s.t.}$$

$$\left[\gamma + (1-\gamma)(1-\lambda)\right] P_{ns}^g + \tilde{A}^g \geq I$$

$$P^g_{ns} \leq Z_0$$
$$\tilde{A}^g \leq A$$
$$0 \leq x^g \leq 1$$

so we set $\tilde{A}^g = A$ and $P^g_{ns} = \frac{I-A}{\gamma+(1-\gamma)(1-\lambda)}$. This gives the good type utility $Z_1 - \left(\frac{I-A}{\gamma+(1-\gamma)(1-\lambda)} + A\right)$. To compare the case $x^g = 0$ with the case $x^g = 1$, note that

$$
\begin{aligned}
(1-\lambda) Z_1 - I &\geq (1-\gamma)\left[(1-\lambda) Z_1 - I\right] \\
Z_1 - \frac{I-A}{\gamma + (1-\gamma)(1-\lambda)} - A &\geq Z_1 - \frac{I-A}{(1-\lambda)} - A
\end{aligned}
$$

so it suffices to show that $Z_1 - \frac{I-A}{(1-\lambda)} - A > (1-\lambda) Z_1 - I$, which follows from the assumption $(1-\lambda) Z_1 > I - A$.

What if $x_s \in (0,1)$? It can also be shown that the optimum is increasing in x_s.

1.9.3 Asymmetric information - IMF

Decentralization

Let the contracts signed with the IMF specify a payment to the IMF in case of no shock P^i_{ns}, a payment to the IMF in case of a shock and completion P^i_s and a payment to the country in case of a shock L^i, all conditional on the project getting funding in the capital markets. Let $c^i = \left(P^i_{ns}, P^i_s, L^i\right)$ denote the contract for type i. The IMF offers a contract menu $\left(c^g, c^b\right)$. Country i chooses contract c^i (due to the Revelation principle I restrict attention to incentive compatible contracts). The choice by the country is observed by capital markets that provide financing for the project $I - A$. The contracts with capital markets specify a payment in case no shock p^i_{ns} that break even given beliefs held by capital markets. The choice of contract affects beliefs about types and therefore the value of the required payment. If $c^s \neq c^w$ type is revealed (update in beliefs) and $p^i_{ns} = \frac{I-A}{1-\lambda^i}$. If $c^s = c^w$ type is not revealed (no update in beliefs) and $p^i_{ns} = \frac{I-A}{\gamma+(1-\gamma)(1-\lambda)}$

Timing:

- IMF offers a menu $\left(c^g, c^b\right)$.

- Country i chooses c^i.

- If $c^g \neq c^b$ type is revealed (update in beliefs).

  If $c^g = c^b$ type is not revealed (no update in beliefs).

  Contract with capital markets specifies $I - A$ in exchange for p in case of success. $p_{ns} \epsilon \left\{ \frac{I-A}{1-\lambda}, \frac{I-A}{\gamma+(1-\gamma)(1-\lambda)}, I - A \right\}$.

Consider separating contracts $c^g \neq c^b$. The set of restrictions for the IMF is given by: the break even constraint for the lenders

$$\left(1 - \lambda^i\right) p^i_{ns} = I - A$$

the break even constraint for the IMF (type by type)

$$\left(1 - \lambda^i\right) P^i_{ns} + \lambda^i x^i \left(P^i_s\right) \geq \lambda L^i$$

the limited pledgeability constraints

$$\begin{aligned} p^i_{ns} + P^i_{ns} &\leq Z_0 \\ P^i_s &\leq Z_0 \end{aligned}$$

the continuation constraints[21]

$$x^i \left[\rho - \left(Z_0 - P^i_s\right)\right] \leq L^i$$

the limited aggregate liquidity

$$L^i \leq \bar{L}$$

And the incentive compatibility constraints given by utility levels for type i

$$U^i_b = \left(1 - \lambda^i\right) \left[Z_1 - P^i_{ns} - p^i_{ns}\right] + \lambda^i x^i \left[Z_1 - Z_0\right] - A$$

[21] Assuming that the IMF may not be diluted.

Incentive compatibility

$$\begin{aligned}
\left[Z_1 - P_{ns}^g - p_{ns}^g\right] - A &\geq \left[Z_1 - P_{ns}^b - p_{ns}^b\right] - A \\
(1-\lambda)\left[Z_1 - P_{ns}^b - p_{ns}^b\right] + \lambda x^b \left[Z_1 - Z_0\right] - A &\geq (1-\lambda)\left[Z_1 - P_{ns}^g - p_{ns}^g\right] + \lambda x^g \left[Z_1 - Z_0\right] - A
\end{aligned}$$

Putting together the break even constraint for the lenders and for the IMF,

$$\left(1-\lambda^i\right)\left(P_{ns}^i + p_{ns}^i\right) + \lambda^i x^i P_s^i \geq \lambda L^i + I - A$$

and using the fact that the continuation constraint will bind, we obtain

$$\left(1-\lambda^i\right)\left(P_{ns}^i + p_{ns}^i\right) + \lambda^i x^i \left(Z_0 - \rho\right) \geq I - A$$

Analogously, if IMF contracts are required to break even in expectation (using the fact that $L^g = 0$ and the continuation constraint will bind for the weak country), we obtain

$$\gamma\left(P_{ns}^g + p_{ns}^g\right) + (1-\gamma)\left[(1-\lambda)\left(P_{ns}^b + p_{ns}^b\right) + \lambda x^b \left(Z_0 - \rho\right)\right] \geq I - A$$

Therefore, the restrictions consider in the text correspond to the decentralized problem.

1.9.4 In expectation (proof of prop. 9)

Consider the set of restrictions for the IMF:

1. IC for good

$$P_{ns}^b \geq P_{ns}^g$$

2. IC for bad (setting $x^g = 0$)

$$(1-\lambda)\left(Z_1 - P_{ns}^b\right) + \lambda x^b \left(Z_1 - P_s^b\right) \geq (1-\lambda)\left(Z_1 - P_{ns}^g\right)$$

3. Break even constraint

$$(1-\gamma)(1-\lambda)P_{ns}^b + \gamma P_{ns}^g + (1-\gamma)\lambda x^b \left(P_s^b - \rho\right) \geq I - A$$

4. Limited pledgeability constraint $(i = g, b)$

$$P^i_{ns}, P^i_s \leq Z_0$$

5. Pareto improvement for the good type

$$P^g_{ns} \leq \frac{I - A}{\gamma + (1-\gamma)(1-\lambda)}$$

6. Pareto improvement for the bad type

$$(1-\lambda)\left(Z_1 - P^b_{ns}\right) + \lambda x^b \left(Z_1 - P^b_s\right) \geq (1-\lambda)\left(Z_1 - \frac{I - A}{\gamma + (1-\gamma)(1-\lambda)}\right)$$

7. continuation restriction

$$x^b\left(\rho - P^b_s\right) \leq \bar{L}$$

Starting at the no IMF pooling equilibrium, all restrictions are satisfied. Consider the following deviation from the no IMF pooling equilibrium: for small $\varepsilon > 0$

$$\begin{aligned} P^b_s &= Z_0 \\ x^b &= \frac{\varepsilon}{\rho - Z_0} \\ P^g_{ns} &= \frac{I - A}{\gamma + (1-\gamma)(1-\lambda)} - \varepsilon_1 \\ P^b_{ns} &= \frac{I - A}{\gamma + (1-\gamma)(1-\lambda)} + \varepsilon_2 \end{aligned}$$

Note: provided ε_1 and ε_2 are positive, IC for good, limited pledgeability for good and Pareto improvement for good are satisfied. Continuation constraint is satisfied as long as ε is small and limited pledgeability for bad is satisfied provided ε_2 is small.

It remains to show that, for given small ε we may find positive ε_1 and ε_2 that satisfy IC for weak and break even constraint.

Subinto the expressions to obtain

$$\begin{aligned}\lambda\frac{\varepsilon}{\rho - Z_0}\left(Z_1 - Z_0\right) &\geq \left(1-\lambda\right)\left(\varepsilon_1 + \varepsilon_2\right)\\ \left(1-\gamma\right)\lambda\varepsilon &\geq \left(1-\gamma\right)\left(1-\lambda\right)\varepsilon_2 - \gamma\varepsilon_1\end{aligned}$$

We may find ε_1 and ε_2 that solve the previous equations with equality as functions of ε and show they positive and increasing in ε.

$$\begin{aligned}\frac{\lambda}{1-\lambda}\frac{\varepsilon}{\rho - Z_0}\left(Z_1 - Z_0\right) - \varepsilon_2 &= \varepsilon_1\\ \left(1-\gamma\right)\lambda\varepsilon &= \left(1-\gamma\right)\left(1-\lambda\right)\varepsilon_2 - \gamma\frac{\lambda}{1-\lambda}\frac{\varepsilon}{\rho - Z_0}\left(Z_1 - Z_0\right) + \gamma\varepsilon_2\\ \varepsilon_2 &= \varepsilon\lambda\frac{\left(1-\gamma\right) + \frac{\gamma}{1-\lambda}\frac{Z_1 - Z_0}{\rho - Z_0}}{\left(1-\gamma\right)\left(1-\lambda\right)+\gamma}\end{aligned}$$

$$\begin{aligned}\frac{\lambda}{1-\lambda}\frac{\varepsilon}{\rho - Z_0}\left(Z_1 - Z_0\right) - \lambda\frac{\left(1-\gamma\right) + \frac{\gamma}{1-\lambda}\frac{Z_1 - Z_0}{\rho - Z_0}}{\left(1-\gamma\right)\left(1-\lambda\right)+\gamma}\varepsilon &= \varepsilon_1\\ \left[\frac{\lambda}{1-\lambda}\frac{Z_1 - Z_0}{\rho - Z_0} - \lambda\frac{\left(1-\gamma\right)}{\left(1-\gamma\right)\left(1-\lambda\right)+\gamma} - \gamma\frac{\lambda}{1-\lambda}\frac{1}{\left(1-\gamma\right)\left(1-\lambda\right)+\gamma}\frac{Z_1 - Z_0}{\rho - Z_0}\right]\varepsilon &= \varepsilon_1\\ \left[\frac{Z_1 - \rho}{\rho - Z_0}\right]\varepsilon\frac{\left(1-\gamma\right)\lambda}{\left(1-\gamma\right)\left(1-\lambda\right)+\gamma} &= \varepsilon_1\end{aligned}$$

Therefore, as long as $\bar{L} > 0$ we may always find a deviation from the no IMF pooling equilibrium that provides some continuation in case of a shock for the bad type and that results in a strict Pareto improvement.

1.9.5 Effort choice (proof of prop. 10)

Call $U(\bar{L}, e) = (1-\lambda+e) Z_1 + (\lambda - e)\frac{\bar{L}}{\rho - Z_0}(Z_1 - \rho) - I - b\frac{e^2}{2}$ and $U(\bar{L}) = U(\bar{L}, e^*(\bar{L}))$. Note

$$\begin{aligned} U(0) &= (1-\lambda) Z_1 - I + \frac{Z_1^2}{2b} \\ U(\rho - Z_0) &= (1-\lambda) Z_1 + \lambda (Z_1 - \rho) - I + \frac{\rho^2}{2b} \\ U'(\bar{L}) &= \left[\lambda - e^*(\bar{L})\right] \frac{Z_1 - \rho}{\rho - z_0} > 0 \\ U''(\bar{L}) &> 0 \end{aligned}$$

Consider 2 cases:

Case 1: $Z_1 - \frac{\gamma}{\left[\gamma + (1-\gamma)\left(1-\lambda+\frac{\rho}{b}\right)\right]^2}(I - A) < \rho$. Implies $e^*(0) > e^*(\rho - Z_0) > \tilde{e}$.
Case 2: $Z_1 - \frac{\gamma}{\left[\gamma + (1-\gamma)\left(1-\lambda+\frac{\rho}{b}\right)\right]^2}(I - A) \geq \rho$. Implies $e^*(0) > \tilde{e} \geq e^*(\rho - Z_0)$.
How does $U(\bar{L} = 0)$ compare to U^{pool}? Compare first to $U^{pool}(e^*(0))$

$$U(\bar{L} = 0) - U^{pool}(e^*(0)) = (\lambda - e^*(0)) \left[-\frac{\gamma (I - A)}{\gamma + (1-\gamma)(1-\lambda+e^*(0))} \right] < 0$$

Using the fact that $U^{pool} > U^{pool}(e^*(0))$, then $U^{pool} > U(\bar{L} = 0)$. That is, when there is very little liquidity, the bad type will rather stay pooled.

How does U^{pool} compare to $U(\bar{L} = \rho - Z_0)$? Compare first to $U(\bar{L} = \rho - Z_0, \tilde{e})$ ...

$$U(\bar{L} = \rho - Z_0, \tilde{e}) - U^{pool} = (\lambda - \tilde{e}) \left[(Z_1 - \rho) - \frac{\gamma (I - A)}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})} \right] > 0$$

Since we have assumed $Z_1 - \rho > I - A$. Using the fact that $U(\bar{L} = \rho - Z_0) > U(\bar{L} = \rho - Z_0, \tilde{e})$, then $U(\bar{L} = \rho - Z_0) > U^{pool}$. That is, when there is sufficient liquidity, the bad type will take the liquidity offer.

Also, given that $U(\bar{L})$ is increasing in $\bar{L}$ we know there is a $\tilde{L}$ that makes the bad type indifferent between pooling or separating: $U^{pool} = U(\tilde{L})$.

Under case 1, the effort level increases relative to the effort level when pooled $\tilde{e}$ for all liquidity provision $\bar{L}$ in $(\tilde{L}, \rho - Z_0]$. In particular, at $\tilde{L}$ the effort choice has a discontinuity (jumps upwards).

What about under case 2? We know that for sufficient liquidity provision, the optimal effort choice will eventually be lower than the effort choice when pooled. However, I show that at $\tilde{L}$ the effort choice jumps upwards.

Given that $\tilde{L}$ satisfies $U^{pool} = U\left(\tilde{L}\right)$ and using the fact that $U\left(\tilde{L}\right) \geq U\left(\tilde{L}, \tilde{e}\right)$ we obtain

$$L^{\min}(\tilde{e}) = \frac{\gamma}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})} \frac{I-A}{Z_1 - \rho}(\rho - Z_0) \geq \tilde{L}$$

To show that effort choice must jump upwards at $\tilde{L}$, it suffices to show that it does not decrease at $L^{\min}(\tilde{e})$ (since $e^*\left(\bar{L}\right)$ is decreasing in $\bar{L}$ and $L^{\min}(\tilde{e}) \geq \tilde{L}$. That is, I need to show that $e^*\left(L^{\min}(\tilde{e})\right) \geq \tilde{e}$.

Note

$$\begin{aligned} e^*\left(L^{\min}(\tilde{e})\right) &= \frac{1}{b}\left[Z_1 - \frac{L^{\min}(\tilde{e})}{\rho - z_0}(Z_1 - \rho)\right] \\ &= \frac{1}{b}\left[Z_1 - \frac{\gamma}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})}(I-A)\right] \end{aligned}$$

So we must verify that

$$Z_1 - \frac{\gamma}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})}(I-A) \geq b\tilde{e}$$

which must hold, since we know from FOC that defines $\tilde{e}$

$$Z_1 - \frac{\gamma}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})} \frac{I-A}{\gamma + (1-\gamma)(1-\lambda+\tilde{e})} = b\tilde{e}$$

Chapter 2

Eligibility Criteria and IMF Contingent Credit Lines

Abstract

The inclusion of eligibility criteria was a critical feature of the IMF Contingent Credit Lines (CCL) to signal the Fund's confidence in a member's economic policy. Emerging economies with *"strong fundamentals"* were the target of the facility. The confidence at the IMF on the beneficial effects that a stamp of approval could have on financial markets, contrasted with the decision of countries not to join the CCL.

This paper studies the role of eligibility requirements that make the CCL close to a rating agency. Risk averse countries seek insurance in international capital markets against aggregate income shocks. Countries differ in the probability of being hit by a shock, which is private information. I focus on a No-IMF benchmark in which the target economies for the facility manage to separate from weaker countries by underinsuring. I model IMF CCL as the introduction of an imperfect stress test that countries may voluntarily take.

The quality of the stress test plays a crucial role to determine the type of equilibria that may arise. If the stress test is good enough, it allows for an equilibrium wherein target economies take the exam and weaker types do not. The IMF generates a Pareto improvement by providing target economies with a cheaper way to separate from weaker economies. However, if the quality of the stress test is low enough, there exists an equilibrium in which no country chooses to take the exam. Provided that the cost of the exam is low enough, I show that forcing all countries to take the exam (e.g. by publishing a list of eligible countries) Pareto dominates the equilibrium in which no country takes the exam.

2.1 Introduction

Emerging economies are exposed to significant macroeconomic risk. The IMF established the Contingent Credit Lines (CCL) in 1999 to "help countries with strong policies avoid contagion crises." The program was instituted to provide an efficient international insurance mechanism to guard against aggregate uncertainty. However, the CCL expired in 2003, never having been utilized. Its successor, the Short Term Liquidity Facility (SLF) introduced in October 2008, suffered the same fate. It was not until the introduction of the Flexible Credit Lines (FCL) in 2009 that the IMF managed to attract countries to join the program.

During the very same period, emerging economies increasingly self-insured through the accumulation of international reserves. Cordella and Levy Yeyati (2005) report that reserve hoarding, as a fraction of GDP, increased from 8.9% in 1992 to 18.1% in 2002 in their sample of 35 emerging economies. Even when optimally managed, this option entails substantial costs (see Caballero and Panageas 2005a,b) and for this reason, external insurance arrangements have been advocated as more efficient insurance mechanisms against small probability events (such as large capital outflows).

The IMF CCL had two distinctive features compared to other IMF lending facilities. The first distinctive feature was to increase eligibility requirements ex-ante. The CCL were not available for all IMF members. Each country had to request to join the program and the IMF Board would assess eligibility. Emerging economies with *"strong fundamentals"* were the target of the facility. The criteria to assess eligibility were broadly defined, allowing for some discretion in the evaluation process. The second distinctive feature was to reduce conditionality ex-post (for qualified countries), so that periods of exceptional financial pressure in the capital account could be met with higher "automaticity" (i.e. large amounts readily available) of funds.

IMF members that were the target of this facility expressed several concerns regarding the potential gains of ex-post reduced conditionality.[1] They suspected that the committed resources (3 to 5 times the country's quota) were not large enough to provide adequate protection in the case of a sudden stop. Also, the "automaticity" of funds was not guaranteed; activation reviews and IMF board approval were required. At the same time, other IMF arrangements were

[1] The SLF and FCL introduced modifications to make the ex-post reduced conditionality more attractive (see Arregui 2009).

improved to speed up the provision of similar amount of resources under similar conditions (but without the requirement of ex-ante eligibility). Throughout this paper I ignore the reduction in ex-post conditionality and focus on the role of eligibility requirements.[2]

The inclusion of eligibility criteria was a "*critical feature of the CCL*"[3] for several reasons. First, it eased concerns that IMF resources would be endangered. From a historical perspective this was the first IMF facility to provide access to large sums without conditionality. Second, the shift from ex-post to ex-ante conditionality was expected to reduce debtor moral hazard by fostering crisis prevention effort rather than crisis resolution effort (see Ostry and Zettelmeyer 2005; Jeanne, Ostry and Zettelmeyer 2008). Finally, restricted eligibility could be used to "*signal the Fund's confidence in the member's economic policy*". The goal was to set the threshold for eligibility at an appropriately high level to avoid the risk of validating a fragile or unsustainable policy framework.

The confidence at the IMF on the beneficial effects that a stamp of approval could have on financial markets, contrasted with the decision of countries not to join the CCL. Not a single IMF member requested to join the initial version of the facility. Quoting IMF reports: "*Potentially eligible countries were not confident that a CCL would be viewed as a sign of strength rather than weakness*".[4]

Eligibility requirements are present in other liquidity facilities other than the IMF CCL. At the national level, the Federal Reserve identified a "stigma" associated with borrowing at the Discount Window. Depository institutions expressed their concern that banking supervisors and others might see borrowing as a sign of financial weakness. "*Such stigma deterred some institutions from using adjustment credit when doing so would have been appropriate.*" In 2003, the Discount Window was modified along several dimensions. A crucial modification was the inclusion of eligibility requirements.[5] Both the Discount Window and IMF CCL include eligi-

[2] Arregui 2009 complements this paper by abstracting from the role of eligibility requirements and focusing on the gains of reduced ex-post conditionality.

[3] IMF, "Review of Contingent Credit Lines", SM/03/64, February 11, 2003, p. 11.

[4] IMF, "Review of Contingent Credit Lines", SM/03/64, February 11, 2003, p. 2.

[5] To qualify for primary credit a depository institution must be in generally sound financial condition as determined by its Reserve Bank. A Reserve Bank reviews an institution's condition on an ongoing basis using supervisory ratings and capitalization data. An institution assigned a composite CAMELS rating of 1, 2, or 3 that is at least adequately capitalized is eligible for primary credit unless supplementary information indicates that the institution is not generally sound.

bility criteria for the same goal: signaling. Quoting a Fed report: "*the proposed changes should appreciably reduce depository institutions' concern that borrowing will be perceived as a sign of weakness, as only financially sound institutions will have access to primary credit*". However, the specific procedures differ.[6] I focus on the procedures of the IMF CCL.

In this paper, I study the role of eligibility requirements that make the CCL close to a rating agency. Risk averse countries seek insurance in international capital markets against (aggregate) income shocks. Countries differ in the probability of being hit by a shock, and this probability is private information. I model the IMF CCL as an imperfect stress test which countries may take voluntarily.

A number of papers study the IMF's role when there is unobservable heterogeneity in countries' characteristics. Marchesi and Thomas (1999) analyze IMF conditionality as a costly action that enables strong countries to credibly signal their type. Basu (2009) and Arregui (2009) both argue that contracts signed with the IMF may reveal information to private capital markets, which should be incorporated into the mechanism design problem of the IMF. In Basu's paper, there is no ex ante heterogeneity and the IMF advantage is to commit to redistributive transfers across types ex post. In Arregui (2009), the IMF is able to commit resources that the private sector cannot, there is heterogeneity at the contracting stage and the IMF may not be able to cross subsidize types. In this paper, the IMF has an advantage relative to the market in extracting countries' private information.

Economic analysts disagree on the value of IMF economic monitoring and analysis. Some view the IMF as a "*... a technical institution which is* ***better suited to monitor*** *the global situation on a daily basis (...).*"[7] Others remain more skeptical because "*the IMF has a* ***patchy record with respect to being able to evaluate risks ex ante.***"[8] I parametrize the IMF's advantage over private capital markets to encompass both views.

First, I consider a setting with only two types of countries: target economies of the CCL facility (called medium types) and countries with a higher probability of adverse shocks (weak

[6] At the national level, banks are supervised periodically and the list of banks eligible to borrow at the Discount Window remains confidential. Also, the loans are usually very short term (typically overnight) and (over) collateralized.

[7] Calvo, Guillermo, "The G20 communiqué: Work in progress but good news for emerging markets", April 6 2009.

[8] Rodrik, Dani, "What would it take to make international finance safe?", April 07, 2009.

types). Without the IMF, medium types underinsure relative to the symmetric information benchmark to credibly signal the market their type. That is, the presence of weak types imposes a negative externality on medium types. Given the game's setting and assumptions, this is the unique equilibrium in capital markets. I refer to it as the No-IMF benchmark. The results obtained in this paper crucially depend on having both types separating in the No-IMF benchmark.

Once the stress test is introduced, countries must chose before going to the market whether to take the stress test or not. I consider a very stylized, simple sort of examination: with certain probability the test reveals the country's true type and it remains uninformative otherwise. We may think of this as the IMF being able to find enough evidence to certify to international capital markets the country's true type or not. I ignore the possibility of mistakes in IMF evaluations. The country taking an exam must face the costs it involves.

Stress test quality plays a vital role in determining the type of equilibria that may arise. As long as the quality of the stress test is good enough, the introduction of the exam allows for an equilibrium wherein target economies take the exam and weak types do not. Even if the exam is not perfectly revealing, in this equilibrium informational rents are eliminated and each country type obtains its symmetric information payoff. The IMF generates a Pareto improvement relative to the No-IMF benchmark by providing a cheaper way for target economies to separate from weak economies. This provides a rationale in favour of the introduction of country-requested CCL for those who optimistically view the IMF.

However, if stress test quality is low, there exists an equilibrium wherein no country chooses to take the exam. If a medium type takes the exam, there is only a small probability it can certify its true type. Otherwise, the exam remains uninformative, the medium type faces the cost of the exam and may still have to incur the costs of underinsurance to credibly signal its type.

If the cost of the exam is low enough, I show that forcing all countries to take the exam[9] Pareto dominates the equilibrium in which no country takes the exam. This provides a rationale for the observation by Cordella and Levy-Yeyati (2005) that: *"It is important to notice that the country entry (signaling) problem depends on the country's need to make the first move to access*

[9] And subsidizing the cost of the exam for those countries whose test is uninformative or reveals them weak.

the facility. These problems would be eliminated if eligibility criteria were made automatic." In fact, the IMF considered re-designing the facility in that direction: *"The potential changes to the CCL include [...] (ii) a more systematic process for periodic assessments of eligibility, independent of a request by the member, with the possibility of a published list of prequalified members;.. ".*[10]

In the model, the exam cost plays a crucial role in deterring countries from requesting the stress test. If we interpret exam cost as the cost of monitoring and evaluation, the costs do not appear significant. However, I propose an alternative interpretation of the cost of requesting a CCL. A typical concern shared by most of the emerging economies that were the target of this facility has been to achieve recognition as stable and reliable economies. For these economies in their "road to graduation", the decision to come to the IMF is largely determined by the image they want to portray to foreign investors. Quoting an IMF report: *"Such a request, even from a member with quite strong perceived fundamentals, could convey a signal of greater underlying vulnerabilities than the market had previously perceived (asymmetric information)."*[11] The "image" or "reputation" costs can be large in magnitude.

I modify the original setting to introduce a third type of country: a strong type without income shocks that does not request a CCL. There are dimensions along which weak and medium countries could benefit from being perceived as a strong type (e.g. countries with access to uncertain investment projects that are cheaper for stronger countries). The medium economy, which is the target of this IMF facility, has two fundamental signaling concerns: (1) an "upward" concern that an exam request reveals it is not the strong type; (2) a "downward" concern that after taking the imperfect test, it might still be mistaken for the weaker type. Both concerns explain the decision of target economies to refuse the eligibility test.

The structure of the paper is as follows. In section 2 I introduce the model, review the symmetric information benchmark and analyze the No-IMF asymmetric information case. Section 3 introduces the IMF in the asymmetric information context and evaluates the procedure which makes examinations compulsory. Section 4 extends the setting to introduce a third country type that the target economies of the CCL try to imitate. Section 5 concludes. All proofs are

[10] *IMF, "Review of Contingent Credit Lines", SM/03/64, February 11, 2003, p. 2.*
[11] IMF, "Review of Contingent Credit Lines", SM/03/64, February 11, 2003, p. 8.

included in the appendix.

2.2 The Model

I borrow the model's basic environment from Rothschild and Stiglitz 1976. The model consists of 2 agents: a risk averse country with utility function $u(x)$ increasing and strictly concave, and risk neutral international lenders. There are 2 periods: $t = 0$, the contracting stage, and $t = 1$. In period $t = 1$ the income for the country is y if there is no shock and $y - d$ if there is a shock. p represents the probability of an adverse shock. There is no discounting in the model.

At $t = 0$, the agents play a two stage game. First, the country proposes a contract $\alpha = (\alpha_1, \alpha_2)$, where α_1 represents a payment to the lender in the case of no shock, and α_2 is a payment from the lender in the case of a shock. The contract gives expected utility $u(\alpha_1, \alpha_2) = pu(y - d + \alpha_2) + (1 - p)u(y - \alpha_1)$. The lender observes the proposal and chooses whether to accept or not.

The symmetric information equilibrium is achieved by contract proposal α^* and acceptance rule $a^*(\alpha)$ when two conditions are satisfied: (1) for any contract α, the lender accepts the proposal if and only if it at least breaks even; (2) given $a^*(\alpha)$, the country chooses α optimally. As the country is risk averse and the lender is risk neutral, in equilibrium, the country is fully insured and consumption is decreasing in the probability of an adverse shock (consumption is $y - pd$ in both states of nature). The lender just breaks even.

In the following subsection, I introduce asymmetric information in the setting (two types -weak and medium- have private information about their probability of being hit by a shock) and characterize the market outcome in the absence of the IMF. I set the game and make assumptions in order to obtain the best separating allocation for the medium type as the unique equilibrium. Weak types impose an externality on medium types, who underinsure in order to credibly signal their type. I refer to this allocation as the No-IMF benchmark. All results of the introduction of the IMF CCL are measured with respect to this particular No-IMF benchmark.

2.2.1 Unobservable borrower heterogeneity

Consider the case of unobservable borrower heterogeneity. There are two types θ of countries $\{w\text{-eak}, m\text{-edium}\}$.[12] Countries differ in the probability of a shock, where $p^w > p^m$. These probabilities are private information for the country. Let λ be the probability of being a m-edium type.

The contracting period $t = 0$ has three stages. First, each country type θ proposes an option contract $\phi(\theta) = (\alpha, \tilde{\alpha})$ where both α and $\tilde{\alpha}$ specify payments for each state of the world (shock, no shock). The lender observes the proposal, updates his beliefs, and accepts if, and only if, the updated expected profit is not negative. Finally, if the lender accepts the proposal, the country must choose either α or $\tilde{\alpha}$. The equilibrium is defined as a Perfect Bayesian Equilibrium in the three stage game.

Maskin and Tirole (1992) proposed this three stage game structure. It departs both from the competitive screening equilibrium definition in Rothschild and Stiglitz (1976) and the two stage game in which each type's contract proposal is accepted or rejected. This game structure avoids dealing with non existent equilibria and limits the number of equilibria when coupled with an assumption regarding the fraction of weak types in the economy.

A crucial allocation in the Maskin and Tirole framework is the low information intensity optimum (liio). The low information intensity optimum (liio) is given by the allocation in which weak types get their symmetric information payoff $u^w_{symm} = u(y - p^w d)$ and medium types attain their maximum utility level subject to a breakeven constraint for lenders and an incentive compatibility constraint, which guarantees that weak types do not rather pretend to be medium types. The medium type's payoff is denoted u^m_{liio} and solves:

$$u^m_{liio} = \max_{\alpha_1, \alpha_2} p^m u(y - d + \alpha_2) + (1 - p^m) u(y - \alpha_1) \quad \text{s.t.}$$

$$\begin{aligned} 0 &\leq -p^m \alpha_2 + (1 - p^m) \alpha_1 \\ u^w_{symm} &\geq p^w u(y - d + \alpha_2) + (1 - p^w) u(y - \alpha_1) \end{aligned}$$

[12] I call country types "weak" and "medium" because a "strong" type is introduced in Section 4.

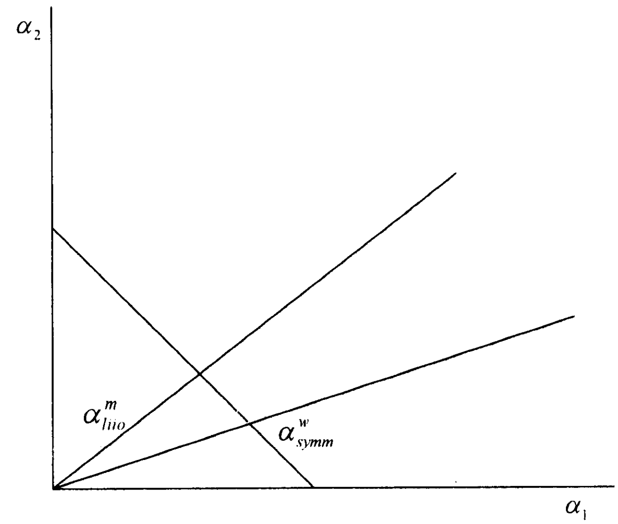

Figure 2-1: Low information intensity optimum (liio)

At any arbitrary (α_1, α_2) the slope of the indifference curve for each type is given by $\frac{1-p^i}{p^i}\frac{u'(y-\alpha_1)}{u'(y-d+\alpha_2)}$ which is decreasing in p^i. Given the medium types' lower probability of facing adverse shocks, they are less eager to obtain insurance. Both constraints must bind. Therefore, the solution is given by the intersection of the two constraints. The medium types underinsure relative to the symmetric information benchmark to separate themselves from weak types. That is, the presence of the weak types imposes a negative externality on the medium types.

The liio is depicted in figure 1. The upward sloping straight lines represent the breakeven constraint for the lender when faced with a medium or weak type. The slope of the indifference curve is higher for medium types than for weak types. The downward sloping straight line represents the contracts which provide full insurance. At the liio, both contracts just break even; the weak type is fully insured but the medium type is not. Its consumption in case of no-shock is higher than in case of a shock.

Direct application of propositions 4, 5 and, theorem 1 in Maskin and Tirole (1992) yield useful results summarized in the following Proposition:

Proposition 16 *(Maskin and Tirole 1992) In the three stage game:*

- *each country type can always guarantee its liio payoff,*

- *the set of equilibrium payoffs for the two types of borrowers is the set of payoffs that* *result from incentive compatible allocations, which are profitable in expectation and weakly Pareto dominate the liio,*

- *there exists a threshold $\tilde{\lambda} \in (0,1)$ such that the liio is the unique (perfect Bayesian) equilibrium of the game if and only if $\lambda \leq \tilde{\lambda}$.*

By offering the option contract $\left(\alpha^m_{liio}, \alpha^w_{symm}\right)$, the borrower guarantees his liio payoff in equilibrium. The contracts in the menu are incentive compatible and break even, type by type, so the lender knows he will break even irrespective of his beliefs about the borrower's type. The liio is the unique equilibrium provided that the fraction of weak types is large enough. Note that the liio coincides with the competitive screening equilibrium proposed by Rothschild and Stiglitz (1976) whenever the latter exists.

Condition 17 *Assume that $0 < \lambda \leq \tilde{\lambda}$. Given this assumption, the liio constitutes the unique equilibrium of the three stage game.*

Given the setting of the three stage game and the assumption concerning the fraction of weak types, the low information intensity optimum is the unique equilibrium in capital markets. Natural candidates for the IMF contingent credit lines would like to insure against liquidity shocks, but the presence of weaker countries pushes for under-insurance as a means of separation.[13] I refer to this allocation as the No-IMF benchmark. All results of the introduction of the IMF CCL are measured with respect to this particular No-IMF benchmark. In the next section, I introduce the IMF in the setting. In terms of the model, I introduce a stress test which reveals a country's type with certain probability and remains silent otherwise.

2.3 IMF as a stress test

In the basic setting, risk-averse countries insure against macroeconomic shocks through international capital markets. Now, I introduce the IMF in the framework, focusing on the role of CCL eligibility criteria which make the IMF close to a rating agency. In terms of the model,

[13] The fact that weaker countries access full insurance (less volatile consumption) is counterfactual. Given that the focus of this paper is on the target economies of the CCL, what is important is that those economies under-insure to separate. In Arregui 2008 I present a setting in which by underinsuring the medium types manage to exclude the uncreditworthy weak types from the market.

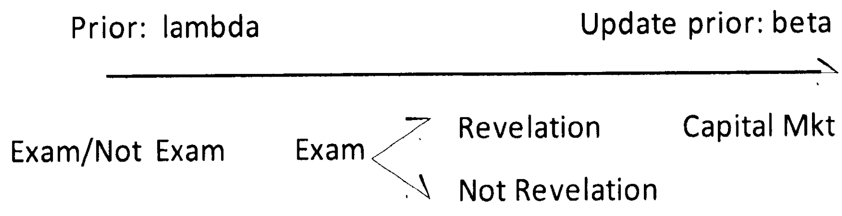

Figure 2-2: Timeline

I introduce a stress test that countries may voluntarily take. At $t = -1$ there is an imperfect examination technology available. I consider a very stylized, simple examination: with probability γ the exam reveals the country's true type, it remains uninformative otherwise. I ignore the possibility of the IMF evaluation mistakes. Taking the test entails a cost c, paid in both states of the world. I interpret "taking the exam" to mean applying for a credit line (eligibility criteria).

The timeline presented in the previous section is extended as shown in figure 2. The timing is as follows: (1) the country chooses whether to take the exam or not $b(\theta) \in \{Exam, NotExam\}$; (2) if the country takes the exam, the result is observed (revelation or not); (3) the lender updates his priors after observing whether the exam is taken and its result when taken. Restrictions on the belief-updating process apply. If the exam is revealing, the types are observed. In this case:

$$\begin{aligned}\beta\left(m/\text{Exam,Revelation}\right) &= 1 \quad \text{if } \theta = m \\ \beta\left(m/\text{Exam,Revelation}\right) &= 0 \quad \text{if } \theta = w\end{aligned}$$

If countries refuse the exam $\beta\left(m/NotExam\right)$, or the exam reveals nothing $\beta\left(m/Exam, Not\, Revelation\right)$, beliefs consistent with Bayesian updating are required on the equilibrium path and are free off the equilibrium path. Finally, the country goes to the credit market to play the game described in the previous section with updated priors and a modified income $\tilde{y} = y - c$ for the countries that took the exam.

I assume the test is not too costly, meaning that if the medium types could effectively use the test to reveal their type they would be willing to incur such a cost.

Condition 18 *Assume $c > 0$ satisfies $\tilde{u}^m_{symm} = u(y - c - p^m d) > u^m_{liio}$.*

The quality of the stress test (indexed by γ) plays a crucial role in determining the type of equilibria that may arise. If the stress test quality is good enough, the introduction of the exam allows for an equilibrium in which target economies take the exam and weak types do not. Even if the exam is not perfectly revealing ($\gamma < 1$), in this equilibrium informational rents are eliminated and each country type obtains its symmetric information payoff. In welfare terms, the IMF generates a Pareto improvement relative to the No-IMF benchmark by providing target economies with a cheaper way to separate from weak economies. Weak types are indifferent and medium types are strictly better.

In equilibrium, weak types receive their symmetric information payoff $u(y - p^w d)$. If they imitate medium types by taking the exam, with probability γ their type is revealed and they incur the cost of the test c in vain. Given that the stress test is not perfect, with probability $1 - \gamma$ the test is not revealing and weak countries benefit from being taken for medium types. A lower bound on γ is required for this deviation not to be profitable for the weak types.

Proposition 19 *if $\gamma^l \leq \gamma \leq 1$, there is a pure strategy separating equilibrium in which medium types take the exam and weak types do not. Where*

$$\gamma^l = \frac{u(y - c - p^m d) - u(y - p^w d)}{u(y - c - p^m d) - u(y - c - p^w d)} < 1$$

This equilibrium captures how the IMF CCL was intended to work and provides a rationale in favour of country-requested CCL. It requires the IMF being able to execute stress tests that are sufficiently better relative to capital markets. This is an optimistic view wherein the IMF is "*..a technical institution which is **better suited to monitor** the global situation on a daily basis (...).*"[14] However, not all economic analysts agree on the value of IMF economic monitoring and analysis. Many analysts remain skeptical because "*the IMF has a **patchy record with respect to being able to evaluate risks ex ante.***"[15] As a matter of fact, no single country requested to join the original version of the facility.

[14]Calvo, Guillermo, "The G20 communiqué: Work in progress but good news for emerging markets", April 6 2009.

[15]Rodrik, Dani, "What would it take to make international finance safe?", April 07, 2009.

If the stress test quality is low enough, there exists an equilibrium in which no country chooses to take the exam. When none of the types takes the exam, beliefs cannot be updated. Given that $\beta\left(m/NotExam\right) = \lambda < \tilde{\lambda}$, each type gets its liio payoff at the unique equilibrium. If a type deviates, with probability γ, its true type is revealed, yielding $u\left(y - c - p^i d\right)$ for $i = w, m$. However, if the exam is not revealing, beliefs are unspecified. Using the results from Maskin and Tirole, each type can always guarantee its liio payoff. In this case, the liio payoffs are computed given income $\tilde{y} = y - c$. I denote those as $u^w_{symm}\left(-c\right)$ and $u^m_{liio}\left(-c\right)$ respectively. The liio payoffs are the unique payoffs each type may obtain provided that $\beta\left(m/Exam, \text{NotRevelation}\right) \leq \tilde{\lambda}$.[16]

In equilibrium, medium types get their liio payoff u^m_{liio}. If they deviate by taking the exam, with probability γ their type is revealed. Given that the stress test is not perfect, with probability $1-\gamma$ their type is not revealed and they must still incur the costs of separating themselves from the weak types. That is, they would have incurred the cost of the test c in vain. An upper bound on γ is required for this deviation not to be profitable for the medium types.

Proposition 20 *if* $0 < \gamma \leq \gamma^u$, *there is a pooling equilibrium in which no type takes the exam. Where*

$$\gamma^u = \frac{u^m_{liio} - u^m_{liio}\left(-c\right)}{u\left(y - c - p^m d\right) - u^m_{liio}\left(-c\right)}$$

This equilibrium shows how expectations play a vital role and countries may be deterred from joining the facility. The actual experience of the IMF CCL seems consistent with the IMF not being able to do a much better job than capital markets in telling apart weak from medium economies.

In terms of welfare, when the IMF CCL go unused each type receives the same payoff as in the No-IMF benchmark. It should be noted that, depending on parameters, we may have $\gamma^u < \gamma^l$ or $\gamma^l < \gamma^u$. The latter case is obtained when the exam cost is high: c is close to $\bar{c}$, where $\bar{c}$ satisfies $u\left(y - \bar{c} - p^m d\right) = u^m_{liio}$. If $\gamma\left(\leq \gamma^u\right)$ is higher than γ^l, the separating and pooling equilibria coexist, with the separating weakly Pareto dominating the pooling equilibrium.

[16] If $\tilde{\lambda} < \beta\left(m/Exam, \text{NotRevelation}\right) < 1$, there are multiple equilibria in the three stage game after deviation. If we ad hoc select the liio payoffs, then it coincides with the case in which $\beta\left(m/Exam, \text{NotRevelation}\right) \leq \tilde{\lambda}$. Choosing any other payoff will make it harder to sustain the pooling equilibrium. The reason is that any other payoff will be higher than the liio and therefore the incentives to deviate are higher.

2.3.1 IMF taking the first step

In the previous subsection, I analyzed the procedure that requires each country to voluntarily request an evaluation before going to capital markets. This procedure raised concern from several economic analysts. For instance, Cordella and Levy-Yeyati 2005 suggested that *"It is important to notice that the country entry (signaling) problem depends on the country's need to make the first move to access the facility. These problems would be eliminated if eligibility criteria were made automatic."* Also, the IMF evaluated the possibility of modifying the procedure in a review of the CCL facility in 2003. Quoting the IMF review report: *"The potential changes to the CCL include [...] (ii) a more systematic process for periodic assessments of eligibility, independent of a request by the member, with the possibility of a published list of prequalified members;.."*.[17] In this subsection, I show that a compulsory test may yield a Pareto improvement if properly implemented, provided that the cost of examination is not too large.

Consider the case in which the IMF imposes compulsory exams for all countries. We may think of this as applying the eligibility criteria to all IMF members and publishing a list of qualifying countries. I assume that the cost of examinations is born only by countries identified as medium types.

A fraction $(1-\lambda)\gamma$ is identified as weak and therefore receive their symmetric information benchmark $u^w_{symm} = u(y - p^w d)$. The exam does not reveal type for a fraction $(1-\gamma)$ of countries. Those economies face capital markets with priors $(\lambda, 1-\lambda)$ and income y. Because $\lambda < \tilde{\lambda}$, the unique equilibrium is given by the liio. Unidentified medium and weak types get u^m_{liio} and u^w_{symm} respectively. A fraction $\lambda\gamma$ of countries is identified as medium types. Their type is revealed to capital markets and their income decreases because they bare the cost of examinations. The identified medium types' new income is given by $y - \frac{c}{\gamma\lambda}$.

Proposition 21 *Provided that $u\left(y - \frac{c}{\gamma\lambda} - p^m d\right) > u^m_{liio}$, imposing a compulsory stress test (financed by those identified as medium types) yields a Pareto improvement relative to the No-IMF benchmark or the pooling equilibrium in which no type takes the examination.*

Systematic public assessments by the Board of CCL eligibility have been proposed by some country officials. Proposition 4 rationalizes the proposal. However, the result depends cru-

[17] *IMF. "Review of Contingent Credit Lines", SM/03/64, February 11, 2003, p. 2.*

cially on the fact that the No-IMF benchmark considered already has weak and medium types separating. In that case, countries identified as weak or countries for which the exam is inconclusive are indifferent between taking the exam or not if they do not bare the cost. The countries identified as medium bare the cost not only of their own examination c , but of all examinations $\frac{c}{\gamma\lambda}$. Therefore, a Pareto improvement relative to the No-IMF benchmark occurs when $u\left(y - \frac{c}{\gamma\lambda} - p^m d\right) > u^m_{liio}$. This is a more stringent version of Condition 2.

If the No-IMF benchmark had weak types pooling with medium types, the introduction of a compulsory test would end cross subsidization for those countries identified as weak. The CCL review report by the IMF recognized this possibility: "(...) *any regime that involves eligibility criteria cannot avoid the adverse implication for members that fail to meet them.": "This approach may be more appealing to potentially eligible members but it would magnify the potentially negative impact on members that did not meet that threshold (...)."*

2.4 Three types

In the model presented in the previous sections, the cost of the exam c plays a crucial role in deterring countries from requesting the stress test. In the separating equilibrium, the weak types do not take the exam because it is costly, and may reveal their weak type with high probability. In the pooling equilibrium, the medium types do not take the exam because it is costly and, with high probability , they may still have to underinsure to credibly signal their type. If we interpret such costs literally as the cost of monitoring and evaluation by the IMF, there is no reason to believe costs are significant. In this section, I propose an alternative broader interpretation of the cost of requesting a CCL.

A typical concern shared by most of the emerging economies that were the target of this facility has been to achieve recognition as stable and reliable economies. For these economies in their "road to graduation", the decision to come to the IMF is largely determined by the image they want portrayed to foreign investors. Quoting IMF reports: "*Potentially eligible countries were not confident that a CCL would be viewed as a sign of strength rather than weakness*", "*Such request could convey a signal of greater underlying vulnerabilities than the market had previously perceived (asymmetric information).*" The "image" or "reputation" costs associated with requesting a CCL can potentially be large in magnitude.

In the model of the previous sections, medium types manage to (costly) separate from weak types in the No-IMF benchmark. Therefore, it does not capture the possibility that applying for a CCL may reveal the country to be worse than capital markets believed. In order to capture those costs, I introduce a third type of country. I refer to this new type as a $s-$trong country ($\theta = s$) because it is never hit by a shock. The fraction of strong, medium and weak types is denoted by λ^s, λ^m and λ^w respectively. I assume that, conditional on not being strong, the fraction of weak types is large, i.e. $\frac{\lambda^m}{\lambda^w+\lambda^m} \leq \tilde{\lambda}$.

Strong countries do not seek insurance because they are not hit by shocks with probability one. That is, under symmetric information strong types would choose a contract $\alpha^s_{symm} = (\alpha_1 = 0, \alpha_2 = 0)$. For simplicity, I assume that strong types behaviorally keep their strategy fixed at α^s_{symm} and do not take the IMF stress test if available. This restricts beliefs because a country trying to get insurance cannot be a strong country:

$$\beta\left(s/\alpha \neq (0,0)\right) = 0$$

If the setting is only modified to include strong types, the equilibrium is not affected. Neither the weak nor the medium types would pool with the strong type. Both would rather be mistaken for the bad type than accept the no insurance contract α^s_{symm}. In equilibrium, the strong type optimally chooses not to insure. Given that the fraction of weak types is large enough $\left(\frac{\lambda^m}{\lambda^w+\lambda^m} \leq \tilde{\lambda}\right)$, the medium and weak types get their symmetric information payoff (u^m_{liio} and u^w_{symm} respectively).

I introduce a second modification to the basic setting: I assume there exists a dimension along which weak and medium countries benefit from being perceived as a strong type. For example, countries may have access to uncertain investment projects which are cheaper to finance for stronger countries. I introduce this into the model in a stylized way. Let $P_i^{(\phi_s,\phi_m,\phi_w)}$ be the extra utility received by country i when the belief about its type is given by the probabilities (ϕ_s, ϕ_m, ϕ_w). I denote P_i^j as the increase in utility when type i is believed to be type j and P_i^{jh} when it is assumed to be either j or h with probabilities $\frac{\lambda^j}{\lambda^j+\lambda^h}$ and $\frac{\lambda^h}{\lambda^j+\lambda^h}$ respectively. For simplicity, I assume that if weak and medium types are identified, they receive no extra benefit:

$P^w_w = P^m_m = 0$. Both types benefit from being mistaken for a strong type, so $P^{ms}_m > P^m_m = 0$ and $P^{ws}_w > P^w_w = 0$. In the context of the investment project, we may think of this as the cross subsidy of cheaper access to credit. Also I assume that $P^s_m > P^{ms}_m > P^{ms}_w > P^{ws}_w$ and $P^s_m > P^s_w$.

2.4.1 Interesting case

To capture the "image"/ "reputation" costs, I focus on the case in which the No-IMF benchmark consists of medium types pooling with strong types and separating from weak types. This equilibrium requires two conditions: (1) cross subsidization benefits for the medium type must compensate for the loss of underinsurance associated with imitating strong types; (2) the weak type benefits of pooling with medium and strong types must be lower than the cost of underinsurance. Note that the cost of autarky (no insurance) relative to the liio described in the previous section is greater for the weak types than for the medium types because they face shocks with higher probability. That is, we require:

$$\begin{aligned} u^m(0,0) + P^{ms}_m &\geq u^m_{liio} \\ u^w_{symm} &\geq u^w(0,0) + P^{ms}_w \end{aligned}$$

There are two cases to distinguish. Consider first the case in which the symmetric information payoff for medium types is lower than the payoff obtained through pooling with strong types (that is, $u^m(0,0) + P^{ms}_m > u^m_{symm} > u^m_{liio}$). The gains in cross subsidies for medium types are so large that they have no interest in revealing their type. As a result, the introduction of a voluntarily, member-requested CCL would prove ineffective (independently of the cost c and the power of the test γ).

For the rest of the paper, I focus on the case in which the medium type's utility, when pooling with strong types, is lower than its symmetric information payoff (i.e. $u^m_{symm} > u^m(0,0) + P^{ms}_m > u^m_{liio}$). The medium type benefits from revealing its type even at the expense of losing cross-subsidization. However, the presence of the weak type imposes a negative externality: medium types can only credibly signal their type by underinsuring. As a result, medium types prefer no insurance and pool with strong types. The medium economy (the target of the IMF CCL) has two fundamental signaling concerns: (1) an "upward" concern that the request for an exam reveals it not to be the strong type, (2) a "downward" concern that after taking the imperfect test, it might still be confused with the weaker type.

In this case, there is a role for the introduction of an IMF stress test as described in the previous section. If the IMF could reduce the informational rents resulting from asymmetric information, generating a Pareto improvement relative to the No-IMF benchmark. To achieve a Pareto improvement, the test must not to be too costly. I assume that if medium types could effectively use the test to reveal their type, they would willingly pay the cost.[18]

Condition 22 *Assume $c > 0$ satisfies $\tilde{u}^m_{symm} = u(y - c - p^m d) > u^m(0,0) + P^s_m$.*

Provided that the stress test is good enough (γ sufficiently high), there exists a separating equilibrium wherein medium types take the exam and weak types do not. Medium types can be identified for taking the exam independently of the result; weak types are identified for seeking insurance in capital markets after not taking the exam. Each type gets its symmetric information utility.

Proposition 23 *if $\gamma^l \leq \gamma \leq 1$, there is a pure strategy separating equilibrium in which medium types take the exam and bad types do not. Where*

$$\gamma^l = \frac{u(y - c - p^m d) - u(y - p^w d)}{u(y - c - p^m d) - u(y - c - p^w d)} < 1$$

If the quality of the stress test is low, there exists an equilibrium in which no country takes the exam and, in capital markets, medium countries pool with strong countries, separating from weak ones. The weak types get full insurance and separate from medium and strong types who get no insurance at all. The medium types benefit from being pooled with strong types. They obtain u^w_{symm} and $u^m(0,0) + P^{ms}_m$ respectively.

If the medium types deviate and take the exam, their type is revealed with probability γ and they receive their symmetric information payoff.[19] However, with probability $1 - \gamma$, the exam is inconclusive. In this case, the country signals that it is not a strong type, but uncertainty remains. If $\beta(m/Exam, \text{NotRevelation}) \leq \tilde{\lambda}$, then liio payoffs are the unique payoffs after

[18] This condition is analogous to condition 2.
[19] With income $\tilde{y} = y - c$ since the exam has to be paid.

taking the exam. Medium types still incur the costs of separating from weak types. As such, an upper bound on γ is required for this deviation not to be profitable. The weak type never deviates by taking the exam, since a payment c is required and the country would still be identified as a weak type.

Proposition 24 *if* $0 < \gamma \leq \tilde{\gamma}^u$, *there is a pooling equilibrium in which neither the weak nor the medium type take the exam. Where*

$$\tilde{\gamma}^u = \frac{u^m(0,0) - u^m_{liio}(-c) + P^{ms}_m}{u(y - c - p^m d) - u^m_{liio}(-c)}$$

Note that the value of $\tilde{\gamma}^u$ is bounded above 0 even if the direct cost of the exam c tends to zero. This happens because the relevant cost for medium types not only includes the monitoring cost c, but also the loss resulting from revealing they are not the strong types the market expected (loss in cross-subsidies).

2.5 Conclusions

Stigma concerns deter potential users from approaching liquidity provision facilities. Depository institutions at the national level and (stronger) emerging economies at the international level have expressed their concerns that financial markets might view borrowing as a sign of financial weakness. The inclusion of eligibility prerequisites is a critical feature of the Discount Window[20] and of the IMF Contingent Credit Line facility.

Eligibility requirements attempt to reduce concerns that borrowing will be perceived as a sign of weakness, because only "*financially sound institutions*"/"*countries with strong fundamentals*" may gain access to such credit. The provision of a "stamp of approval" is expected to have beneficial effects on financial markets. However, the Fed has documented certain reluctance of banks to borrow at the Discount Window (DW) and no single emerging economy joined the initial version of the Contingent Credit Line (CCL) facility of the IMF.

This papers studies the role of eligibility in providing a stress test that may reduce asymmetric information. The specific procedures for eligibility determination and monitoring vary

[20] After its modification in 2003.

across facilities. I center my attention on the IMF CCL. In order to qualify for the CCL, a country must make an explicit request to the IMF and be approved by the Board.

The quality of the stress test plays a crucial role to determine the type of equilibria that may arise. As long as the quality of the stress test is good enough, the introduction of the exam allows for an equilibrium in which target economies take the exam and weak types do not. The IMF generates a Pareto improvement relative to the No-IMF benchmark by providing target economies a cheaper way to separate from weak economies. This equilibrium shows how the IMF CCL was intended to work and provides rationale for country-requested CCL. However, economic analysts disagree on the value that a stamp of approval by the IMF may have. Given low stress test quality, there exists an equilibrium in which no country opts to take the exam. This equilibrium captures how CCL actually worked. Also, provided that the cost of the exam is sufficiently low, I show that forcing countries to take the exam[21] Pareto dominates the equilibrium in which no country takes the exam.

I propose a broader interpretation of potential costs associated with requesting a CCL beyond monitoring costs. A typical concern shared by most of the emerging economies that were the target of this facility has been to achieve recognition as stable and reliable economies. "Image" or "reputation" costs can be quite large for these countries. CCL-targeted economies have two fundamental signaling concerns: (1) an "upward" concern that the request for the exam will reveal it is not as strong the market anticipated; (2) a "downward" concern that after taking the imperfect test it might still be confused with a weaker economy. Both concerns play a role in explaining their decision to refuse the eligibility test.

The results of the paper crucially depend on the No-IMF benchmark in which the imperfect stress test is introduced. In the two type case, I focused on a No-IMF benchmark in which target economies for the facility manage to separate from weaker countries by underinsuring. In the three type case, I considered a benchmark in which the target economies pool with better countries, separating from weaker countries. Further work should explore the effects of imperfect stress tests in other settings. Also, research should seek to understand the effect of IMF mistakes in country evaluations. Finally, it is important to analyze the pros and cons of making ratings more informative (beyond the current dichotomy join versus not join).

[21] And subsidizing the cost of the exam for those countries whose test is uninformative or reveals them weak.

Bibliography

[1] Arregui, N., "Signaling Concerns and IMF Contingent Credit Lines", Job Market Paper, MIT, 2009.

[2] Basu, S., "Optimal IMF Policy with Private Capital Flows", Chapter 3, PhD Dissertation, MIT, 2009.

[3] Borensztein, E. and P. Mauro, "The Case for GDP-Indexed Bonds", Economic Policy, 2004, Vol. 19, pp 165-216.

[4] Broda, C., and E. Levy-Yeyati, "Dollarization and the Lender of Last resort," in Dollarization: Debates and Policy Alternatives, ed. by E. Levy-Yeyati and F. Sturzenegger, (Cambridge, Massachusetts: MIT Press), 2003.

[5] Caballero, R.J., "The Future of the IMF," MIT mimeo, January 2003.

[6] Caballero, R.J., and A. Krishnamurty, "A Vertical Analysis of Monetary Policy in Emerging Markets," MIT mimeo, March 2002a.

[7] Caballero, R.J., and A. Krishnamurty, "A Dual Liquidity Model for Emerging Markets," American Economic Review, Papers and Proceedings, May 2002b.

[8] Caballero, R.J., and S. Panageas, "Hedging Sudden Stops and Precautionary Recessions: A Quantitative Framework," NBER Working paper No. 9778 (Cambridge, Massachusetts: National Bureau of Economic Research), 2003.

[9] Caballero, R.J., and S. Panageas, "Contingent Reserves Management: An Applied Framework," NBER Working paper No.10786 (Cambridge, Massachusetts: National Bureau of Economic Research), 2004.

[10] Calvo, Guillermo, "The G20 communiqué: Work in progress but good news for emerging markets", April 6 2009. Available at http://www.voxeu.org/index.php?q=node/3420 .

[11] Chang, R. and A. Velasco, "Financial Crises in Emerging Markets: A Canonical Model," Federal Reserve Bank of Atlanta, WP98-10, July 1998.

[12] Chang, R. and A. Velasco, "Financial Crises in Emerging Markets: Theory and Policy", Federal Reserve Bank of Atlanta, WP99-15, October 1999.

[13] Cordella, T. and E. Levy Yeyati, "A (New) Country Insurance Facility", IMF Working Papers 05/23, International Monetary Fund, 2005.

[14] Federal Reserve, "The Federal Reserve Discount Window", Aug 2007. Available at http://www.frbdiscountwindow.org/discountwindowbook.cfm?hdrID=14&dtlID=43.

[15] Federal Reserve, "The Primary and Secondary Lending Programs", Nov 2009. Available at http://www.frbdiscountwindow.org/programs.cfm?hdrID=14&dtlID=45.

[16] Holmstrom, B., and J. Tirole, "Private and Public Supply of Liquidity," Journal of Political Economy 106-1, February 1998, pp. 1-40.

[17] Holmstrom, B., and J. Tirole, "Modeling Aggregate Liquidity", The American Economic Review, Vol. 86, No. 2, May 1996, pp. 187-191

[18] IMF, 2003, Review of Contingent Credit Lines (IMF SM/03/64) available online at : http://www.imf.org/external/np/pdr/fac/2003/021103.htm

[19] Jeanne, O., and J. Zettelmeyer, "The Mussa Theorem: and Other Results on IMF Induced Moral Hazard," IMF Working Papers 04/192, International Monetary Fund, 2004.

[20] Jeanne, O., J. Zettelmeyer and J. Ostry, "A Theory of International Crisis Lending and IMF Conditionality," IMF Working Papers 08/236, International Monetary Fund, 2008.

[21] Lorenzoni, G., "Inefficient Credit Booms," Review of Economic Studies, 75 (3), July 2008, 809-833.

[22] Madigan, Brian F. and William R. Nelson, "Proposed Revisions to the Federal Reserve's Discount Window Programs" , Federal Reserve Bulletin, vol. 88 (July 2002), pp. 313-319.

[23] Marchesi, S. and J. Thomas, "IMF Conditionality as a Screening Device", The Economic Journal, Vol. 109, N0. 454, Mar. 1999.

[24] Maskin, E. and J. Tirole, "The Principal-Agent Relationship with an Informed Principal, II: Common Values", Econometrica, Vol. 60, No. 1, 1992, pp1-42.

[25] Morris, S., and H.S. Shin, "Catalytic Finance: When Does It Work?" Journal of International Economics 70 (2006), 161-177.

[26] Ostry J. and J. Zettelmeyer, "Strengthening IMF Crisis Prevention", IMF Working Papers 05/206, International Monetary Fund, 2005.

[27] Rodrik, Dani, "What would it take to make international finance safe?", April 07, 2009. Available at http://rodrik.typepad.com/dani_rodriks_weblog/2009/04/what-would-it-take-to-make-international-finance-safe.html.

[28] Rothschild, M. and J. Stiglitz , "Equilibrium in competitive insurance markets: an essay on the economics of imperfect information", Quarterly Journal of Economics, Vol 90, Issue 4, Nov. 1976.

[29] Tirole, J., "Financial Crises, Liquidity and the International Monetary System", Princeton University Press, 2002.

[30] Tirole, J., "The Theory of Corporate Finance", Chap 6, Princeton University Press, 2006.

2.6 Appendix

2.6.1 Proof of Proposition 2

If $\gamma^l \leq \gamma \leq 1$, there exists a pure strategy equilibrium in which the medium types take the exam and the bad types do not. That is,

$$\begin{aligned} a(w) &= NotExam \\ a(m) &= Exam \\ \beta(w/NotExam) &= 1 \\ \beta(m/Exam, \operatorname{Re}velation) &= \beta(m/Exam, Not\operatorname{Re}velation) = 1 \end{aligned}$$

On equilibrium, the medium and weak types reveal their types and get $u(y - c - p^m d)$ and $U(y - p^w d)$ respectively.

If the medium type were to deviate and not take the exam, it would be taken for a weak type. Still, in capital markets the liio is a lower bound on how much each type can get. The medium type would get u^m_{liio} and given condition 2, this deviation is not profitable.

If the weak type were to deviate and take the exam, with probability γ its type would be observe and the payoff would be $u(y - c - p^w d)$. With probability $1 - \gamma$ the exam remains inconclusive, the type is taken for a medium type and the payoff is $u(y - c - p^m d)$. The weak type does not deviate provided that:

$$u(y - p^w d) \geq \gamma u(y - c - p^w d) + (1 - \gamma) u(y - c - p^m d)$$

which imposes a lower bound on γ.

2.6.2 Proof of Proposition 3

If $0 < \gamma \leq \gamma^u$, there exists a pure strategy equilibrium in which none of the types takes the exam $a(m) = a(w) = NotExam$. Regarding beliefs, we require

$$\begin{aligned} \beta(m/NotExam) &= \lambda \\ \beta(m/Exam, \operatorname{Re}velation) &= 1 \quad \text{if } \theta = m \end{aligned}$$

and we are free to choose $\beta\left(m/Exam, Not\operatorname{Re}velation\right)$.

I assume that $\beta\left(m/Exam, Not\operatorname{Re}vealing\right) \leq \tilde{\lambda}$.

On equilibrium, there is no update in beliefs and as $\beta\left(m/NotExam\right) < \tilde{\lambda}$ there is a unique equilibrium in capital markets given by the liio. The medium and weak types get u_{liio}^{m} and $u\left(y - p^{w}d\right)$ respectively.

If the weak type were to deviate and take the exam, with probability γ its type would be observed and the payoff would be $u\left(y - c - p^{w}d\right)$. With probability $1 - \gamma$ the exam remains inconclusive and given that $\beta\left(m/Exam, Not\operatorname{Re}vealing\right) \leq \tilde{\lambda}$ the type gets its liio, $u\left(y - c - p^{w}d\right)$. Therefore, the weak type does not deviate

If the medium type were to deviate and take the exam, with probability γ its type is learned and it gets $u\left(y - c - p^{m}d\right)$. With probability $1 - \gamma$ the exam is inconclusive and given that $\beta\left(m/Exam, Not\operatorname{Re}vealing\right) \leq \tilde{\lambda}$ the medium type gets its liio: $u_{liio}^{m}\left(-c\right)$. For the medium type not to deviate we require

$$u_{liio}^{m} \geq \gamma u\left(y - c - p^{m}d\right) \ + \left(1 - \gamma\right) u_{liio}^{m}\left(-c\right)$$

That is, the exam cannot be too revealing (provided the cost c is small).

What is $u_{liio}^{m}\left(-c\right)$?

$$\begin{aligned}
u_{liio}^{m}\left(-c\right) &= \max p^{m}u\left(y - c - d + \alpha_2\right) + \left(1 - p^{m}\right) u\left(y - c - \alpha_1\right) \text{ s.t.} \\
0 &\leq -p^{m}\alpha_2 + \left(1 - p^{m}\right)\alpha_1 \\
u\left(y - c - p^{w}d\right) &\geq p^{w}u\left(y - c - d + \alpha_2\right) + \left(1 - p^{w}\right) u\left(y - c - \alpha_1\right)
\end{aligned}$$

Note that $u_{liio}^{m} > u_{liio}^{m}\left(-c\right)$. Proof:

$$\begin{aligned}
u_{liio}^{m}\left(-c\right) &= \max_{\alpha_1,\alpha_2} p^{m}u\left(y - c - d + \alpha_2\right) + \left(1 - p^{m}\right) u\left(y - c - \alpha_1\right) \quad \text{s.t.} \\
0 &\leq -p^{m}\alpha_2 + \left(1 - p^{m}\right)\alpha_1 \\
u\left(y - c - p^{w}d\right) &\geq p^{w}u\left(y - c - d + \alpha_2\right) + \left(1 - p^{w}\right) u\left(y - c - \alpha_1\right)
\end{aligned}$$

Call $\hat{\alpha}_1 = \alpha_1 + c$ and $\hat{\alpha}_2 = \alpha_2 - c$, we may rewrite the maximization problem as

$$\begin{aligned} u^m_{liio}(-c) &= \max_{\hat{\alpha}_1, \hat{\alpha}_2} p^m u(y - d + \hat{\alpha}_2) + (1 - p^m) u(y - \hat{\alpha}_1) \quad \text{s.t.} \\ c &\leq -p^m \hat{\alpha}_2 + (1 - p^m) \hat{\alpha}_1 \\ u(y - c - p^w d) &\geq p^w u(y - d + \hat{\alpha}_2) + (1 - p^w) u(y - \hat{\alpha}_1) \end{aligned}$$

A higher value of c makes both restrictions tighter and has no effect on the payoff function. Using that at the optimum both restrictions must bind we conclude that the inequality must be strict.

2.6.3 Proof of Proposition 6

If $0 < \gamma \leq \tilde{\gamma}^u$, there exists a pure strategy equilibrium in which none of the types takes the exam $a(m) = a(w) = NotExam$. Regarding beliefs, we require

$$\begin{aligned} \beta(m/NotExam) &= \frac{\lambda^m}{\lambda^m + \lambda^w} \\ \beta(m/Exam, \text{Re}\,velation) &= 1 \quad \text{if } \theta = m \end{aligned}$$

and we are free to choose $\beta(m/Exam, Not\,\text{Re}\,velation)$.

I assume that $\beta(m/Exam, Not\,\text{Re}\,vealing) \leq \tilde{\lambda}$.

On equilibrium, the weak type gets $U(y - p^w d)$. If the weak type were to deviate and take the exam, with probability γ its type would be observed and the payoff would be $u(y - c - p^w d)$. With probability $1 - \gamma$ the exam remains inconclusive and given that $\beta(m/Exam, Not\,\text{Re}\,vealing) \leq \tilde{\lambda}$ the type gets its liio, $u(y - c - p^w d)$. Therefore, the weak type does not deviate.

The medium type gets $u^m(0,0) + P^{ms}_m$ on equilibrium. If the medium type were to deviate and take the exam, with probability γ its type is learned and it gets $u(y - c - p^m d)$. With probability $1 - \gamma$ the exam is inconclusive and given that $\beta(m/Exam, Not\,\text{Re}\,vealing) \leq \tilde{\lambda}$ the medium type gets its liio: $u^m_{liio}(-c)$. For the medium type not to deviate we require

$$u^m(0,0) + P^{ms}_m \geq \gamma U(y - c - p^m d) \; + (1 - \gamma) U^m_{liio}(-c)$$

That is, the exam cannot be too revealing (provided the cost c is small).

2.7 Appendix II

This appendix summarizes the relevant results in Maskin and Tirole 1992 for the purpose of this paper. Most steps are borrowed from "The theory of corporate finance", Tirole, 2006.

The borrower (principal) may have type b or $\tilde{b}$. His type is private information and therefore is unknown for the lender (agent). The fraction of type b borrowers is λ. Let $U_b(c)$ and $\tilde{U}_b(c)$ denote the two types ' net utilities for arbitrary contractual terms c. Let $U_l(c)$ and $\tilde{U}_l(c)$ denote the lender's expected profit when contractual terms are c and the borrower turns out to be b or $\tilde{b}$, respectively.

Timing: 3 stage game

1. Principal θ proposes an option contract $c(\theta) = (c, \tilde{c})$ within a set of feasible contracts C.

2. Agent updates beliefs and accepts iff $EU/c \geq 0$.

3. If accepted, Principal must choose between c and $\tilde{c}$.

Equilibrium definition: a Perfect Bayesian equilibrium (PBE) in the 3 stage game.

Let an allocation be a pair of type contingent contractual terms $(c, \tilde{c})$.

Definition 25 *An allocation $(c, \tilde{c})$ is incentive compatible if*

$$\begin{aligned} U_b(c) &\geq U_b(\tilde{c}) \\ \tilde{U}_b(\tilde{c}) &\geq \tilde{U}_b(c) \end{aligned}$$

Definition 26 *An incentive compatible allocation $(c, \tilde{c})$ is profitable type-by-type if*

$$\begin{aligned} U_l(c) &\geq 0 \\ \tilde{U}_l(\tilde{c}) &\geq 0 \end{aligned}$$

Definition 27 *An incentive compatible allocation $(c, \tilde{c})$ is profitable in expectation if*

$$\lambda U_l(c) + (1-\lambda)\tilde{U}_l(\tilde{c}) \geq 0$$

where λ is the proportion of type b borrowers.

Definition 28 *An incentive compatible allocation* $(c, \tilde{c})$ *that is profitable in expectation is interim efficient if it is Pareto optimal for the two types of borrower in the set of incentive compatible profitable in expectation allocations.*

Definition 29 *Utility* $U_b(c^*)$ *for borrower type* b *is the low information intensity optimum for that type if it maximizes type* b*'s utility in the set of incentive compatible, profitable type-by-type allocations.*

Program I (type b)

$$(c^*, \tilde{c}^*) = \arg\max_{(c,\tilde{c})} U_b(c) \;\; s.t.$$

$$\begin{aligned} U_b(c) &\geq U_b(\tilde{c}) \\ \tilde{U}_b(\tilde{c}) &\geq \tilde{U}_b(c) \\ U_l(c) &\geq 0 \\ \tilde{U}_l(\tilde{c}) &\geq 0 \end{aligned}$$

Analogously, utility $\tilde{U}_b(\tilde{c}_0^*)$ for borrower type $\tilde{b}$ is the low information intensity optimum for that type if it maximizes type $\tilde{b}$'s utility in the set of IC, profitable type-by-type allocations:

Program I (type $\tilde{b}$)

$$(c_0^*, \tilde{c}_0^*) = \arg\max_{(c,\tilde{c})} \tilde{U}_b(\tilde{c}) \;\; \text{s.t.}$$

$$\begin{aligned} U_b(c) &\geq U_b(\tilde{c}) \\ \tilde{U}_b(\tilde{c}) &\geq \tilde{U}_b(c) \\ U_l(c) &\geq 0 \\ \tilde{U}_l(\tilde{c}) &\geq 0 \end{aligned}$$

Definition 30 *The payoff pair* $\left[U_b(c^*), \tilde{U}_b(\tilde{c}_0^*)\right]$ *is called the low information intensity optimum. We also call the allocation* $(c^*, \tilde{c}_0^*)$ *the low information intensity optimum.*

Proposition 31 *The allocation* $(c^*, \tilde{c}_0^*)$ *is itself incentive compatible.*

Lemma 32 *The borrower can guarantee herself her low information intensity optimum.*

Idea of proof: offer $(c^*, \tilde{c}_0^*)$, then the lenders will break even even whatever their belief about the borrower's type.

Theorem 33 *(Maskin and Tirole 1992) the 3 stage game has a unique Perfect Bayesian equilibrium if the low information intensity optimum is interim efficient relative to prior beliefs* $(\lambda, 1-\lambda)$. *The borrower then obtains her low information intensity optimum.*

Idea of proof: an equilibrium allocation must be incentive compatible and must weakly Pareto dominate the low information intensity optimum. It cannot however strictly dominate the low information intensity optimum since the latter is (interim efficient), and so must yield the same utilities. In the insurance model presented in this paper, the separating allocation we solved for is the low information intensity optimum and is interim efficient if $\lambda \leq \tilde{\lambda}$.

Theorem 34 *(Maskin and Tirole 1992) if the low information intensity optimum is not interim efficient, then the set of equilibrium payoffs for the two types of borrowers is the set of payoffs that result from an incentive-compatible, profitable-in-expectation allocation that weakly Pareto-dominate the low information intensity optimum.*

Chapter 3

Signaling Concerns, Discount Window Borrowing and Competing Liquidity Facilities

Abstract

The financial crisis started in mid 2007 constitutes the most recent challenge for the discount window facility (DW). At the onset of the crisis, the Federal Reserve saw little demand for primary credit through its discount window, even after lowering the discount rate from 100bp to 50bp above the federal funds target. Alternative liquidity facilities, such as the Federal Home Loan Bank system (FHLB) and the Term Auction Credit Facility (TAF), took the early lead and were the dominant sources of liquidity during the crisis.

This paper studies the role of the DW in the presence of competing liquidity facilities with market determined interest rates. There is stigma attached to borrowing at the DW. Stigma costs are assumed to be fixed costs and therefore banks borrow at the DW only when the fed funds market is severely tight. When the fed funds market is "mildly" tight supply adjusts to meet demand solely via the provision of new funds by alternative facilities. A more attractive DW (lower discount rate or lower signaling costs) results in higher DW borrowing and a higher fraction of banks borrowing from the facility. It is also accessed in more states of the world.

Liquidity Facilities and Signaling

by

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Abstract

I propose an empirical approach based on cross-district data to test for the stigma hypothesis.Variations in Federal Reserve district characteristics (e.g. number and size distribution of depository institutions) serve as a proxy for variations in (unobservable) signaling costs to test their effect on borrowing at the DW facility.

3.1 Introduction

The discount window (DW) constitutes the longest standing liquidity provision facility by the US government. Its goal is to function as a safety valve in relieving pressures in reserve markets and therefore relieve liquidity strains in depository institutions and the banking system as a whole. However, depository institutions have expressed their concern that banking supervisors, other banks, and investors might see borrowing as a sign of financial weakness. According to a Fed report, "*such stigma deterred some institutions from using adjustment credit when doing so would have been appropriate.*" Starting in the mid and late 1980s, banks showed a growing reluctance to borrow at the discount window (Pearce 1993, Peristiani 1998, Dow 2001). Discount window borrowing declined dramatically and the close relationship between borrowing and the spread between the federal funds rate and the discount rate (the so-called "borrowing function") effectively disappeared.

In 2003, the discount window was redesigned in an attempt to reduce market stigma and costly regulatory monitoring, which were believed to hinder borrowing at the facility (Madigan and Nelson 2002). Adjustment credit, the previous version of the facility, was characterized by a below-market discount rate and a requirement that depository institutions borrow only to meet short term needs after exhausting all available sources of funds. The new version, in particular the Primary Credit program, was designed to more closely resemble a Lombard facility. The Primary Credit program provides funds to financially sound depository institutions at an above-market rate but with very little administration and no restrictions on the use of the proceeds.

There is no consensus on whether the redesign of the facility achieved its goal. Empirical studies yield contradicting conclusions depending on the time horizon considered. Furfine 2001 and 2003 study the experience with the Special Lending Facility[1] (SLF) and the results of the first three months of the redesigned discount window facility. He concludes that despite the removal of administrative costs, depository institutions remained hesitant to borrow from the Fed because stigma could not be eliminated completely.

Allowing for a three year time lapse of the new regime, Artuc and Demiralp 2007 find differ-

[1] A facility similar in design to the new discount window program temporarily established by the Fed to ensure adequate liquidity provision around Y2K.

ent results. The authors analyze daily borrowings behavior before and after the establishment of the new facility. They estimate implicit costs of borrowing using the fixed cost model proposed by Clouse and Dow 1998. They find that stigma substantially decreased and the borrowing function (i.e. the sensitivity of total DW borrowing to the spread between the fed funds and the discount rate) became operational again.

The financial crisis started in mid 2007 constitutes the most recent challenge for the DW facility. At the onset of the crisis, the Federal Reserve received little demand for primary credit through its discount window, even after lowering the discount rate from 100 basis points to 50 basis points above the federal funds target. Economic analysts interpreted this as evidence of how signaling concerns still hinder borrowing at the DW facility. Ashcraft, Bech and Frame 2008 (ABF 08) propose an alternative explanation: the presence of an alternative lower cost government sponsored liquidity facility. The authors document the important role played by alternative liquidity facilities, like the Federal Home Loan Bank (FHLB) and the Term Auction Credit Facility (TAF).

The Federal Home Loan Bank (FHLB) System is a government-sponsored liquidity facility consisting of 12 cooperatively owned wholesale banks which function as a general source of liquidity for its member financial institutions. Liquidity is provided through advances (over-collateralized loans) to members. In order to raise funding, the FHLB system issues debt instruments (bonds and discount notes). Obligations consolidate borrowing needs of all institutions into joint securities offerings which are sold in capital markets. Members share the funds raised by the sale of securities and share the obligation to repay. Being a government sponsored enterprise, the perception in financial markets is that of an implicit Federal government guarantee. Overnight advances are priced to compete with the federal funds rate.

The Term Auction Credit Facility (TAF), introduced on December 12, 2007, complements the DW in providing liquidity to sound depository institutions. The facilities are close substitutes in many respects. Both offer funding to the same set of eligible institutions, against the same collateral, and using identical haircut calculations. However, the interest rate for the TAF is determined competitively through an auction as opposed to the posted discount rate for the DW.[2] The supply of liquidity at market rates, determined by competitive auctions, attempts

[2]For each TAF auction, the Federal Reserve announces an amount to be allocated. Eligible financial insti-

to circumvent the stigma associated with the DW.

Figure (3-1) shows total liquidity provision during the last crisis by the Term Auction Credit facility, the Discount Window facility, and the Federal Home Loan Bank system.[3] During the first four months of the crisis, the FHLB system was the dominant source of government sponsored liquidity. It was not until December 2007 that the Federal Reserve began to lend significant amounts, as a result of the introduction of the Term Auction Facility (TAF). The FHLB remained an important source of liquidity through 2008.[4] In addition, several other liquidity facilities were introduced during the crisis, including the Primary Dealer Credit Facility (PDCF) and the Term Securities Lending Facility (TSLF). Quoting ABF 08: "*While the FHLB System was the lowest-cost source of secured term funding for U.S. depository institutions during fall 2007, the new liquidity facilities created by the Fed in Dec. 2007 complemented FHLB advances by extending "stigma free" term dollar credit to non-FHLB members including foreign institutions.*" Armantier, Ghusels, Sarkar and Shrader 2010 document that during the summer of 2008 banks preferred to pay, on average, at least 34bp more to borrow from the Fed's Term Auction Facility than from the discount window.

The Federal Reserve implemented a number of important changes to the primary program after the financial crisis emerged. On August 17, 2007, the penalty spread was reduced from 100 bp to 50bp, with maturities extended up-to 30 days. On March 16, 2008, the spread was further reduced to 25bp and maturities extended up-to 90 days. However, borrowing at the DW remained insignificant until late March 2008.

In this paper, I study the role of the discount window in the presence of competing liquidity facilities with market determined interest rates, such as the FHLB system or the Term Auction Facility (TAF). A bank's reserve position is subject to individual and aggregate shocks. Banks that face a deficiency must borrow at the market determined interest rate or at the discount window. Accessing the DW involves a direct cost (the posted discount rate) and an indirect cost,

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tutions may submit a bid (subject to a maximum amount) consisting of at most two rate-quantity pairs. Bids are accepted starting with the highest rate submitted until the announced offering amount has been allocated or until the minimum bid rate is reached. The lowest accepted interest is the "stop-out rate", and is paid by all partitcipants with awarded bids. There are also differences in maturity, availability frequency, prepayment options and borrowing limits.

[3] The FHLB time series is constructed subtracting the value of advances in January 2007.

[4] In spite of the fact that in the second quarter of 2008, the borrowing costs and advance rates for the FHLB increased as a result of the association of this government sponsored facility with Fannie Mae and Freddie Mac.

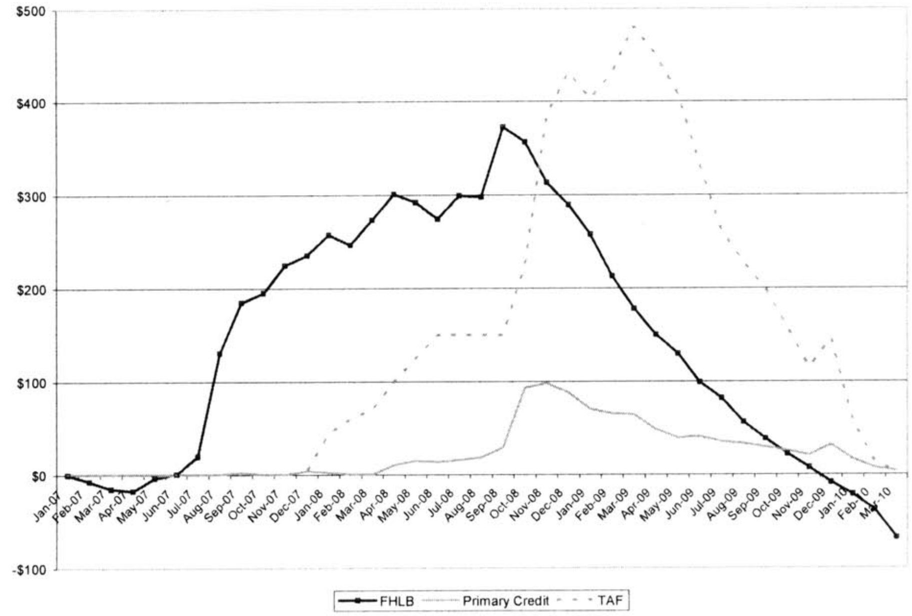

Figure 3-1: Crisis liquidity provision per facility.

since it may raise concern in the market about the institution's financial condition (a signaling cost). I assume a key distinction: signaling costs are attached to the discount window but not to alternative liquidity sources. Signaling costs are fixed costs as in Clouse and Dow 1998 (CD 98) and Artuc and Demiralp 2007 (AD 07). The presence of fixed costs explains instances of extremely high fed funds rate and heterogeneous behavior across banks with respect to the discount window.

The total supply of federal funds is given by banks with excess reserves which choose to lend in the fed funds market, and by the provision of funds by an alternative liquidity facility. Because the discount window is subject to fixed costs, some banks borrow at the DW only when the fed funds market is severely tight (as a consequence of large negative aggregate shocks). When the fed funds market is "mildly" tight (as a result of negative but not too large aggregate shocks), supply adjusts to meet demand solely via the provision of new funds by an alternative facility. No bank borrows at the discount window.

As opposed to AD 07, the presence of an alternative liquidity facility makes the aggregate supply of funds elastic with respect to the interest rate. As a result, given the aggregate shock, changes in signaling costs and the discount rate affect both equilibrium prices and quantities. A more attractive facility (lower discount rate or lower signaling costs) results in more total discount window borrowing and a higher fraction of banks borrowing at the facility. Also, a more attractive facility is accessed in more states of the world.

The model offers an alternative interpretation of two findings made by Reddy and Shaffer 2007. The authors find that the DW redesign did not significantly change the average level of aggregate overnight DW borrowing. They interpret this as the higher direct cost of borrowing (above-market interest rate) offsetting the lower indirect costs (reduced stigma and administration costs). They also find that the pricing of overnight FHLB system loans did not respond to the systemic change in the discount rate, concluding that the FHLBs do not view the DW as a primary competitor in overnight lending. However, these findings are consistent with a period of mildly tight fed funds markets in which the discount window is not systematically used (e.g. borrowing due to technical reasons), and the discount rate and signaling costs have no effect on the equilibrium interest rate. It should be noted that the authors' sample (from January 10, 2003 to January 1, 2005) included only two instances when the intra-day maximum fed funds rate exceeded the discount rate.

I propose an empirical approach to test for the stigma hypothesis. The empirical approach is based on exploiting differences across Federal Reserve districts. Signaling costs are unobservable, so we cannot directly test the hypothesis that signaling costs affect discount window borrowing. However, district characteristics (e.g. number and size distribution of institutions, variance of shocks, etc.) may function as a proxy for variations in signaling costs to test their effect on borrowing at the facility.

Individual bank discount window borrowing is strictly confidential. Primary credit data is published only aggregated across Federal Reserve districts or across several liquidity facilities. The signaling concern is that market participants may combine this information with bidding behavior in the federal funds market to infer the identity of institutions borrowing at the discount window. Consider, for example, cross-district variation in the number of eligible institutions for primary credit. All things equal, it should be harder to identify a borrowing bank in a district with more eligible institutions because banks may "hide in the bushes" more easily. A higher number of eligible institutions may be used as a proxy for lower signaling costs.

Under the identifying assumptions that fixed costs represent signaling costs and the number of institutions proxies variations in signaling costs across districts, we may test the predictions of the model. All else equal, districts with more institutions should experience a higher fraction of banks accessing the facility and higher district average DW borrowing.

The relationship between DW borrowing and the spread between the fed funds rate and the discount rate should indicate the presence of fixed costs. If borrowing at the government facility had no indirect costs attached, then the discount rate should function as an upper bound on the fed funds rate and no discount window borrowing is expected when the fed funds rate falls below the bound. A fixed cost attached to DW borrowing explains those occasions when the fed funds rate rises above the discount rate. I study the evolution of the relationship between DW borrowing and the spread since 2003. I divide the sample into three sub-periods: pre-crisis, first phase of the crisis, and last phase of the crisis through recovery.

Despite the differences in scale (given the arrival and deepening of the financial crisis), the pattern is similar in the first two subperiods. When the fed funds rate falls below the discount rate, discount borrowing is low. When the spread is positive, borrowing increases in the spread. The figures are consistent with the revival of the borrowing function proposed by Artuc and Demiralp 2007. The figures suggest the presence of fixed costs attached to DW borrowing. The last sub-period shows a positive relationship between DW borrowing and the spread. I observe a new, salient feature in the last phase: there are large amounts of borrowing at negative spreads. This phenomenon may be explained by banks, with sound credit quality, scaling back their lending to other banks (e.g. due to increased uncertainty in counterparty risk) in times of financial turmoil . As a result some institutions may have limited access to those funds and are forced to borrow from government facilities.

The structure of this paper is as follows: section 2 introduces the model of the discount window facility with competing liquidity sources and solves for the equilibrium; section 3 compares predictions of the model to Artuc and Demiralp 2007 and reinterprets the findings by Reddy and Shaffer 2007; section 4 proposes an empirical approach to test for the stigma hypothesis; section 5 studies the evolution of the relationship between DW borrowing and the spread since 2003; section 6 concludes. All proofs are included in the appendix.

3.2 The model

I borrow the basic setting from Clouse and Dow 1998 (CD 98) and Artuc and Demiralp 2007 (AD 07). In this setting a bank's reserve position is subject to individual and aggregate shocks. Banks that face deficiencies are forced to borrow at the federal funds market or the discount window. Accessing the liquidity facility involves both a variable and a fixed cost.

The bank's reserve position is realized at the beginning of the period and is given by $a+u+v$; where a is a constant, u is a shock common to all banks, and v is a bank specific shock. Aggregate and individual shocks are assumed to be independent symmetric shocks with bounds $[-k, k]$. I assume $0 < a < k$.

If a bank has positive reserves $(a + u + v > 0)$ it may either lend the reserves at the fed funds market (at the fed funds rate i), or hold on to the reserves receiving a marginal benefit γ. If the bank is deficient in reserves $(a + u + v < 0)$, it may borrow at the fed funds rate i, or access the discount window at discount rate i^{dw}. The latter involves stigma costs modelled as a fixed cost P. I assume $\gamma < i^{dw}$ throughout the paper.

There is a continuum of banks; the individual shock v indexes the distribution of banks. Following CD 98 and AD 07, I assume that banks borrowing at the discount window may not re-lend funds to other banks. Otherwise, given the presence of fixed costs, there would be an incentive for only one bank to borrow at the discount window and re-lend to all other banks with deficiencies.[5]

The total supply of federal funds has two sources: (1) some banks with excess reserves choose to lend in the fed funds market; (2) there exists an extra source of federal funds which increases in the interest rate i when the interest rate rises above the marginal benefit γ. The extra source of liquidity is given by the function $Ah(i-\gamma)$ for $i \geq \gamma$; with $h(0) = 0$ and $h'(.) > 0$. This extra source of funds is the key departure from CD 98 and AD 07, because it makes the total federal funds supply an elastic function of the federal funds rate. For a given spread of the fed funds rate over the banks' marginal benefit $i - \gamma$, the extra funds going into the market increase with A. Note that the model encompasses CD 98 and AD 07, which correspond to $A = 0$.

The extra source of funds represents a competing and complementary liquidity facility, which

[5] However, it should be noted that after the modification of the Discount Window facility in 2003, Primary Credit lending imposes no restrictions on the use of the borrowed funds.

allocates funds to the fed funds market when market gets tighten, similar to the Federal Home Loan Bank system (FHLB) or the Term Auction Facility (TAF). This facility includes market determined interest rates and is not subject to stigma concerns.

3.2.1 Equilibrium

In this section I characterize the equilibrium of the model. Given the continuum of banks and that $E(v) = 0$, the aggregate reserve position is $a + u$. For each value of the aggregate shock u, the equilibrium interest rate i^* must be such that demand meets supply.

If the aggregate reserve position is positive, $a + u > 0$, then total positive reserve positions are greater than total negative reserve positions. Therefore, given that supply is greater than demand, the federal funds rate is brought down to the marginal value of reserves, $i = \gamma$. Note that because $\gamma < i^{dw}$, there is no bank borrowing at the discount window. There is no borrowing at the alternative liquidity facility either.

If $a + u \leq 0$, fewer funds can be lent than are demanded. As such, the fed funds rate rises above γ (I refer to this situation as a tight market). Consequently, extra funds enter the market (increasing supply) and some banks may choose to borrow at the discount window (reducing demand).

I characterize supply and demand in turn. To simplify notation, I define the state variable $x = -a - u$. High values of x correspond to large negative aggregate shocks. The federal funds supply is given by

$$S(x, i) = \bar{S}(x) + \tilde{S}(i)$$

where $\bar{S}$ refers to the supply of funds by banks with excess reserves,[6]

$$\bar{S}(x) = \int_x^k (v - x)\, dF(v)$$

and $\tilde{S}$ refers to the extra source of funds

$$\tilde{S}(i) = \begin{cases} 0 \text{ if } i \leq \gamma \\ Ah(i - \gamma) \text{ if } i > \gamma \end{cases}$$

[6]Actually, $\bar{S}(x) \in \left[0, \int_x^k (v - x)\, dF(v)\right]$ if $i = \gamma$ and $\bar{S}(x) = 0$ if $i < \gamma$.

Banks in need of funds lie in the interval $-k < v < x$. Within this interval, some borrow at the fed funds market and some may go to the discount window. Given the fixed costs, a bank prefers to either borrow entirely in the market or at the discount window. The total cost of market borrowing for a bank with shock v is given by $-i(v-x)$. The total cost of borrowing at the discount window is given by $P - i^{dw}(v-x)$. When $i < \frac{P}{k+x} + i^{dw}$, even the bank with the worse shock prefers borrowing at the market to borrowing at discount window. Therefore, demand is given by the function

$$D(x,i) = \begin{cases} \bar{D}(x) = -\int_{-k}^{x}(v-x)\,dF(v) & \text{if } \gamma < i < \frac{P}{k+x} + i^{dw} \\ -\int_{x-\frac{P}{i-i^{dw}}}^{x}(v-x)\,dF(v) & \text{if } i \geq \frac{P}{k+x} + i^{dw} \end{cases}$$

As shocks get worse, there are three effects affecting demand. First, some banks shift from supplying to borrowing fed funds. Given that the marginal bank does not demand nor supply funds, the effect of a marginal worsening in the shock x is negligible. Second, each bank that continues to borrow at the fed funds market will demand more funds, increasing demand. Finally, provided that the market is tight $(x > 0)$ and that the interest rates are sufficiently high $(i \geq i^{dw} + \frac{P}{x+k})$, some banks exit the fed funds market to borrow at the discount window. This effect reduces demand for fed funds. I assume that the second effect dominates the latter. Therefore, demand weakly increases when the market is tighter.

Condition 35 [7] *Assume for* $x > 0$ *and* $i \geq i^{dw} + \frac{P}{x+k}$

$$F(x) - F\left(x - \frac{P}{i-i^{dw}}\right) \geq \frac{P}{i-i^{dw}} f\left(x - \frac{P}{i-i^{dw}}\right)$$

In a tight market $(x > 0)$ there are fewer funds to be lent than are demanded, which puts upward pressure on interest rates (that rise above γ). Given fixed costs, no bank exits the fed funds market to borrow at the discount window unless the interest rate is high enough $\left(i \geq \frac{P}{k+x} + i^{dw}\right)$. Thus, there exists a region in which supply adjusts to meet demand solely via the provision of new funds entering the market $\tilde{S}(i) > 0$.

Potentially, a large inflow of funds from alternative sources could keep the interest rate suffi-

[7] *This condition is satisfied for the uniform distribution which is used in CD 98 and AD 07.*

ciently low, deterring banks from borrowing at the discount window for any shock x. Throughout this paper, I assume that the alternative source of funds $\tilde{S}(i)$ allows for borrowing at the discount window given certain values of x. This condition requires an upper bound on A.

Condition 36 *Assume that* $Ah\left(i^{dw} + \frac{P}{2k-a} - \gamma\right) < k - a$.

As a result, a tight market ($x > 0$) requires that we distinguish two regions. In the first region, when the shock is not too large, demand for fed funds is met by banks with excess reserves and by funds from an alternative liquidity source. The interest rate rises above γ but not enough for banks to borrow at the discount window. I refer to this region as Region 1. If the market tightens enough, in spite of the provision of funds from the alternative liquidity source, the interest rate becomes high enough inducing some banks to borrow at the discount window facility. This is the case whenever the aggregate shock is large enough $x > \bar{x}$, where $\bar{x}$ solves

$$\bar{x} = \tilde{S}\left(\frac{P}{k+\bar{x}} + i^{dw}\right) = Ah\left(\frac{P}{k+\bar{x}} + i^{dw} - \gamma\right)$$

Given condition 2, there exists a unique value $\bar{x}$ that satisfies this expression. The region without discount window borrowing expands with the signaling cost P, the discount rate i^{dw} and the parameter A. The region shrinks with the cost of funds γ. Next, I analyze equilibrium determination in Region 1 ($x \in [0, \bar{x}]$) and Region 2 ($x > \bar{x}$).

Proposition 37 *$\bar{x}$ is increasing in P, i^{dw} and A, and decreasing in γ.*

Region 1: $x \in [0, \bar{x}]$

When the fed funds market is mildly tight ($x \in [0, \bar{x}]$) there is no discount window borrowing. In this case, the equilibrium interest rate $i^*(x)$ is given by

$$\tilde{S}(i^*) = \bar{D}(x) - \bar{S}(x)$$

or equivalently

$$Ah(i^* - \gamma) = x$$

The equilibrium interest rate $i^*(x)$ is increases with shock x and satisfies $\gamma < i^*(x) \leq \frac{P}{k+x} + i^{dw}$.

Region 2: $x > \bar{x}$

When the fed funds market tightens severely ($x > \bar{x}$), some banks exit the market to borrow at the discount window. The equilibrium interest rate $i^*(x)$ satisfies

$$\bar{S}(x) + \tilde{S}(i^*) = -\int_{x-\frac{P}{i^*-i^{dw}}}^{x} (v-x)\, dF(v)$$

or equivalently

$$Ah(i^* - \gamma) = -\int_{x-\frac{P}{i^*-i^{dw}}}^{k} (v-x)\, dF(v)$$

In this region, the equilibrium interest rate satisfies $i^*(x) > \frac{P}{k+x} + i^{dw}$. The mass of banks exiting to the discount window lies in the interval $\left[-k, x - \frac{P}{i^*-i^{dw}}\right]$, with total discount window borrowing given by

$$DW^*(x) = -\int_{-k}^{x-\frac{P}{i^*-i^{dw}}} (v-x)\, dF(v)$$

As aggregate conditions worsen the supply of bank funds decreases and, given condition 1, demand for funds weakly increases. As a result, the equilibrium interest rate $i^*(x)$ and equilibrium discount window borrowing $DW^*(x)$ are both increasing in x and therefore, positively related in region 2. The mass of banks borrowing at the discount window $F\left(x - \frac{P}{i^*-i^{dw}}\right)$ also increases with shock x.

Note that at $\bar{x}$, the equilibrium interest is sufficiently high for banks with the worst individual shocks to consider borrowing at the discount window. That is, at the threshold between the two regions, $i^*(\bar{x}) = \frac{P}{k+\bar{x}} + i^{dw}$ and $\bar{x} - \frac{P}{i^*(\bar{x})-i^{dw}} = -k$. Figure (3-2) illustrates equilibrium prices and quantities when shocks are uniformly distributed and the extra source of funds is linear $\tilde{S}(i) = A(i-\gamma)$ for $i \geq \gamma$.

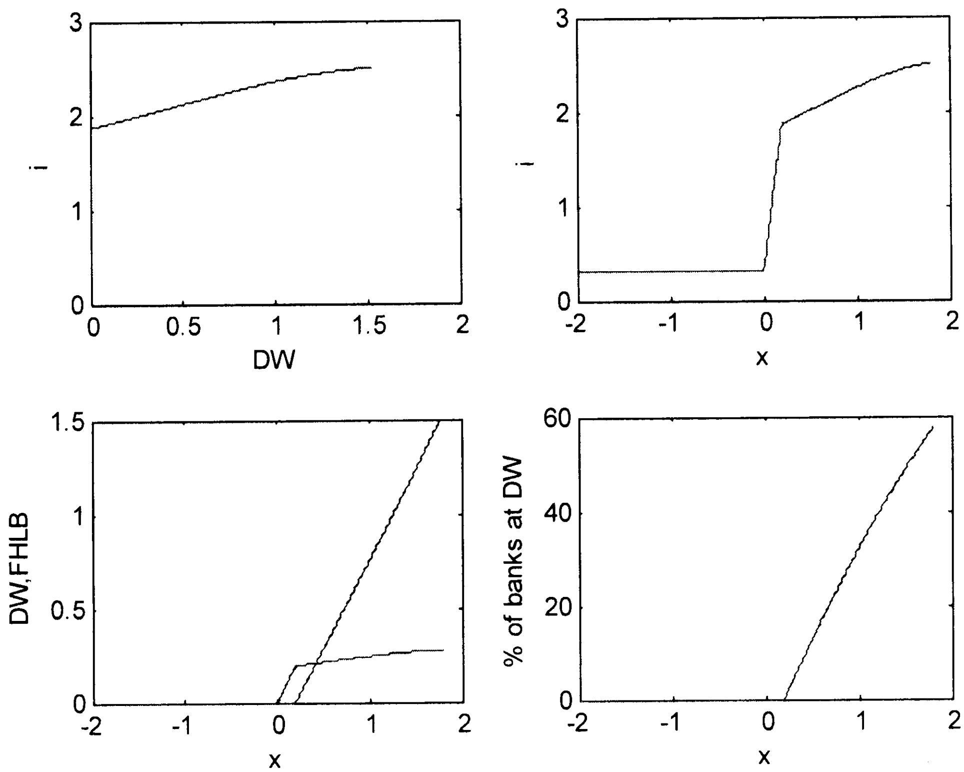

Figure 3-2: Example: $u, v \sim U[-2, 2]$, $P = 3$, $i^{dw} = 0.5$, $\gamma = 0.3$, $a = 0.2$, $A = 1/8$.

3.3 Comparative Statics

In this section, I analyze and relate the model results to other relevant papers that study the new discount window facility established in January 2003. Consider the discount window model proposed by Artuc and Demiralp 2007. The authors' framework yields counterintuitive results due to the inelastic federal funds supply built in the model. Under such conditions, given the aggregate shock x, the signaling cost P, the discount rate i^{dw} (provided that $i^{dw} > \gamma$) and the marginal benefit γ (provided $i^{dw} > \gamma$) have no effect on the mass of banks accessing the DW, the total amount borrowed at DW, nor on the states of the world in which the DW is used. Also, the marginal benefit γ (identified as the target rate by the authors in their empirical estimation) has no effect on the equilibrium interest rate when the market is tight.

In AD 07, aggregate shock x entirely determines the supply of funds in the fed funds markets. In equilibrium, total demand must equal total supply. Therefore, total demand at the fed funds market is also entirely determined by the shock x. For a given x, variations in P, i^{dw} or γ are accommodated solely by the equilibrium interest rate; there are no quantity effects.

After the introduction of an alternative liquidity facility, the federal funds total supply is no longer inelastic, so variations in P, i^{dw}, and γ have both price and quantity effects. A more attractive facility (lower i^{dw} or P) results, for each $x > \bar{x}$, in more total discount window borrowing and a higher fraction of banks borrowing at the facility. Also, a more attractive facility is accessed in more states of the world (lower $\bar{x}$).

When the opportunity cost of funds γ increases,[8] liquidity provision by the alternative liquidity facility is reduced (for each value of the interest rate) and banks with excess reserves require higher payments to lend at the fed funds market. As a result, a higher value of γ reduces supply and increases equilibrium interest rates. Because some banks borrow at the DW, the effect on the fed funds rate is lower in region 2. The following propositions summarize the comparative statics of the model.

Proposition 38 *If $A, P > 0$, for each value of the shock x, the federal funds rate $i^* (x)$ is*

- *decreasing in A, increasing in γ and independent of i^{dw}, P in Region 1: $x \in [0, \bar{x}]$.*

[8] I continue to assume $\gamma < i^{du}$.

- *decreasing in A, increasing in γ, i^{dw}, P in Region 2: $x > \bar{x}$*

Proposition 39 *If $A, P > 0$, for each value of the shock x, the provision of funds by the alternative liquidity facility $Ah(i^*(x) - \gamma)$ is*

- *independent of A, γ, i^{dw}, P in Region 1: $x \in [0, \bar{x}]$.*
- *decreasing in γ and increasing in A, i^{dw}, P in Region 2: $x > \bar{x}$*

Proposition 40 *If $A, P > 0$, for each value of the shock x, total discount window borrowing $DW^*(x)$ and the fractions of banks accessing the facility are*

- *zero in Region 1: $x \in [0, \bar{x}]$.*
- *increasing in γ and decreasing in A, i^{dw}, P in Region 2: $x > \bar{x}$*

The model in AD 07 also predicts that the sensitivity of DW borrowing to the fed funds rate $\frac{\partial DW^*}{\partial i^*}(x)$ is decreasing in the fixed cost of accessing the facility P. With the introduction of the extra source of liquidity, the relationship is no longer straightforward. Consider the case in which the shocks are uniformly distributed ($u, v \sim U[-k, k]$) and the additional source of funds is linear $\tilde{S}(i) = A(i - \gamma)$. In this case, the sensitivity of DW borrowing to the fed funds rate $\frac{\partial DW^*}{\partial i^*}(x)$ is decreasing in the fixed cost of accessing the facility P provided that A is not too large.[9]

The model in this paper suggests an alternative interpretation of the empirical findings by Reddy and Shaffer 2007, who study the effects of the re-design of the discount window facility. The authors find that "*the new program did not significantly change the average level of aggregate overnight DW borrowing (...) consistent with a roughly equal offset between the higher direct cost of borrowing and lower indirect costs under the new policy.*" In terms of the model, the authors interpret modifications to the facility as an increase in the discount rate $\uparrow i^{dw}$ and a decrease in the non-price cost $\downarrow P$. These forces push DW borrowing in opposite directions in Region 2. However, an alternative interpretation may characterize the period following the modification of the facility as having mild aggregate shocks that lead to no

[9] The actual condition is given by that $4k\frac{\left(i^*(x) - i^{dw}\right)^3}{P^2}A < 1$.

systematic borrowing at the discount window (Region 1). The observed borrowing may have occurred due to technical reasons.[10] In this region, the discount rate i^{dw} and the fixed cost P have no effect on equilibrium interest rates. It should be noted that in the authors' sample (from January 10, 2003 to January 1, 2005) the intra-day maximum fed funds rate exceeded the discount rate i^{dw} only twice.

This alternative story would modify the authors' conclusion that "*several simple tests indicated that the pricing of overnight Federal Home Loan Banks system loans did not respond to the systemic change in the discount rate, suggesting that the FHLBs do not view the DW as a primary competitor for their lending overnight*". We may think of the FHLB system as an alternative liquidity facility. Even though changes in i^{dw} and P have no effect on equilibrium interest rates i^* in Region 1, the alternative liquidity facility and the DW facility may still compete.

3.4 Empirical test proposal

Many economists have argued that the "stigma" attached to borrowing at the Discount Window explains banks' reluctance to use the facility. The argument is straightforward from a theoretical point of view, but empirical evidence supporting the hypothesis remains elusive. Empirical research regarding discount window borrowing has been limited because individual bank discount window borrowing is strictly confidential. Primary credit data is published only aggregated across Federal Reserve districts or across several liquidity facilities (i.e. primary, secondary and seasonal credit and other liquidity programs).[11] The signaling concern is that market participants may combine this information with the bidding behavior in the federal funds market to infer the identity of borrowing institutions.

Furfine 2001/03 and Armantier, Ghusels, Sarkar and Shrader 2010 (AHSS 10 hereafter) are notable exceptions. Furfine 2001 documents that whenever market interest rates rose noticeably, borrowing in the federal funds markets at 150 or more basis points above target dwarfed lending

[10] E.g. technical difficulties with the Fedwire payment system or the realization of unexpected transactions late in the day, that may not leave sufficient time to find a suitable counterparty in the fed funds market.

[11] The pre-2003 version of the facility published adjustment credit data at a distric level (see Mitchell and Pearce 91).

at a facility[12] similar in design to the new DW that charged 150bp over the fed funds target. Furfine 2003 finds that borrowing at the new DW was significantly lower than predicted using interbank borrowing behavior past data. Even at less attractive interest rates, the volume of fed funds borrowing was several times larger than DW borrowing. AHSS 10 find that during the summer of 2008 banks preferred to pay on average at least 34bp more to borrow from the Fed's Term Auction Facility than from the discount window.

Given the DW's economic importance, it is crucial to obtain rigorous and robust evidence for the existence of stigma. The non-disclosure policy by the Fed has been challenged recently by various news organizations. During the last year, Bloomberg News and Fox News have brought lawsuits against the Federal Reserve because it refuses to provide discount window documentation under the Freedom of Information Act. In March 2010, the federal appeals court ruled that the Fed must disclose documents related to individual borrowing from DW. However, in May 2010, Fed representatives asked the federal appeals court to reconsider the ruling because *"banks would be less likely to use the DW (...) if they know their use would be made public"*, that is *"the disclosure of the identity of financial institutions (...) will severely undermine the board's ability to implement lending programs critical to the economy (...)"*.

In this section, I propose an empirical approach to test for stigma. The empirical approach is based on exploiting differences across districts.[13] According to the model, signaling costs affect discount window borrowing. Signaling costs are unobservable so the hypothesis cannot be tested directly. However, district characteristics (e.g. number and size distribution of institutions, variance of shocks, etc.) affect the ability of market participants to identify institutions borrowing at the DW. Therefore, we may use district characteristics as a proxy for variations in signaling costs in order to test how these affect borrowing at the facility.

Consider, for example, cross district variation in the number of eligible institutions for primary credit. All else equal, it should be harder to identify a borrowing bank in a district with more eligible institutions because banks can "hide in the bushes" more easily. Higher numbers of eligible institutions may proxy for lower signaling costs. Under the identifying

[12] The Special Lending Facility (SLF) was a temporary facility that operated between October 1, 1999 and April 7, 2000.

[13] Data disaggregated at a district level is currently confidential. However, it represents a useful middle-step to obtain solid evidence for stigma without the disclosure of individual bank borrowing data.

assumptions that fixed costs represent signaling costs and that number of institutions proxies for variations in signaling costs across districts, we may test the model's predictions. According to the model, we should expect the following in districts with more institutions:

- the fraction of banks and the probability that a bank will access the DW is higher,
- district average DW borrowing is higher,
- the sensitivity of average DW borrowing to the fed funds rate $(\frac{\partial DW^*}{\partial i^*})$ is higher (under certain conditions, see section 3)

We may also use heterogeneity in bank size as a proxy for signaling costs. In order to conduct the test, I consider a variation of the specification proposed by Artuc and Demiralp. The authors use daily data to estimate pre and post 2003:

$$DW_t = \alpha_0 + \alpha_1 s_t + \hat{\alpha}_2 X_t + \varepsilon_t$$

where DW_t denotes daily aggregate primary credit at the Federal level, s_t is the spread between the fed funds rate and the discount rate, and X_t is a vector of other controls.[14] They find that, after the modifications of the DW facility in 2003, the borrowing function is again effective, i.e. their estimate for α_1 is positive and significant.

To test the stigma hypothesis, I extend the time series specification into a panel. Let DW_{it} be discount window borrowing in district i at date t.To proxy for signaling costs, I use the number of institutions per district (NUM_{it}) and the within district depository institution size variance (σ_i). I control for total depository institutions assets in each district and use the same vector of controls as in Artuc and Demiralp X_{it}. The specification to estimate is given by

$$\frac{DW_{it}}{NUM_i} = \beta_0 + \beta_1 NUM_i + \beta_2 \sigma_i + \beta_3 SIZE_i + \beta_4 s_{it} + \beta_5 (s_{it} * NUM_i) + \beta_6 (s_{it} * \sigma_i) + \hat{\beta}_7 X_{it} + \varepsilon_{it}$$

[14] The vector of controls X_t includes: the spread between the intra-day maximum fed funds rate and the fed funds target when higher than 1 bp, the spread between the fed funds rate at the close of the day and the fed funds target, the spread between the fed funds rate and the fed funds target on the previous day, the log of required operating balances, a dummy for the last day of the maintenance period, a dummy for special pressure days, a dummy for Fedwire extension days, the intraday fed funds volatility and a time trend.

The model, subject to the identifying assumptions stated above, predicts positive coefficients for β_1 and β_2. Empirical estimation would allow to identify if the borrowing function is still effective at the district level ($\beta_4 > 0$) or if it is a result of aggregation across districts. Finally, subject to certain conditions (see section 3), the model predicts positive coefficients for the interaction terms (β_5 and β_6)

3.5 Evolution of the borrowing function

In this section, I study the evolution of the relationship between DW borrowing and the spread between the fed funds rate and the discount rate since 2003. This relationship should indicate the presence of fixed costs.

The discount window facility is designed to place an upper bound on the rates at which institutions lend to one another overnight, reducing the volatility of the overnight interest rate, which is typically the rate targeted by the central bank. If borrowing at the government facility is not associated with any indirect costs, then the discount rate should work as an upper bound on the fed funds rate and no discount window borrowing is expected when the fed funds rate falls below the bound.

A fixed cost (e.g. stigma costs) associated with borrowing at the facility explains instances when the fed funds rate rises above the discount rate. Fixed costs might also explain heterogeneous behavior across banks towards the discount window. Still, we expect no discount window borrowing when the fed funds rate is below or slightly above (Region 1 in terms of the model) the discount rate. In practice, some noise is expected because not all depository institutions are eligible for DW borrowing at each moment in time, and discount window borrowing may be triggered by non-systematic reasons (e.g. technical difficulties in the "Fedwire" system).

I focus on the relationship between DW borrowing and the spread between the intra-day maximum fed funds rate and the discount rate. Wednesday's primary credit at the federal level provided by the Fed Board and interest rate data provided by the NY Fed is used in the construction of the figures. I divide the sample in three sub-periods: pre-crisis, first phase of the crisis, and last phase of the crisis through recovery.

Figures (3-3) and (3-4) depict the relationship between borrowing and the spread from

January 15, 2003 until August 15, 2007 and from August 22, 2007 until October 8, 2008 respectively. Despite the differences in scale (possibly due to the arrival and deepening of the financial crisis), the pattern is the same in both figures. When the fed funds rate falls below the discount rate, discount borrowing is low. When the spread is positive, borrowing at the facility increases with the spread. The figures are consistent with the revival of the borrowing function proposed by Artuc and Demiralp 2007. The figures suggest the presence of fixed costs attached to DW borrowing.

The last period, corresponding to October 15, 2008 until April 7, 2010 is shown in Figure 3-5. DW borrowing still shows a positive relationship with the spread. However, the large amount of borrowing at negative spreads (when the discount rate is above the federal funds rate) is the salient feature of the figure. This piece of evidence cannot be explained by the model in this paper as it stands. A possible explanation may be that in times of financial turmoil, banks with sound credit scale back their lending to other banks (e.g. due to increased uncertainty in counterparty risk). As a result, some institutions may have limited access to those funds and be forced to borrow from government facilities.

In terms of the model, we may think that a fraction of the banks with very negative reserve positions ($a + u + v < \bar{b} < 0$) must borrow directly at the discount window (e.g. because banks with positive reserve positions do not want to transact with them). As aggregate shocks worsen, more banks are forced to exit the fed funds market. These banks borrow at the facility even if the spread is negative. Also, worse aggregate shocks reduce the supply of funds and (under certain assumptions) increase the demand for funds, putting upward pressure on the interest rate. These results explain the positive correlation between the interest rate and positive discount window borrowing at negative spreads.

3.6 Conclusion

The discount window is designed to function as a safety valve, relieving pressure on reserves markets, liquidity strains on depository institutions, and the banking system as a whole. In 2003, the facility was redesigned to reduce market stigma and costly regulatory monitoring, which many believe hindered borrowing at the facility (Madigan and Nelson 2002). The new

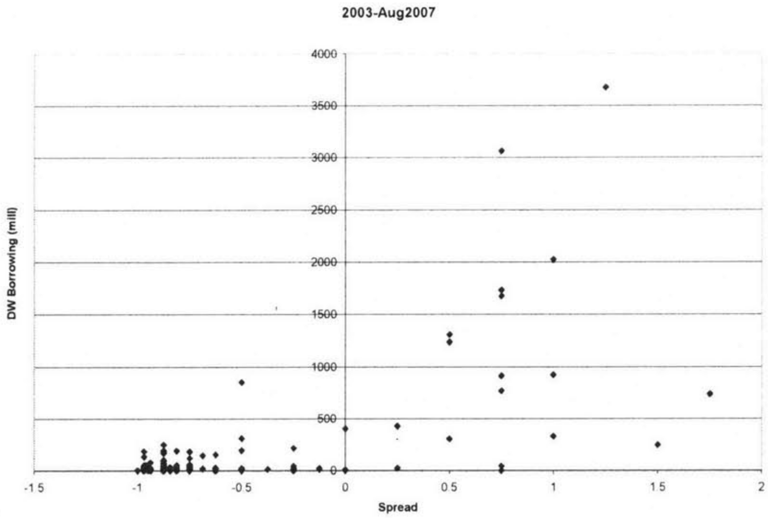

Figure 3-3: Pre-crisis period.

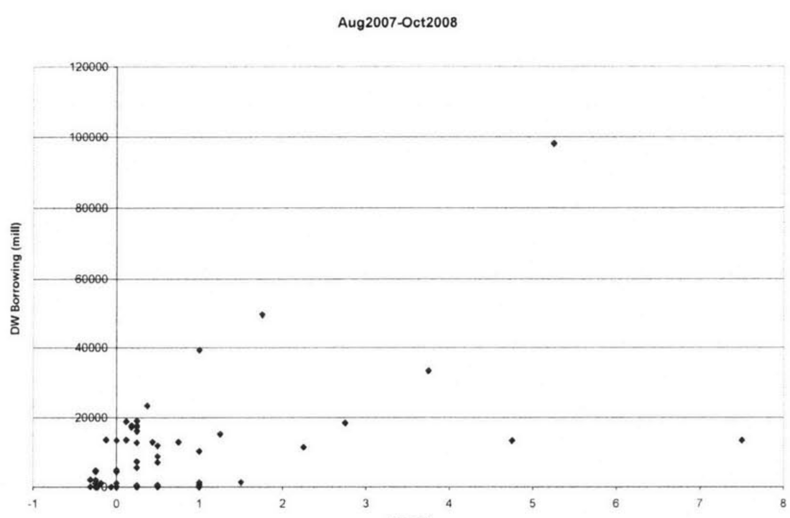

Figure 3-4: Initial phase of the crisis.

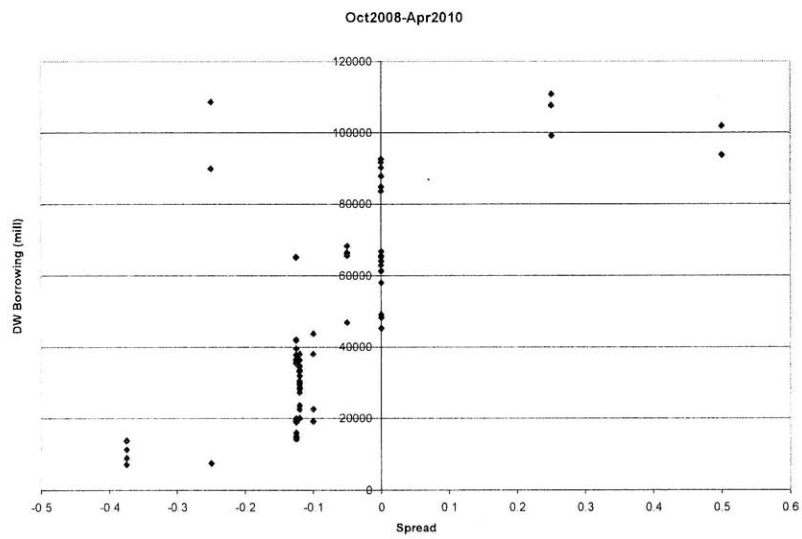

Figure 3-5: Last phase of the crisis and recovery.

version, in particular the Primary Credit program, provides funds to financially sound depository institutions at an above market rate but with very little administration and no restrictions on the use of the proceeds.

There is no consensus on whether the redesign of the facility has achieved its goal. Empirical studies yield different conclusions depending on the time period considered. The financial crisis started in mid 2007 constitutes the most recent challenge for the facility. At the onset of the crisis, the Federal Reserve saw little demand for primary credit through its discount window, even after lowering the discount rate from 100 basis points to 50 basis points above the federal funds target. Many economic analysts interpreted this as evidence of how signaling concerns still hinder borrowing at the facility. Alternative liquidity facilities like the Federal Home Loan Bank (FHLB) and the Term Auction Credit Facility (TAF) took the early lead and were the dominant sources of liquidity.

This paper proposes a model of the DW facility that incorporates both the notion of stigma and competing liquidity facilities with market determined interest rates. Within the paper, stigma costs are assumed to be fixed costs. Therefore, banks borrow at the DW only when the fed funds market is severely tight. When the fed funds market is "mildly" tight supply adjusts to meet demand solely via the provision of new funds by the alternative facilities. A more attractive discount window (lower discount rate or lower signaling costs) results in higher total discount window borrowing and a higher fraction of banks borrowing at the facility. It is also accessed in more states of the world.

This paper proposes an empirical approach based on cross-district data to test for stigma. Variations in Federal Reserve district characteristics (e.g. number and size distribution of depository institutions) are used as a proxy for variations in (unobservable) signaling costs to test their effect on borrowing at the DW facility. Districts with more institutions should yield a higher fraction of banks accessing the facility and higher DW district average borrowing. The data needed to perform such test is currently confidential.[15] The release of information aggregated at a district level represents a major step in the pursue of rigorous and robust evidence for the existence of stigma.

On the theoretical side, the reasons why accessing the DW may send a worse signal than borrowing above the discount rate on the market are still not fully understood. Ennis and Weinberg (2009) suggest that borrowing at the DW may be observed by participants other than the credit market who may interpret borrowing at the facility as a negative signal. However, it is hard to justify why alternative government liquidity facilities like the TAF are not subject to the same scrutiny. Theoretical efforts should focus on understanding the consequences in terms of stigma of posted-rates versus market-determined-rates liquidity facilities.

[15] The period of response to my Freedom of Information Act request (No. 2010100287) submitted in April 2010 has been extended twice and the answer is still pending.

Bibliography

[1] Adam B. Ashcraft & Morten L. Bech & W. Scott Frame, 2008. "The Federal Home Loan Bank System: the lender of next-to-last resort?," Staff Reports 357, Federal Reserve Bank of New York.

[2] Armantier, Olivier, Ghysels, Eric, Sarkar, Asani and Shrader, Jeffrey, "Stigma in Financial Markets: Evidence from Liquidity Auctions and Discount Window Borrowing During the Crisis", March 15, 2010. Available at SSRN: http://ssrn.com/abstract=1572066

[3] Armantier, Olivier, Krieger, Sandy and McAndrews, "James, The Federal Reserve's Term Auction Facility", Current Issues in Economics and Finance, Vol. 14, No. 5, July 2008.

[4] Artuç Erhan and Selva Demiralp, 2009. "Provision of Liquidity through the Primary Credit Facility during the Financial Crisis: A Structural Analysis," Working Papers 0912, TUSIAD-Koc University Economic Research Forum.

[5] Artuç Erhan and Selva Demiralp, 2010. "Discount window borrowing after 2003: The explicit reduction in implicit costs," Journal of Banking & Finance, Elsevier, vol. 34(4), pages 825-833, April.

[6] Clouse, James A., "Recent developments in discount window policy", Federal Reseve Bulletin, Nov. 1994, p. 965-977.

[7] Clouse, James A. & Dow Jr., James P., 1999. "Fixed costs and the behavior of the federal funds rate," Journal of Banking & Finance, Elsevier, vol. 23(7), pages 1015-1029, July.

[8] Cosimano, Thomas F & Sheehan, Richard G, 1994. "Is the Conventional View of Discount Window Borrowing Consistent with the Behavior of Weekly Reporting Banks?," The Review of Economics and Statistics, MIT Press, vol. 76(4), pages 761-70, November.

[9] Ennis, Humberto M. and John A. Weinberg, "A model of stigma in the fed funds market," Economics Working Papers we095937, Universidad Carlos III, Departamento de Economía, 2009.

[10] Dow, James P., The Recent Behavior of Adjustment Credit at the Discount Window. Journal of Macroeconomics, Vol. 23, No. 2, Spring 2001.

[11] Federal Reserve, "The Federal Reserve Discount Window", Aug 2007. Available at http://www.frbdiscountwindow.org/discountwindowbook.cfm?hdrID=14&dtlID=43.

[12] Federal Reserve, "The Primary and Secondary Lending Programs", Nov 2009. Available at http://www.frbdiscountwindow.org/programs.cfm?hdrID=14&dtlID=45

[13] Furfine, Craig, The Reluctance to Borrow from the Fed. Economics Letters, Vol. 72, No. 2., Sept 2001.

[14] Furfine, Craig , "Standing facilities and interbank borrowing: evidence from the Federal Reserve new discount window," Working Paper Series WP-04-01, Federal Reserve Bank of Chicago, 2003.

[15] Furfine, Craig, Discount window borrowing: understanding recent experience Chicago Fed Letter The federal reserve Bank of Chicago, March 2005, N212.

[16] Goldfeld, Stephen M. and Kane, Edward J., 1966. The Determinants of Member Bank Borrowing: An Econometric Study. Journal of Finance, 499-514.

[17] Goodfriend, Marvin, 1983. Discount Window Borrowing, Monetary Policy, and the post-October 6, 1979 Federal Reserve Operating Porcedure. Journal of Monetary Economics 12, 343-356.

[18] Hamdani, Kausar and Stavros Peristiani, 1991. "A disaggregate analysis of discount window borrowing," Quarterly Review, Federal Reserve Bank of New York, issue Sum, pages 52-62.

[19] Madigan, Brian F. and William R. Nelson, "Proposed Revisions to the Federal Reserve's Discount Window Programs" , Federal Reserve Bulletin, vol. 88 (July 2002), pp. 313-319.

[20] Pearce, Douglas K., 1983. Discount Window Borrowing and Federal Reserve Operating Regimes. Economic Inquiry 31, 564-579.

[21] Peristiani, Stavros, 1991. "The Model Structure of Discount Window Borrowing," Journal of Money, Credit and Banking, Blackwell Publishing, vol. 23(1), pages 13-34, February.

[22] Peristiani, Stavros, 1994. "An empirical investigation of the determinants of discount window borrowing: a disaggregate analysis," Journal of Banking & Finance, Elsevier, vol. 18(1), pages 183-197, January.

[23] Peristiani, Stavros,1998. "The Growing Reluctance To Borrow At The Discount Window: An Empirical Investigation," The Review of Economics and Statistics, MIT Press, vol. 80(4), pages 611-620, November.

[24] Poole, William, 1969. Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy. Journal of Finance 23, 769-791.

[25] Polakoff, Murray E., Reluctance Elasticity, Least Cost, and Member-Bank Borrowing: A Suggested Integration, The Journal of Finance, Vol. 15, No. 1 (Mar., 1960), pp. 1-18

[26] Reddy, Britney and Shaffer, Sherrill, 2007. Effects of the Federal Reserve's Primary Credit Program. International Applied Economics, 4(1), March 2007, 14-27.

3.7 Appendix

3.7.1 Existence of $\bar{x}$

Given condition 2, there exists a value $\bar{x} > 0$ such that $S\left(\bar{x}, \frac{P}{k+\bar{x}} + i^{dw}\right) = \bar{D}(\bar{x})$.

Proof: Let $\Phi(x) = \bar{S}(x) - \bar{D}(x) + \tilde{S}\left(\frac{P}{k+x} + i^{dw}\right)$, then

$$\begin{aligned}\Phi(x=0) &= \tilde{S}\left(\frac{P}{k} + i^{dw}\right) > 0 \\ \Phi'(x) &= \bar{S}'(x) - \bar{D}'(x) - \tilde{S}'\left(\frac{P}{k+x} + i^{dw}\right)\frac{P}{(k+x)^2} < 0\end{aligned}$$

Also, condition 2 may be written as $\bar{S}(k-a) + \tilde{S}\left(i^{dw} + \frac{P}{2k-a}\right) < \bar{D}(x = k-a)$, and therefore, $\Phi(x = k-a) < 0$. As $\Phi(x)$ is continuous, there exists a value $\bar{x} > 0$ such that $S\left(\bar{x}, \frac{P}{k+\bar{x}} + i^{dw}\right) = \bar{D}(\bar{x})$.

3.7.2 Comparative statics

Restrict attention to $x > \bar{x}$.

- **Interest rate**

  $i^*(x)$ satisfies

$$\int_{x-\frac{P}{i^*-i^{dw}}}^{k} (v-x)\, dF(v) + \tilde{S}(i^*) = 0$$

  And

$$\frac{\partial i^*}{\partial x} = \frac{F(k) - F\left(x - \frac{P}{i^*-i^{dw}}\right) - \frac{P}{i^*-i^{dw}} f\left(x - \frac{P}{i^*-i^{dw}}\right)}{\tilde{S}(i^*)' + \frac{P2}{\left(i^*-i^{dw}\right)^3} f\left(x - \frac{P}{i^*-i^{dw}}\right)}$$

  which is positive given condition 1.

  Also,

$$\frac{\partial i^*}{\partial P} = \frac{\frac{1}{\left(i^*-i^{dw}\right)} f\left(x - \frac{P}{i^*-i^{dw}}\right)}{\frac{P}{\left(i^*-i^{dw}\right)^2} f\left(x - \frac{P}{i^*-i^{dw}}\right) + \frac{i^*-i^{dw}}{P} \tilde{S}(i^*)'} > 0$$

- **Discount window borrowing**

  $DW^*(x)$ is given by

$$DW^*(x) = -\int_{-k}^{x-\frac{P}{i^*(x)-i^{dw}}} (v-x)\, dF(v)$$

$$\begin{aligned}\frac{\partial DW^*}{\partial x} &= \frac{P}{i^*(x)-i^{dw}} f\left(x - \frac{P}{i^*(x)-i^{dw}}\right)\left[1 + \frac{P}{\left(i^*(x)-i^{dw}\right)^2}\frac{\partial i^*}{\partial x}\right] \\ &+ F\left(x - \frac{P}{i^*(x)-i^{dw}}\right) - F(-k)\end{aligned}$$

  Given that $\frac{\partial i^*}{\partial x} > 0$, we get $\frac{\partial DW^*}{\partial x} > 0$.

Let $b^*(x) = x - \frac{P}{i^*-i^{dw}}$, banks with v in $[-k, b^*(x)]$ borrow at the discount window and

$$\frac{\partial b^*}{\partial P} = -\left[\frac{i^* - i^{dw} - P\frac{\partial i^*}{\partial P}}{(i^* - i^{dw})^2}\right]$$

The numerator is given by

$$i^* - i^{dw} - P\frac{\partial i^*}{\partial P} = \left(i^* - i^{dw}\right)\left[1 - \frac{\frac{P}{\left(i^*-i^{dw}\right)^2} f\left(x - \frac{P}{i^*-i^{dw}}\right)}{\frac{P}{\left(i^*-i^{dw}\right)^2} f\left(x - \frac{P}{i^*-i^{dw}}\right) + \frac{i^*-i^{dw}}{P}\tilde{S}(i^*)'}\right] > 0$$

And therefore the higher the fixed cost P, the fewer banks go to the DW $\frac{\partial b^*}{\partial P} < 0$.

Using the result, we conclude total discount window borrowing (for a given x) is decreasing in P.

$$\frac{\partial DW^*}{\partial P} = -(b^* - x) f(b^*) \frac{\partial b^*}{\partial P} < 0$$

3.7.3 Uniform example

Assume that individual shocks are uniformly distributed $v\tilde{\ }U[-k, k]$ and $\tilde{S}(i^*)$ is linear $Ah(i - \gamma) = A(i - \gamma)$. In this case,

$$\frac{\partial i^*}{\partial x} = \frac{1}{2k} \frac{k - x}{\tilde{S}(i^*)' + \frac{P^2}{\left(i^*-i^{dw}\right)^3}\frac{1}{2k}}$$

$$\frac{\partial DW^*}{\partial x} = \frac{1}{2k}\left[\frac{P^2}{(i^*(x) - i^{dw})^3}\frac{\partial i^*}{\partial x} + x + k\right]$$

$$\frac{\partial i^*}{\partial P} = \frac{\frac{P}{\left(i^*-i^{dw}\right)^2}\frac{1}{2k}}{\frac{P^2}{\left(i^*-i^{dw}\right)^3}\frac{1}{2k} + \tilde{S}(i^*)'}$$

Then:

$$\frac{\partial DW^*}{\partial i^*} = \frac{\frac{\partial DW^*}{\partial x}}{\frac{\partial i^*}{\partial x}} = \frac{x + k}{k - x}\tilde{S}(i^*)' + \frac{1}{k - x}\frac{P^2}{(i^* - i^{dw})^3}$$

Compute:

$$\frac{\partial\left[\frac{\partial DW^*}{\partial i^*}\right]}{\partial P} = \frac{x+k}{k-x}\tilde{S}\left(i^*\right)''\frac{\partial i^*}{\partial P}+\frac{2}{k-x}\frac{P}{\left(i^*-i^{dw}\right)^3}$$
$$-\frac{3}{2k}\frac{1}{k-x}\frac{P^3}{\left(i^*-i^{dw}\right)^6}\frac{1}{\frac{P^2}{\left(i^*-i^{dw}\right)^3}\frac{1}{2k}+\tilde{S}\left(i^*\right)'}$$

If $\tilde{S}\left(i^*\right)' = A = 0$ we obtain the result in AD 07: the sensitivity of DW borrowing to the fed funds rate is decreasing in P.

$$\frac{\partial\left[\frac{\partial DW^*}{\partial i^*}\right]}{\partial P} = -\frac{1}{k-x}\frac{P}{\left(i^*-i^{dw}\right)^3} < 0$$

If $\tilde{S}\left(i^*\right)' = A$ then

$$\frac{\partial\left[\frac{\partial DW^*}{\partial i^*}\right]}{\partial P} == \frac{-\frac{1}{k-x}+\frac{4k}{k-x}\frac{\left(i^*-i^{dw}\right)^3}{P^2}A}{\frac{\left(i^*-i^{dw}\right)^3}{P}+\frac{\left(i^*-i^{dw}\right)^6}{P^3}2kA}$$

The sensitivity of DW borrowing to the fed funds rate is decreasing in P provided that $4k\frac{\left(i^*-i^{dw}\right)^3}{P^2}A < 1$.