INTERNATIONAL FINANCIAL CRISES, TERM STRUCTURE OF FOREIGN DEBT AND MONETARY POLICY IN OPEN ECONOMIES

A Dissertation

by

AHMET CALISKAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2006

Major Subject: Economics

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Approved by:

Chair of Committee,	Paula Hernandez-Verme
Committee Members,	Dennis Jansen
	Qi Li
	Michael Hand
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ABSTRACT

International Financial Crises, Term Structure of Foreign Debt
and Monetary Policy in Open Economies. (May 2006)
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Chair of Advisory Committee: Dr. Paula Hernandez-Verme

In this dissertation, I study international financial crises. For this purpose, I build two models. In the first model, I focus on financial crises in developing, large open economies where foreign debt with various maturities and issue dates is available. The objective is to measure the vulnerability of the domestic financial system to domestically triggered bank runs and externally triggered sudden stops. The main contribution of this model is that both types of crises are treated as rational responses of domestic depositors and international creditors. Such vulnerability measures are linked to fundamentals and equilibrium term structure of foreign debt. Banks' vulnerability to runs increases if they hold a relatively shorter term debt. Also, a larger cost of liquidating the long-term investment before maturity makes the banks more fragile. In the next step, given a domestic banking crisis, I allow international creditors to decide whether they want to stop lending to domestic banks (in which case a "sudden stop" takes place) or not. A sudden stop is more likely if (i) creditors highly discount future consumption, (ii) creditors' current income is small relative to their future income, and (iii) the cost of liquidating the long-term investment before maturity is small.

In the second model, I investigate the merits of alternative monetary policies with respect to financial fragility. In this monetary model of an explicit financial system, I motivate the demand for two fiat currencies by spatial separation and limited communication of agents. There is a domestic and a foreign currency freely traded without restrictions. I analyze the policy of a constant growth rate of domestic money supply with a floating exchange rate regime. Both currencies are held in positive amounts at the steady-state only if the growth rate of domestic money supply is equal to the world inflation rate (WIR). If the former rate is larger than the WIR, domestic currency is not held at the steady-state. Also, total real money balances held is negatively related with WIR. Finally, monetary policy in the form of a constant growth rate of domestic money supply is *neutral* with respect to welfare.

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CHAPTER I

INTRODUCTION

After the Mexican (1995) and the Asian (1997) financial crises, the theoretical literature on emerging market crises has changed direction both in terms of the mechanism and the determinants of crises. The first and the second generation models of crises had emphasized the unsustainability of a fixed exchange rate regime under a speculative attack in the former and under macroeconomic problems in the latter. However, these models of currency crises could not explain, for example, the severe recessions that followed all three crisis episodes mentioned above. Therefore, a new type of model was needed to explain the "twin crises" of banking problems on the one hand and balance of payments problems on the other. Kaminsky and Reinhart (1999) showed that problems in the banking sector typically precede a currency crisis. One strand of literature emphasized the role of financial intermediaries and liquidity effects in emerging market crises. In this line of research, Sachs, Tornell and Velasco (1996), Radelet and Sachs (1998, 2000) and Chang and Velasco (2000a, 2000b) viewed twin crises as manifestations of banking system problems in the foreign exchange market. In addition to the mechanism of the crisis, these papers also changed the folk view on the determinants of whether and when the crises occur. The earlier literature held that crises were largely predictable given unsustainable policies and fundamentals, dubbed the "fundamentalist" view. This view was unable to explain the Mexican and Korean crises because both of these economies were viewed as success stories on the eve of their catastrophe. Both countries were newly admitted to OECD and Mexico became a member of the North American Free Trade Agreement in November 1993. After the catastrophe in those countries, authors cited above have argued that there was a strong self-fulfilling element in the unfolding of events.

This dissertation focuses on the Mexican (1995), the Asian (1997) and the Turkish (2001) financial crises. Following the same line of literature mentioned, I focus

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This dissertation follows the style of *The American Economic Review.*

on the role of financial intermediaries and their fragility. Radelet and Sachs (2000) report that in Philippines, Thailand and Korea, foreign liabilities of the commercial banking system increased rapidly during the period of 1990-1996. In addition, those liabilities were significant as a share of GDP, ranging from 9.2 % in Malaysia to 26.8 % in Thailand in 1996. They also point out that a sudden withdrawal of international funds to the region was a major cause of the Asian crisis.

Sachs, Tornell and Velasco (1996) observe similar patterns in the period of 1990-1994 leading up to the 1995 Mexican crisis. Capital inflows increased until they abruptly stopped through a financial panic. The same authors showed that the relatively short-term composition of foreign liabilities contributed to the vulnerability of the banking system.

In Chapter II of this dissertation, I focus on the role of international capital inflows in problems of the domestic banking system. This chapter is similar in spirit to Chang and Velasco (2000a) as I explicitly build an open banking system with microfoundations using Diamond and Dybvig's (1983) paradigm. Banks are allowed to borrow foreign capital at various maturities and issue dates from international creditors. Also, banks are subject to runs from their domestic depositors. However, in contrast to Chang and Velasco (2000a), I develop a world general equilibrium model in which I explicitly consider the behavior of international creditors. Equilibrium supply of capital and the interest rates on debt are endogenously determined through the interactions between domestic banks and international creditors. Creditors make initial lending plans based on good expectations about the future. However, according to the developments in the domestic economy, those funds are subject to "sudden stops" if creditors find it optimal to stop lending to banks. I ask the following questions. How are the maturity and term structure of the foreign liabilities of a banking system related to its vulnerability to runs? How, if at all, is the risk of a crisis related to fundamentals of the domestic economy and the rest of the world? Once a bank run takes place, how is the risk of a sudden stop related to the same fundamentals?

I find that risk of a bank run is very closely related to the choice of foreign debt maturity. A relatively shorter term debt maturity increases the risk of a liquidity crisis. Also, equilibrium term structure of interest rates is a relevant indicator of risk. In the presence of multiple equilibria with various interest rate configurations, larger short-term interest rates relative to long-term rates are associated with a greater risk of crisis. The nature of the investment technology in the domestic economy is an important indicator of the fragility of the financial system. If the cost of liquidating the long-term investment before maturity is relatively large, then the system is more prone to crises. In the next step, given a domestic bank run, I evaluate the risk of a sudden withdrawal of funds by international creditors. To an important extent, I find that the risk of a sudden stop is closely related to global fundamentals. First, a sudden stop is more likely if creditors' current income is small relative to their future income. Second, it is more likely if creditors highly discount future consumption. Third, a smaller cost of liquidating the long-term asset before maturity makes a sudden withdrawal more likely.

Akyüz and Boratav (2003) note the large extent of foreign borrowing made by Turkish commercial banks on the eve of the 2001 crisis. The banking system had large short-term, dollar-denominated liabilities. Chang and Velasco (2000b) studied the choice of monetary policy and the exchange rate regime with respect to the financial fragility of a banking system. They evaluated currency boards, fixed exchange rates and flexible exchange rates with and without the Central Bank acting as a lender of last resort. In Chapter III of this dissertation, I investigate the effect of alternative monetary policies on financial fragility. I include two fiat currencies, domestic and foreign, that circulate freely in my general equilibrium model. The important contribution of my model is that I take the definition of a fiat currency seriuosly in that both currencies are intrinsically useless. I use spatial separation and limited communication of agents to motivate the demand for these currencies. This is in contrast to the treatment of Chang and Velasco (2000b) who assume that domestic money holdings generate utility. Also, deviating from their three-period framework, I study an overlapping-generations-model with an infinite sequence of two-period lived generations. As a first step, I find the steady-state equilibria of the model under the policy of a fixed growth rate of domestic money supply and a floating exchange rate regime. For both currencies to be held in positive amounts at the steady-state, the growth rate of domestic money supply (and hence the domestic inflation rate) must be equal to the world inflation rate (WIR). If, on the other hand, the growth rate of domestic money supply is larger than WIR, then the domestic currency is not held in steady-state equilibrium. The implication is that the choice of monetary policy is critical to which of the two currencies is held in equilibrium. However, I also find that monetary policy in the form of a constant growth rate of domestic money supply is *neutral* with respect to social welfare. The WIR and *total* (domestic and foreign) real currency balances held in equilibrium have a negative relationship. The relationship between the WIR and welfare depends on the initial level of WIR. If the initial level is larger (smaller) than some critical level, then a rise in the WIR implies a rise (fall) in welfare.

In Chapter IV of this dissertation, I draw some conclusions and point to some extensions of the models discussed.

CHAPTER II

ENDOGENOUS BANK RUNS, SUDDEN STOPS AND TERM STRUCTURE OF FOREIGN DEBT IN A LARGE OPEN ECONOMY

This chapter constructs a model of a financial system in a large open economy where foreign liabilities that are date-specific and maturity-specific are available. The maturity structure of debt and term structure of interest rates are both determined endogenously through the interaction of domestic banks and international creditors. In this environment, financial crises in the form of domestic bank runs and/or international sudden stops might arise endogenously. I use a world general equilibrium approach and consider optimizing international creditors. First, I measure the vulnerability of the domestic financial system to bank runs and sudden stops. Second, I link such vulnerabilities to fundamentals of the economy. The purpose is to design a mechanism that can potentially select "healthy" equilibria over crisis equilibria. I measure vulnerability of domestic banks to runs by their liquidity position. Longer maturity of foreign liabilities improves the liquidity position of banks. A larger cost of liquidating the long-term asset before maturity increases the risk of bank runs. Once a bank run occurs, I measure the vulnerability of the domestic financial system to sudden stops by the solvency position of the banks. International creditors stop lending and a sudden stop occurs if banks are insolvent. Creditors stop lending if their cost from reduced current consumption outweighs their benefit from future loan repayments. Therefore, a sudden stop is more likely if (i) creditors highly discount future consumption, (ii) creditors' current income is small relative to their future income, and (iii) the cost of liquidating the long-term asset before maturity is small. Third, I compare my open financial system which is allowed to borrow international capital to closed financial systems in terms of financial fragility. I find that access to international capital markets reduces the vulnerability to outcomes in which some domestic agents are left without consumption.

II.1 Introduction

In this chapter, I analyze financial crises in developing large open economies where foreign debt with different maturities is available. I restrict my attention to unexpected financial crises that can take the form of bank runs and/or sudden stops. The focus is on economies in which the private sector is a net foreign borrower and where the financial system is mostly composed of banks. Deviating from the previous literature, I explicitly allow for different types of foreign debt that are date-specific and maturity-specific. In addition, the corresponding equilibrium term structure of interest rates is determined endogenously by the interaction of banks and international creditors in the markets for these assets.

During the early 1990s, two stylized facts were observed in the world economy: first, there was a sharp increase in capital flows from developed economies into emerging market economies. Second, the financial sectors in most recipient countries appeared to be healthy. However, later in the decade and into the early 2000s, both facts were reversed in some borrower economies such as Mexico (1994-1995), East Asia (1997-1998) and Turkey (2000-2001). Several elements have been blamed to have caused these crises. On the domestic side, some people blamed the banks' illiquid positions. On the international side, "sudden stops" of capital inflows were thought to be the trigger of such crises. Specifically, the term "sudden stop" in this chapter refers to a situation where gross capital inflows become zero instead of the expected or planned positive inflows for that point in time[1]. Regardless of the alleged causes of those crises, the financial systems in these countries collapsed and millions of individuals were directly affected by the adverse consequences. In addition, these economies shared some common characteristics. First, their private sectors were net borrowers from the rest of the world. Second, their financial systems were relatively less developed and regulatory mechanisms such as deposit insurance and banking supervision were either non-existent or inefficient. Third, they had higher real interest rates than developed economies.

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[1] Chari, Kehoe and McGrattan (2005) define sudden stops as "abrupt declines in capital inflows". Hutchison and Noy (2004) include in the definition the simultaneous occurrence of currency/balance of payments crisis with a reversal in capital inflows. The definition I use in this chapter is closer to Chari, Kehoe and McGrattan (2005) since I have a non-monetary economy in this chapter.

This chapter is a theoretical exercise that focuses on such economies. Chang and Velasco (2000) studied those economies by modeling the domestic financial system explicitly from microfoundations. However, they assumed that these economies are small open economies facing exogenous international interest rates. Moreover, they considered trivial international lenders in the sense that external borrowing was constrained exogenously. In my model, I consider a world general equilibrium approach where international creditors follow an optimizing behavior. This approach allows both bank runs and sudden stops to be the outcome of the individuals' rational behavior when facing unexpected sunspots from different sources. Seo (2003) studied a world general equilibrium model, but she only included one short-term debt instrument and did not consider debt maturity. In this chapter, I am addressing the following issues. First, I assess the vulnerability of the economy to either bank runs and/or sudden stops. Second, I investigate whether I can link such vulnerability measures to fundamentals of both the domestic and the global economy, with the purpose of designing a mechanism that can potentially select "healthy" equilibria.

In order to address these issues, I imagine the world as consisting of two large economies: a developing domestic economy and a developed rest of the world. I explicitly model the financial system in the domestic economy using Diamond and Dybvig's (1983) approach for an open economy. Domestic banks provide insurance against a liquidity preference shock faced by domestic agents (depositors). In addition, banks are able to borrow internationally at various maturities and issue dates. The rest of the world is composed of many creditors who are natural lenders.

In such an environment, both maturity structure of foreign debt and term structure of interest rates are endogenously determined through the interactions between domestic banks and international creditors. Both bank runs and sudden stops may arise endogenously. In this chapter, I only consider unexpected sunspots observed by domestic depositors.

As a first step, I present and discuss equilibria where no crises take place. This is already an important contribution to the literature because it allows me to characterize equilibria in terms of maturity structure of foreign debt and the term structure of interest rates. Then, I present equilibria where crises are possible. As an example, I analyze crises originated domestically as a sunspot observed by domestic depositors. Then I characterize such equilibria in terms of solvency of banks. When a sunspot is observed, depositors check the liquidity condition of banks. If banks are illiquid, that is, if their potential liabilities exceed their potential assets, then a bank run occurs: all deposits are withdrawn early. Otherwise, no crises take place and domestic depositors behave according to their original plan. So the illiquidity condition is a measure of vulnerability of the financial system to bank runs. Next, when a bank run takes place, I analyze the conditions under which international creditors choose to stop lending or otherwise bail the banks out. If the international creditors stop lending, a sudden stop arises.

Diamond and Dybvig (1983) did an excellent job of illustrating the economic role of a bank. They offered an explanation of how banks vulnerable to runs can attract deposits. The environment they built has four ingredients. First, there is individual uncertainty over desired times of consumption. In a three-date economy, individuals of the impatient type wish to consume only in the second date and individuals of the patient type wish to consume only in the third date. Agents do not know their types in the first date when they need to make investment and consumption decisions. There is no aggregate uncertainty, and the probability of being of either type is public information. The second ingredient is that information of a particular individual's type is private and cannot be verified. This rules out insurance contracts based on type information. It also makes runs on banks possible as a patient depositor could misrepresent her type and withdraw early. The third ingredient is the availability of liquid and illiquid assets with smaller and larger returns respectively. The fourth ingredient is the sequential service constraint: the bank serves its customers on a first-come, first-served basis[2]. Within this environment, they demonstrated that the demand deposit contract offered by the bank achieves better allocations compared to autarky. They also showed the existence of a bank run equilibrium where patient agents misrepresent their type and rush to withdraw

[2] Neil Wallace (1998) derives the sequential service constraint from more primitive assumptions such as physical isolation of depositors from each other.

in the second date. This causes the bank to liquidate part or all of its long-term assets and possibly validate fears of a close-down, yielding lower welfare than in autarky.

Chang and Velasco (2000) applied the Diamond and Dybvig setup to the case of a small open economy. One of their objectives was to determine how a bank should optimally arrange the maturity of its foreign liabilities. They modeled their domestic economy as composed of a continuum of perfectly competitive banks. They allowed these banks to borrow external funds. However, by virtue of the small economy assumption, they did not model international creditors' behavior explicitly. Therefore the international debt markets had trivial and exogenous interest rates in their world partial equilibrium model. Moreover, they imposed an exogenous limit on foreign borrowing in order to ensure the existence of equilibria. Supply of loans was perfectly elastic up to this exogenous limit. In this chapter, I model a *large* open domestic economy. There are no such exogenous constraints on foreign borrowing. The only limit to borrowing is the willingness and resources of international creditors. In my model, they solve their own lifetime utility maximization problem. Domestic banks and international creditors participate in free debt markets where interest rates are endogenously determined. Thus, the term structure of foreign debt is nontrivial and endogenous.

Seo (2003) studies a world general equilibrium model with a large open economy similar to this chapter. However, unlike this chapter, she focuses only on short-term debt and does not study the choice of foreign debt maturity or the term structure of interest rates. Moreover, while in her paper the cause of a domestic bank run is the pessimistic expectations of the international creditors, in this chapter it is the pessimistic expectations of domestic depositors.

My analysis of different types of equilibria proceeds in two stages. At the initial stage, I describe equilibria where no crises take place: these are separating equilibria where agents behave according to their true type. At this stage, I find that there exist equilibria both when the no arbitrage condition holds and does not hold. By the term "no arbitrage condition", I refer to the comparison of the equilibrium long-term interest rate and short-term interest rates compounded over the same time to maturity. Based on this comparison, there are three categories of equilibria: long-term rate can be equal to (in which case the no arbitrage condition holds), greater than, or smaller than short-term rates compounded over the same time to maturity. Equilibrium maturity structure of debt is closely related to the equilibrium term structure of interest rates. In particular, if the long-term interest rate is larger (smaller) than the compounded short-term interest rates, equilibrium debt borrowed is long-term (short-term)[3]. If the no arbitrage condition holds, the equilibrium maturity structure of debt usually cannot be uniquely determined[4], with varying degrees of determinacy of the equilibrium interest rates. These results show that modeling the behavior of international creditors explicitly can provide a more comprehensive analysis of how international capital markets work.

Indeterminacy and multiplicity characterize the sets of separating equilibria. Indeterminacy is observed both in terms of equilibrium interest rates (price indeterminacy) and quantities of various debt instruments traded (quantity indeterminacy). I classify different sets of equilibria according to the degree of price determinacy. The equilibrium price (interest rates) vector can be unique, locally unique or irregular[5]. Quantity indeterminacy is mostly observed when the no arbitrage condition holds. This observation can be interpreted as an apparent tradeoff between price determinacy and quantity determinacy. When the price vector is more determinate, the quantity vector is less determinate and vice versa.

At the second stage I analyze the equilibria in which bank runs are possible. One of the distinguishing features of my approach in this chapter is that a bank run takes place as a *completely unexpected, surprise event* that is triggered by the adverse beliefs (sunspots) of domestic depositors[6]. Unlike Chang and Velasco (2000), there is no

[3] Here, I am referring to the choice between the two debt instruments that are available to the domestic economy for the initial date of the model. As will be explained later, there is a third short-term debt instrument available to the domestic economy for the second date of the model. The latter debt amount is always positive in all equilibria with no crises.
[4] Except in one corner solution.
[5] "Locally unique" refers to uniqueness of relative prices. If the price vector does not show relative price uniqueness, then I refer to it as "irregular". See section II.4 for details.
[6] There could be other potential sources of crises, such as sunspots of international creditors. I find that the source of the crisis matters, but due to lack of space, I focus on the sunspots of domestic agents in this chapter.

exogenous probability of a bank run that agents can take into account when they make their date-zero decisions in my three-date economy. As I have explained above, when a sunspot is observed, depositors check the liquidity condition of banks. If banks are illiquid then a bank run occurs. Otherwise, no crises take place and depositors behave according to their true type. Thus the liquidity condition is a measure of vulnerability of the financial system to bank runs. I find that illiquidity condition depends on two factors: equilibrium debt maturity structure and the fundamentals of both the domestic economy and the rest of the world. First, longer maturity of foreign debt improves the liquidity position of banks. As a result, banks are more (less) vulnerable to bank runs when compounded short-term interest rates are larger (smaller) compared to long-term rates: this is because in that case, debt maturity is short-term (long-term) in equilibrium[7]. Second, among other parameters, a larger cost of liquidating the long-term investment before maturity makes the banks more fragile.

Once a bank run happens, the international creditors re-evaluate some of their date-zero decisions at date one. In this chapter, I assume that after a bank run, the equilibrium interest rates on debt stay constant at their levels before the run. However, I allow creditors to re-evaluate and adjust the amounts of lending under the new conditions. In particular, they decide whether they are going to stop lending or lend an amount sufficient to bail the banks out of the crisis. They make this decision only on the basis of the new information and their own lifetime utility maximization problem (hence the term *endogenous* sudden stops in my title). First, I show that there cannot be any equilibrium where creditors lend a positive amount but the banks collapse at date one and cannot repay. Creditors either do not lend at all and banks collapse (sudden stop) or they lend an amount that will enable the banks to survive the crisis and repay their new

[7] This may appear counter-intuitive at first. To illustrate why I find such a pattern, consider the following example. Suppose the long-term rate is smaller than compounded short-term rates over the same maturity. In this case, banks want to borrow completely long-term, but the international creditors do not want to lend long-term at all (their supply of long-term debt is zero). Then there cannot be any equilibrium with positive long-term debt. On the other hand, equilibrium short-term debt must be positive, because the sum of short-term and long-term debt must be positive by the creditor's problem explained below. This is due to the net borrower property of the domestic private sector. As a result, equilibrium debt maturity is found to be short-term. In summary, I find that supply side has a greater bargaining power in my framework.

debt (bailout). Second, I explore the *insolvency* condition under which creditors choose to stop lending or otherwise bail the banks out. A sudden stop occurs if the creditors' cost from current reduced consumption outweighs their benefit from future loan repayments. Therefore, a sudden stop is more likely if the creditors' current endowment is small relative to their future endowment. Also, it is more likely if the cost of liquidating the long-term investment before maturity is small. Lastly, if the creditors highly discount future consumption over current consumption, a sudden stop is more likely.

It is worth stressing that my model is rich enough to allow outcomes in which creditors rationally choose to bail the banks out of a bank run. This happens when creditors find the banks solvent, i.e. the insolvency condition is not satisfied. As an example, I show the existence of a bailout equilibrium.

Lastly, I compare my open financial system which is allowed to borrow foreign capital to closed financial systems in terms of vulnerability to crises. In particular, access to international capital markets seems to reduce the vulnerability to very bad outcomes in which some domestic agents are left without consumption.

The remainder of the chapter is organized as follows. Section II.2 describes the environment and the interaction between different types of agents. Section II.3 presents an overview of the different types of equilibria that may arise. Section II.4 presents and characterizes equilibria with no bank runs and no sudden stops. Section II.5 characterizes equilibria where bank runs occur, and the circumstances under which a sudden stop can also be triggered. Section II.6 presents the main conclusion of my study and future extensions in this line of research.

II.2 Environment

Consider a *large open* economy version of the Diamond and Dybvig (1983) setup, in the spirit of Chang and Velasco (2000). The model I present in this chapter features two most distinguishing elements. First, I use a world general equilibrium approach by modeling explicitly the behavior of international creditors[8]. I consider the interaction and market clearing between banks and international creditors explicitly. Second, I introduce date-specific and maturity-specific international debt instruments[9]. In particular, I consider two short-term debt instruments that are date-specific and one long-term debt instrument.

The world consists of only two pure exchange economies. The domestic economy is a large open economy in which the private sector is a net borrower from the rest of the world. The second economy can be thought of as the rest of the world and it will henceforth be called so.

At each date there is a single tradable investment/consumption good. This good is homogeneous across countries. The world economy lasts for three dates, indexed by $t = 0$, *1* and *2.* At $t = 0$, a population of domestic agents is born in the domestic country and a population of international agents is born in the rest of the world. For simplicity and without much loss of generality, I normalize the size of the population in each country to a continuum of agents with unit mass.

II.2.1 Endowments, Preferences and Informational Structure

II.2.1.1 The Domestic Economy

Each domestic agent is endowed with g units of the single good at birth, but nothing at $t = 1$ and $t = 2$. All domestic agents are ex ante (as of $t = 0$) identical. However, they face uncertainty regarding their consumption patterns. Ex post (as of $t = 1$), they are of one of two types. With probability π, a domestic agent is of the "impatient" type and wishes to consume the good only at $t = 1$; with probability $1-\pi$, she is of the "patient" type and wishes to consume the good only at $t = 2$. Every domestic

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[8] One exception in the previous literature is Seo (2003).

[9] Seo (2003) considers only one short-term debt instrument.

agent learns her type at the beginning of $t = 1$. The probability π is public information. Also, type realizations are i.i.d. across domestic agents. Then, by the law of large numbers, π is also the fraction of impatient agents in the domestic economy. However, the information regarding an individual's type and her consumption and investment activities is private and it cannot be observed or verified by others. Hence, while there is individual uncertainty regarding preferences, there is no aggregate uncertainty.

Let x denote the consumption of a domestic agent at $t = 1$ if she is of impatient type, and y denote her consumption at $t = 2$ if she is of patient type. To fix ideas, I use a logarithmic utility function. Then, as of $t = 0$, a domestic agent's expected utility can be written as

$$E_0[U(x, y)] = \pi \ln(x) + (1 - \pi)\ln(y) . \tag{1}$$

Following Diamond and Dybvig, there is an illiquid technology available to agents and financial institutions of the domestic economy. One unit of the good invested at $t = 0$ can be transformed into capital that yields R units of the consumption good at $t = 2$. However, this is an illiquid asset in the sense that once one unit of the good is invested at $t = 0$, an early liquidation at $t = 1$ yields a return of s units of the consumption good where $s < R$[10]. One of the key elements of this chapter is to allow for non-trivial interest rates corresponding to each date and debt maturity. Therefore, unlike Diamond and Dybvig, I do not allow for a one-to-one storage technology of the consumption good between $t = 0$ and $t = 1$[11]. However, only individual domestic agents *can* potentially go underground and store goods between $t = 1$ and $t = 2$ receiving a gross rate of return equal to one[12]. As I will show later, this assumption is necessary to allow the patient agents to have the option to withdraw early by misrepresenting their type at $t = 1$. Notice

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[10] Here, for the sake of remaining as general as possible, I do not restrict liquidation value s to be less than one, as earlier literature did. In fact, since storage of the consumption good is not allowed between $t = 0$ and $t = 1$, liquidation value s will be compared to the short-term interest rate between $t = 0$ and $t = 1$, not to one.

[11] Otherwise, if I were to allow for the storage of the good, by no arbitrage condition, all interest rates would be equal to one unless there is a default risk.

[12] By assumption, this storage technology is *never* available to coalitions of domestic depositors (banks) or international creditors. It is only available to individual depositors between *t=1* and *t=2*. This assumption gives the depositors an alternative asset between these dates so that they can misrepresent their type and abscond goods.

that if domestic agents could not store and abscond the good at this date, there would never be bank runs in equilibrium.

As it is standard in the literature, one can easily show that in the environment described, coalitions of domestic agents organized as a bank can achieve superior outcomes relative to autarky where agents make consumption and investment decisions individually. This is due to the fact that in autarky, an individual agent will invest her entire endowment in the illiquid asset. Then, in case of the unfortunate event that she turns out to be impatient, she will liquidate her entire investment at a loss. However, the absence of aggregate uncertainty enables the banks to pool resources and completely avoid liquidation in the case where bank runs are not possible. However, as the previous literature made it clear, in the case where there is a run on the banks, the resulting allocations may be worse than autarky[13]. Henceforth I assume that there is a continuum of perfectly competitive banks in the domestic economy, and I will call domestic agents depositors.

II.2.1.2 The Rest of the World

In the rest of the world, each international agent is endowed with *m, n* and *b* units of the good at $t=0$, $t=1$ and $t=2$ respectively. For simplicity, I assume that there is no investment or storage technology available to agents born in the rest of the world. However, international agents have access to the international debt markets, and they are natural lenders in these markets. Hence, from now on I will call them international creditors. Each creditor wishes to consume at both $t=1$ and $t=2$. Let u and v denote the consumption of an international creditor at $t=1$ and $t=2$, respectively. Then, I can write her lifetime utility as

$$U(u,v) = \ln(u) + \beta \ln(v) \tag{2}$$

where again, to fix ideas, I use a logarithmic utility function and $0 < \beta \leq 1$ is the intertemporal discount rate.

I assume that international creditors can invest in the domestic economy *only* through domestic banks. In other words, while domestic depositors individually do not

[13] See Diamond and Dybvig (1983), Cooper and Ross (1998), Ennis and Keister (2004) for more on this.

have access to international debt markets, coalitions of them organized as banks do. In making such an assumption, I follow the observation made by Diamond and Rajan (2000) about the 1997-98 Asian crisis that most of the foreign borrowing made was made by domestic banks, rather than domestic individuals[14].

There are three markets for debt where banks borrow from international creditors. Let d_{ij} denote the equilibrium amount of debt of a bank contracted at date i and has to be repaid at date j. There are two markets for short-term debt where equilibrium amounts borrowed are denoted by d_{01} and d_{12}. The corresponding gross real interest rates are r_{01} and r_{12}. In addition, there is a long-term debt option for both banks and international creditors: d_{02} denotes the equilibrium amount borrowed at $t=0$ and to be repaid at $t=2$. The corresponding equilibrium gross real interest rate is r_{02}. Each bank, creditor and depositor takes the interest rates r_{01}, r_{12} and r_{02} on these debt instruments as given when they make their consumption, borrowing and lending decisions at $t=0$.

II.2.2 The Representative Domestic Bank's Problem

The banking arrangement in this environment is described as follows. Each bank offers a demand deposit contract that promises to pay x units of the consumption good to domestic depositors who withdraw at $t=1$, and y units to domestic depositors who withdraw at $t=2$. Accepting this contract, domestic agents deposit their entire endowment of g units of the good with banks at $t=0$. At $t=0$, the bank determines its demand for each of the three loans available: short-term (d^d_{01} and d^d_{12}) and long-term (d^d_{02})[15]. Thus, in addition to deposits g, the resources of the representative bank at $t=0$ include the short-term d^d_{01} and the long-term d^d_{02} loans. The bank invests these resources in the long-term asset in order to maximize the representative domestic depositor's expected utility (1). Denoting by k the amount invested in long-term asset,

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[14] Exception is Indonesia. A possible justification as to why international creditors would not lend to individual depositors may be the advantages of the domestic banks over international banks in collecting agent-specific information regarding credit-worthiness. Alternatively, there could be minimum capital requirements for access to international credit markets that individuals could not meet. Seo (2003) justifies this assumption by noting that agents can hide and avoid repayment while banks can always be located by creditors.

[15] Here, superscripts in d^d_{ij} indicate demand function. Later, when I will discuss international creditors' problem, I will have d^s_{ij} as indicating supply of funds in the debt markets.

$$k \leq g + d^{d}{}_{01} + d^{d}{}_{02} \tag{3}$$

is the resource constraint faced by the bank corresponding to $t = 0$.

The representative bank's source of funds for $t = 1$ includes additional short-term borrowing at the amount of $d^{d}{}_{12}$. In addition, its second source of funds is the early liquidation of the long-term asset. Such early liquidation is costly since it only yields the return of s units per one unit invested at $t = 0$ and liquidated at $t = 1$ where $s < R$. Let l denote the amount of the long-term asset liquidated early. Using these resources, the bank has to pay x to each depositor claiming to be impatient and repay short-term debt $d^{d}{}_{01}$ at the market interest rate of r_{01}. Then, the resource constraint at $t = 1$ can be written as[16]

$$\pi x + r_{01} d^{d}{}_{01} \leq d^{d}{}_{12} + sl\,. \tag{4}$$

At $t = 2$, the bank receives the returns from the non-liquidated part of the long-term asset $k - l$, obtaining the return R for each unit not liquidated. The liabilities of the bank include a payment of y units to each patient depositor and repayments of short-term ($d^{d}{}_{12}$) and long-term ($d^{d}{}_{02}$) loans plus interest:

$$(1 - \pi) y + r_{12} d^{d}{}_{12} + r_{02} d^{d}{}_{02} \leq R(k - l)\,. \tag{5}$$

When $l = 0$, the constraints (4) and (5) correspond to the case where there are no runs and hence no misrepresentation of type by patient agents. This implies that the fraction of early withdrawals is equal to the fraction of impatient depositors. Thus, the bank has to give the right incentives to the patient agents in the demand deposit contract offered so that they want to participate and they do not want to misrepresent their type. If a patient depositor would claim to be impatient, she would receive x units of consumption at $t = 1$. Since she would want to consume it only at $t = 2$, the best she could do is to store it at the rate of one for one. So she could consume x units at $t = 2$. Then, the following incentive compatibility constraint must be included in the no bank runs case:

[16] Here, note the implicit assumption that there will not be any misrepresentation of type by patient depositors at the initial stage, so that the fraction of depositors that actually withdraws at $t=1$ is equal to the fraction of impatient agents (π). In the next stage when I allow for runs, withdrawals at $t=1$ may be larger than π. This case is analyzed in section II.5.

$$x \leq y \tag{6}$$

Finally, the following non-negativity constraints apply:

$$d^d{}_{01}, d^d{}_{02}, d^d{}_{12}, l \geq 0 \text{ and } k, x, y > 0 \tag{7}$$

In summary, the representative bank chooses $\{k, d_{01}{}^d, d_{02}{}^d, d_{12}{}^d, l, x, y\}$ in order to maximize (1) subject to (3)-(7) taking $r_{01}, r_{02}, r_{12}, g, \pi, R$ *and* s as given.

II.2.3 The Representative International Creditor's Problem

One of the most distinguishing features of this chapter is that I explicitly model the problem of international lenders (creditors). At $t = 0$, each creditor decides on how to allocate her endowment *m* between short-term or long-term loans to the banks:

$$d^s{}_{01} + d^s{}_{02} \leq m \tag{8}$$

Also at this date, the creditor formulates a plan for $d^s{}_{12}$, taking all market interest rates as given. At $t = 1$, the representative creditor has additional endowment of *n* and receives payment of the first short-term loan plus interest as resources. She allocates her resources between consuming *u* units of the good or lending additional short-term funds to the domestic banks, $d^s{}_{12}$:

$$u + d^s{}_{12} \leq r_{01} d^s{}_{01} + n \tag{9}$$

At $t = 2$, the international creditor consumes an amount of *v* using her endowment of *b* goods and the short-term and long-term debt repayments plus interest:

$$v \leq b + r_{12} d^s{}_{12} + r_{02} d^s{}_{02} \tag{10}$$

Finally, the following non-negativity constraints also apply:

$$d^s{}_{01}, d^s{}_{02}, d^s{}_{12} \geq 0 \text{ and } u, v > 0 \tag{11}$$

In summary, the representative international creditor chooses $\{d_{01}{}^s, d_{02}{}^s, d_{12}{}^s, u, v\}$ in order to maximize (2) subject to (8)-(11) taking interest rates and *m, n, b* as given.

II.2.4 The Parameter Space and Existence of Equilibria

In this section I discuss the restrictions on two key parameters: s and R. These restrictions are needed to ensure the existence of non-trivial equilibria. Assumption 1 ensures that equilibria with banks dominate autarky. Banks help achieve better allocations than autarky when there is no liquidation of the long-term asset. For there to be no liquidation of the long-term asset, return from such liquidation s needs to below some threshold. Assumption 2 gives a sufficient condition for the incentive compatibility constraint (6) to be satisfied in all cases.

II.2.4.1 Assumption on *s*

In order to eliminate equilibria where the role of banks is trivial, I need an upper bound on the possible values that s can take. In the case where there are no crises, it is not optimal for the bank to liquidate the long-term asset. The following assumption II.1 is necessary to motivate equilibria with banks as opposed to autarky. If it does not hold, then equilibrium allocations with banks are identical to those without them. In simple terms, there is no welfare gain from having banks in the model.

Assumption II.1: *For zero liquidation of the long-term asset to be optimal, the following condition is necessary or sufficient depending on the particular case:*

$$s < \min\left\{\frac{n\beta}{m + \pi(1+\beta)g + b/R}, \frac{n\beta}{\pi(1+\beta)(g+m) + b/R}\right\} \tag{12}$$

Moreover, banks may not borrow positive debt from abroad if (12) does not hold because they would find liquidation more profitable.

Proof: The proofs for each case listed in section II.3 are included in Appendix A.

The intuition is that the opportunity cost of liquidation $\left(\frac{R}{s}\right)$ needs to be large enough so that individuals decide to establish a financial system that can avoid liquidation and provide some insurance[17]. Henceforth, I assume that (12) holds.

[17] In this case, banks cannot provide full insurance ($x = y$) because liquidation of the long term asset is costly.

II.2.4.2 Assumption on *R*

The following assumption ensures that the incentive compatibility condition is satisfied in all equilibria of the model. This condition is very closely related to the magnitude of the return on the long-term asset, *R*.

Assumption II.2: *A sufficient condition for the incentive compatibility (IC) condition, i.e.* $y \geq x$*, to be satisfied in all sets of equilibria except one is that the return on the long-term asset is sufficiently large:*[18]

$$R \geq \max\left\{\frac{n\beta - b}{m + \pi(1+\beta)g}, \frac{n\beta - b}{\pi(1+\beta)(g+m)}\right\} \tag{13}$$

In one set of equilibria, a sufficient condition for IC is found as $b \geq n\beta$.

Proof: The proofs are provided in Appendix A.

It is not surprising that the IC condition holds if the return on long-term asset is above a threshold. Notice that the long-term investment matures at $t = 2$. This is the same date that the bank promises to make a payment of y units of goods to each patient depositor. Therefore, it is only natural to presuppose a positive relationship between *R* and the optimally chosen value of y. Henceforth, I assume that (13) holds.

II.3 Types of Equilibria

In this section, I present an overview of the possible types of equilibria resulting from the model. Section II.3.1 describes the outcomes with no bank runs and no sudden stops. Section 3.2 characterizes possible outcomes when I allow for the possibility of crises.

II.3.1 Overview of Equilibria with No Crises

Here I focus on the cases where crises never take place. Figure 2.1.1 describes the timeline of events in this three-date economy.

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[18] Notice that which of the terms in parentheses becomes the lower bound for *R* depends on whether $\pi(1+\beta) < 1$ or not. If $\pi(1+\beta) < 1$ ($\pi(1+\beta) > 1$), then the second (first) term is the lower bound for *R*.

t=0 | t=1 | t=2

-Depositors deposit their endowment g in banks.
-Banks choose $\{k, d_{01}{}^{d}, d_{02}{}^{d}, d_{12}{}^{d}, l, x, y\}$.
-International creditors choose $\{d_{01}{}^{s}, d_{02}{}^{s}, d_{12}{}^{s}, u, v\}$.
-Markets clear: d_{ij} and r_{ij} get determined.

-Banks repay $r_{01}d_{01}$ to creditors, pay πx to impatient depositors using $d_{12} + sl$.
-Creditors receive $n + r_{01}d_{01}$, lend d_{12} to banks, consume u.
-Impatient depositors consume x.

-Banks repay $r_{12}d_{12} + r_{02}d_{02}$ to creditors and pay $(1-\pi)y$ to patient depositors using $R(k-l)$ returns.
-Creditors receive $b + r_{12}d_{12} + r_{02}d_{02}$ and consume v.
-Patient depositors consume y.

FIGURE 2.1.1: TIMELINE OF EVENTS WITH NO CRISES

All decisions by banks and international creditors regarding their choice variables are made at date zero. Notice that there are no unexpected events in this case. Thus at subsequent dates, no new decisions are made, but only date-zero decisions are carried out. Section II.4 presents the sets of equilibria with no crises. I find that there are multiple equilibria both with respect to the term structure of interest rates and the maturity structure of debt. In particular, there are equilibria both when the no arbitrage condition holds, i.e. $r_{02} = r_{01}r_{12}$ and when it does not hold. The equilibrium maturity structure of debt is closely related to the term structure of interest rates. In particular, if the long-term interest rate is larger (smaller) than short-term interest rates compounded over two periods, i.e. $r_{02} > r_{01}r_{12}$ ($r_{02} < r_{01}r_{12}$), then (i) equilibrium debt borrowed at date zero is entirely long-term (short-term), (ii) the equilibrium amount of d_{12} borrowed is uniquely determined in each case. If the no arbitrage condition holds, the maturity structure of debt typically cannot be uniquely determined. There is one exception to this pattern at one corner solution in which international creditors do not want to lend short-term at $t=0$.

II.3.2 Overview of Equilibria When Crises Are Possible

In this section, I present an overview of equilibria allowing for the possibility of crises in the form of bank runs and sudden stops. Figure 2.1.2 summarizes the workings of the economy on an event tree. As it will be explained shortly, any crisis takes place as a *completely unexpected, surprise event*. Therefore, agents' date zero decisions cannot take into account the possibility of a crisis. Agents still make their date zero decisions as if no crises were going to take place. Date zero allocations are identical regardless of whether the crises actually take place or not. I present here the case where only domestic depositors are hit first by the surprise event.

First, there cannot be any crisis if there is no sunspot. If domestic depositors see a sunspot, they immediately check the liquidity position of the banks. If the banks are liquid, there is no run on the banks. The liquidity condition is based on a worst-case scenario in which depositors run and creditors do not lend at date one. Therefore, it is possible to avoid all runs (and hence all crises) if the banks are liquid. Proposition 1 below proves this result. Henceforth I assume that domestic withdrawals have legal priority over international debt repayments. I also assume that long-term debt repayments $r_{02}d_{02}$ have priority over short-term debt repayments $r_{12}d_{12}$ at date two.

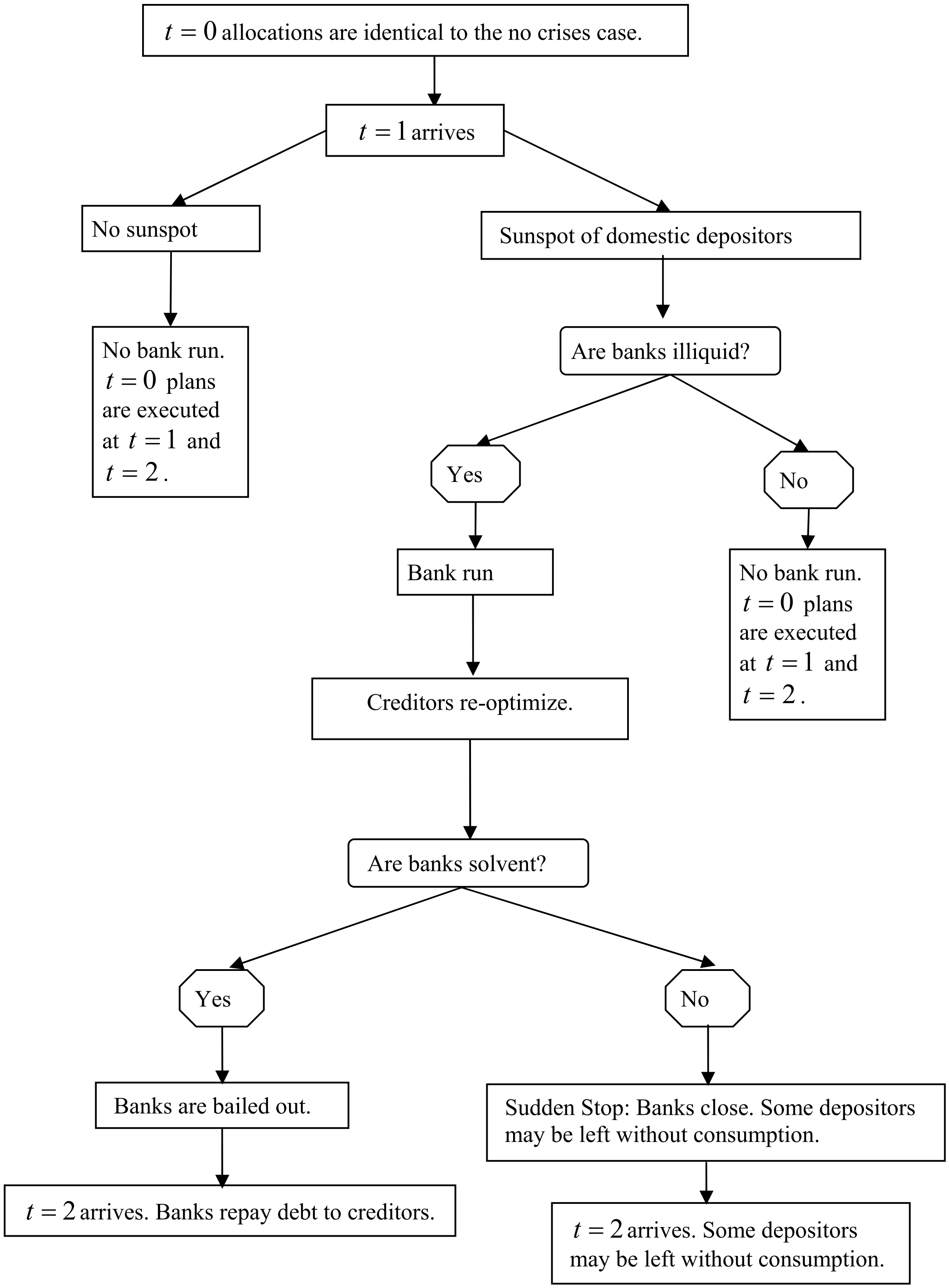

FIGURE 2.1.2: POSSIBLE EVENTS WITH POSSIBLE CRISES ORIGINATED DOMESTICALLY

Proposition 1: *If the banks are internationally liquid, that is if*

$$x + r_{01}d_{01} < sk \tag{14}$$

is satisfied, then there cannot be any bank runs in equilibrium.

Proof: Suppose that (14) holds. Suppose also that creditors do not lend at date one[19]. Suppose now that all patient depositors except one run to the banks for withdrawal. Given the situation, let us look at this one patient depositor's incentives. If she runs, she will get x units of the good. Then she will store it for the next date and consume the same amount. If she does not run, by (14), the bank will not close as it will still have some resources left after all depositors withdraw and foreign debt is repaid at date one. As date two arrives, the first obligation of the bank by assumption is to pay y to our patient depositor. Since the incentive compatibility condition $y \geq x$ is always satisfied, our patient depositor would prefer to wait for date two. Then, this would be the equilibrium and no patient depositor would withdraw early. QED

The above proposition proves that there cannot be a crisis if the banks are liquid. In this case, everything goes as was planned at date zero. Creditors lend d_{12} amount of resources as was promised, banks service withdrawals and repay all debt instruments at dates one and two. If, at the beginning of date one, banks are illiquid, then the allocations satisfy

$$x + r_{01}d_{01} \geq sk \tag{15}$$

When (15) holds, there is a possibility that patient depositors may have a sunspot and run to the banks for withdrawal. When a bank run happens, I find that under some solvency conditions it may be in the international creditors' interest to bail the banks out of the crisis[20]. In other circumstances, there is no way the bank could be saved. In the latter case, a sudden stop takes place.

[19] The liquidity position of the bank cannot be worse than it is when creditors stop lending and depositors run. If, in this case I am able to show that a bank run is not possible, then the bank is in a better position in all other cases with positive lending. Hence a run is not possible in those other cases as well.

[20] Chang and Velasco (2000) argue that if the banks are illiquid, international creditors will never lend any amount at date one. In this chapter, I argue that positive lending is still possible under some conditions studied in section II.5 below.

Once a run happens, the banks have to pay x goods instead of πx goods in aggregate to depositors. International creditors observe this crisis and reconsider their decisions about whether to lend the previously promised amount d_{12} goods to banks or not. This decision is based upon *solvency* position of the banks. At $t = 1$, after domestic depositors run on illiquid banks, these banks can still be solvent and thus worth bailing out by international creditors. If bailed out, banks survive until $t = 2$ and they are able to repay their debts at $t = 2$. However, if the banks are insolvent, they are considered not worth of bailing out by international creditors: such banks will fail inevitably at $t = 1$.

After observing that a run has taken place, international creditors re-optimize according to the new circumstances. They adjust the amounts of debt they want to lend to the banks. In equilibrium, they lend a gross amount of z_{12} units at date one. This amount is not necessarily equal to the anticipated amount d_{12} that was originally promised at date zero. Also, creditors may want to adjust the quantity of the long-term debt to a new level denoted by z_{02}. Lastly, the banks may liquidate part of the long-term asset; $l \geq 0$.

A possible method of measuring solvency of banks is the following: Banks are considered insolvent when even if they were to liquidate the long-term asset completely, their current level of borrowing would not be sufficient to fulfill their obligations at date one. On the one hand, banks are insolvent when the following sufficient condition holds:

$$x + r_{01} d_{01} > sk + z_{12} \tag{16}$$

In section II.5, proposition 5, I prove that (16) is a sufficient condition for a sudden stop to take place. On the other hand, banks *may be* solvent when the following condition holds:[21]

$$x + r_{01} d_{01} \leq sk + z_{12} \,. \tag{17}$$

There are two possible outcomes of the creditors' re-optimization problem. In the first outcome, international creditors choose $z_{12} = z_{02} = 0$, deciding not to bail the banks out of the crisis, because the latter are insolvent. This event is called a *sudden stop*. By

[21] Although (16) is sufficient for insolvency, (17) is not sufficient for solvency. It is only necessary.

illiquidity condition (15) and the assumption that domestic liabilities have priority over international, the banks must partially or fully default on short-term debt d_{01}. If default on this debt instrument is full, then it must be that some depositors waiting in line do not have the chance to obtain any payment before banks close down[22]. Those depositors are left without consumption. This is a "very bad outcome" as the utility of those depositors left without consumption is infinitely negative. This implies that the domestic economy is worse off than it would be without any banks. This is because in the case of autarky, each domestic depositor is able to consume a positive amount of goods. This "very bad outcome" happens if creditors do not bail the banks out *and* the following condition holds:

$$x > sk \tag{18}$$

In section II.5.3, I analyze the cases in which a "very bad outcome" occurs. In particular, I compare closed and open financial systems in terms of vulnerability to a very bad outcome. If there is a sudden stop, banks close down at date one after liquidating the long-term asset completely.

In the second outcome, creditors set $z_{12} > 0$ and $z_{02} > 0$, thus bail the banks out of the crisis. They find it rational to do so after they re-optimize under the new conditions. When banks are bailed out, all domestic depositors consume the amount of goods originally promised to impatient depositors. Banks survive to date three and repay their new debt to creditors. Notice that in a bailout, banks do not have any domestic obligations at date three. I propose a solution to the creditors' re-optimization problem and find the bank's solvency condition in section II.5.2.

In the next section, I start describing separating equilibria where crises are never observed. In section II.5, I analyze equilibria allowing for the possibility of crises.

[22] This possibility is a result of the sequential service constraint.

II.4 Equilibria with No Bank Runs and No Sudden Stops

In this section, I describe sets of separating equilibria in which no sunspots exist and probability of a crisis is zero.

II.4.1 Market Clearing Conditions

There is a single world market for each of the three debt instruments d_{01}, d_{02} and d_{12}. These markets clear at $t = 0$ when the world aggregate supply of funds equals the world aggregate demand for funds:

$$d^{s}{}_{01} = d^{d}{}_{01} \tag{19}$$

$$d^{s}{}_{02} = d^{d}{}_{02} \tag{20}$$

$$d^{s}{}_{12} = d^{d}{}_{12} \tag{21}$$

These conditions determine the set of equilibrium interest rates on these debts r_{01}, r_{02} and r_{12}.

II.4.2 General Equilibrium and Determinacy

> For a theorist, the best of the all possible worlds is one in which the social situation being analyzed can be formalized in a manner that, on the one hand, is very parsimonious…and on the other, manages to predict a unique outcome.
>
> –Mas-Colell, Whinston and Green (1995)

Although the model presented in this chapter seems to start as a simple exercise and satisfies the first part of the above recommendation, its outcome is not unique. Depending on the borrowing and lending behavior of the banks and the international creditors, at least thirteen sets of equilibria arise with varying degrees of multiplicity. One meaningful criterion to classify those equilibria seems to be on the basis of *the degree of determinacy*. The degree of determinacy has two dimensions: price determinacy and quantity determinacy.

Price determinacy can be understood by envisioning the space of admissible equilibrium interest rates at each set of equilibria. Starting from the more determinate to the less determinate, the sets of equilibria can be classified into three categories: *points*, *curve segments* and *convex surfaces* in the space of equilibrium interest rates (r_{01}, r_{12}, r_{02}).

(i) A *point* in the space of (r_{01}, r_{12}, r_{02}) represents a unique price vector. There exists one such equilibrium when both banks and international creditors are at an interior solution for all three assets.

(ii) Sets of equilibria that admit *curve segments* in the interest rate space[23]. Mas-Colell, Whinston and Green (1995) describe this class of equilibria as *locally unique* or *regular*. Here, the relative price vector (the normalized interest rates vector) is unique. So I consider this class of equilibria to have more predictive power than the next class below. As Mas-Colell, Whinston and Green (1995) put it:

> "From the theoretical point of view, if uniqueness is not achievable, the next-best property is local uniqueness."

(iii) There are six sets of equilibria that admit *convex surfaces* in the space of interest rates. These are characterized by a multiplicity of relative price vectors. I call these sets of equilibria *irregular*[24].

The second dimension of determinacy is in terms of the equilibrium quantities of assets (debt) traded. In some cases, equilibrium quantities of assets traded are indeterminate: both banks and creditors are indifferent to a continuum of vectors of the amounts of the three assets (d_{01}, d_{12}, d_{02}) that satisfy certain conditions. This phenomenon is observed typically when the no arbitrage condition holds: $r_{02} = r_{01} r_{12}$.

[23] One common property of the cases in this group is that out of five first order conditions on both problems, always *three* of them are at interior solution providing three equalities.

[24] There is at least one set of equilibria that admit *volumes* in the space of interest rates. However, I do not explore those equilibria in this chapter.

An alternative criterion for classifying different sets of equilibria seems to be the *no arbitrage condition*. This condition specifies the relationship between the interest rates on two short-term and one long-term debt instruments. Proposition 2 analyzes the cases where the no arbitrage condition holds, i.e. $r_{02} = r_{01}r_{12}$. No arbitrage means that borrowing (lending) two consecutive short-term assets costs (yields) the same as borrowing (lending) the long-term asset from the banks' (international creditors') perspective. Proposition 3 analyzes the cases where compounded short-term interest rates are smaller than long-term rates, i.e. $r_{02} > r_{01}r_{12}$. Proposition 4 presents the cases where long-term borrowing is relatively cheaper, i.e. $r_{01}r_{12} > r_{02}$. The proofs of these propositions are included in Appendix A.

II.4.2.1 Equilibria Where the No Arbitrage Condition Holds

This section analyzes the cases where the long-term interest rate is equal to the short-term interest rates compounded over the same maturity. The proofs of the propositions 2, 3 and 4 are included in Appendix A.2, A.3 and A.4 respectively.

Proposition 2: *When the no arbitrage condition in the international debt markets* $r_{02} = r_{01}r_{12}$ *holds, five sets of equilibria are observed with no liquidation and no sudden stops. Case 1.A is observed when both the banks and the international creditors are at an interior solution for all assets. Case 1.B is observed when only creditors are at an interior solution for all assets, but bank behavior varies. Case 1.C is observed when only banks are at an interior solution for all assets, but creditors are at a corner solution. Table 2.1 offers a summary.*

TABLE 2.1: SETS OF EQUILIBRIA WHEN THE NO ARBITRAGE CONDITION HOLDS

Case	Interest rates	Demand F.O.C.	Supply F.O.C.	Quantities traded
1.A	$R=r_{01}r_{12}=r_{02}$	d^d_{01} *interior*	d^s_{01} *interior*	d_{01} *indeterminate*
	Unique	d^d_{02} *interior*	*N/A*	d_{02} *indeterminate*
		d^d_{12} *interior*	d^s_{12} *interior*	d_{12} *indeterminate*
1.B.1	$R > r_{02} = r_{01}r_{12}$	d^d_{01} *interior*	d^s_{01} *interior*	d_{01} *indeterminate*
	Locally Unique	d^d_{02} *right corner*	*N/A*	d_{02} *indeterminate*
		d^d_{12} *right corner*	d^s_{12} *interior*	d_{12} *indeterminate*
1.B.2	$R > r_{02} = r_{01}r_{12}$	d^d_{01} *right corner*	d^s_{01} *interior*	d_{01} *indeterminate*
	Locally Unique	d^d_{02} *right corner*	*N/A*	d_{02} *indeterminate*
		d^d_{12} *interior*	d^s_{12} *interior*	d_{12} *indeterminate*
1.B.3	$R > r_{02} = r_{01}r_{12}$	d^d_{01} *right corner*	d^s_{01} *interior*	d_{01} *indeterminate*
	Irregular	d^d_{02} *right corner*	*N/A*	d_{02} *indeterminate*
		d^d_{12} *right corner*	d^s_{12} *interior*	d_{12} *indeterminate*
1.C	$R = r_{02} = r_{01}r_{12}$	d^d_{01} *interior*	$d^s_{01} = 0$	$d_{01} = 0$
	Locally Unique	d^d_{02} *interior*	*N/A*	$d_{02} = m$
		d^d_{12} *interior*	d^s_{12} *right corner*	$d_{12} = \pi r_{01} g$

Note: Notice that I have only two first order conditions from the international creditors' problem, while I have three first order conditions from the banks' problem.

Now I characterize each case in detail. From now on, I refer to the solution to the creditors' optimization problem as only the creditors' problem and solution to the banks' optimization problem as the banks' problem.

Case 1.A This case arises when international creditors want to lend and banks want to borrow finite amounts of debt in all three markets. Then there exists a set of equilibria with a unique price vector. In this set, the market interest rates are determinate as $r_{01} = \dfrac{n\beta}{m + \pi(1+\beta)g + \dfrac{b}{R}}$, $r_{12} = \dfrac{R[m + \pi(1+\beta)g] + b}{n\beta}$ and $r_{02} = R$. The quantities of assets traded are indeterminate, but the following relationships describe a continuum of equilibria. From the creditors' problem, $d_{01} + d_{02} = m$ and $d_{12} = r_{01}d_{01} + \dfrac{n\beta}{1+\beta} - \dfrac{mr_{01}}{1+\beta} - \dfrac{b}{(1+\beta)r_{12}}$. From the banks' problem, $d_{12} = r_{01}d_{01} + r_{01}\pi g$.

Case 1.B Case 1.B is observed when only creditors are at an interior solution for all assets, but bank behavior varies.

Case 1.B.1 This case arises when

(i) international creditors want to lend finite amounts of debt in all three markets, but

(ii) banks want to borrow arbitrarily large amounts of long-term debt at date zero and short-term debt at date one.

Then there exists a set of locally unique equilibria in terms of prices. In this set, $r_{02} < R$ and

$$r_{12}(r_{01}) = \frac{-B_1 + \sqrt{B_1^{\;2} - 4A_1C_1}}{2A_1} \tag{22}$$

where $A_1 \equiv \pi\beta r_{01}(mr_{01} + n)$, $B_1 \equiv (1-\pi)R\beta n - r_{01}\left[\pi b + Rm(1+\beta\pi) + R\pi g(1+\beta)\right]$ and $C_1 \equiv -(1-\pi)Rb$. The amounts of debt traded are indeterminate, but are described by the following relationships. From creditors' problem, $d_{01} + d_{02} = m$ and $d_{12} = r_{01}d_{01} + \dfrac{n\beta}{1+\beta} - \dfrac{mr_{01}}{1+\beta} - \dfrac{b}{(1+\beta)r_{12}}$. From banks' problem, $d_{12} = r_{01}d_{01} + r_{01}\pi\dfrac{[R(g+m) - mr_{01}r_{12}]}{(1-\pi)R + \pi r_{01}r_{12}}$.

Case 1.B.2 This case arises when

(i) international creditors want to lend finite amounts of debt in all three markets, but

(ii) banks want to borrow arbitrarily large amounts of both short and long-term debt at date zero.

Then there exists a set of locally unique equilibria in terms of prices. In this set, $r_{02} < R$ and

$$r_{12}(r_{01}) = \frac{\pi R(g+m)(1+\beta)+b}{r_{01}m[\pi(1+\beta)-1]+n\beta} \tag{23}$$

The amounts of debt traded are indeterminate, but are described by the following relationships. From the creditors' problem, $d_{01}+d_{02}=m$ and $d_{12}=r_{01}d_{01}+\frac{n\beta}{1+\beta}-\frac{mr_{01}}{1+\beta}-\frac{b}{(1+\beta)r_{12}}$. From the banks' problem, $d_{12}=r_{01}d_{01}+\frac{\pi R(g+m)}{r_{12}}-r_{01}\pi m$.

Case 1.B.3 This case arises when

(i) international creditors want to lend finite amounts of debt in all three markets, but

(ii) banks want to borrow arbitrarily large amounts of debt in all three markets.

Then there exists a set of irregular equilibria. In this set, $r_{02} < R$ and the set of equilibrium interest rates lie as values between the curves described in cases 1.B.1 and 1.B.2 that are on the surface defined by the no arbitrage condition, $r_{02}=r_{01}r_{12}$. The amounts of debt traded are indeterminate, but are described by the following relationships. From the creditors' problem, $d_{01}+d_{02}=m$ and $d_{12}=r_{01}d_{01}+\frac{n\beta}{1+\beta}-\frac{mr_{01}}{1+\beta}-\frac{b}{(1+\beta)r_{12}}$. From the banks' problem, $d_{12}<r_{01}d_{01}+\frac{\pi R(g+m)}{r_{12}}-r_{01}\pi m$ and $d_{12}>r_{01}d_{01}+r_{01}\pi\frac{[R(g+m)-mr_{01}r_{12}]}{(1-\pi)R+\pi r_{01}r_{12}}$.

Case 1.C This case arises when

(i) international creditors do not want to lend short-term at date zero, but want to lend arbitrarily large amounts at date one, and

(ii) banks want to borrow finite amounts of debt in all three markets.

Then there exists a set of locally unique equilibria. In this set, $r_{02} = R$ and $r_{01}r_{12} = R$. The amounts of debt traded are determined as $d_{01} = 0, d_{02} = m \ and \ d_{12} = r_{01}\pi g$.

While equilibrium interest rates are uniquely determined in case 1.A, the amounts of assets traded are indeterminate. There is a continuum of equilibria with different combinations of the vector (d_{01}, d_{12}, d_{02}) satisfying three relationships stated in the proposition. Each one of these equilibria delivers the same consumption vector for both domestic depositors and international creditors. The consumption levels are uniquely determined in terms of parameters. Consumption offered per impatient agent (x) depends negatively on the equilibrium interest rate at date one (r_{12})[25]. Therefore, effects that change the latter also change the former. First, as the fraction of impatient agents π rises, the equilibrium interest rate at date one rises and it is more difficult to borrow at this date. This makes sense because as the number of impatient agents rises, demand for funds d^d_{12} increases as date one obligations of the bank are larger. Consequently, the impatient agents' level of consumption decreases. Second, this consumption level is positively (and closely) related to the international creditor's endowment (income) at date one, but negatively related to the international creditor's endowment (income) at other dates. Therefore the consumption level of impatient depositors is sensitive to changes in income of the rest of the world. On the other hand, domestic consumption at date two offered by the bank's demand deposit contract (y) only depends on the domestic endowment at date zero and the return on long-term investment. In other words, patient agents' consumption is independent of effects coming from rest of the world in this case. International creditors' date two consumption (v) is closely (and positively) related to the return on domestic long-term investment (R).

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[25] In case 1.A, $x = \frac{gR}{r_{12}}$ and $y = gR$ where $r_{12} = \frac{R[m + \pi(1+\beta)g] + b}{n\beta}$.

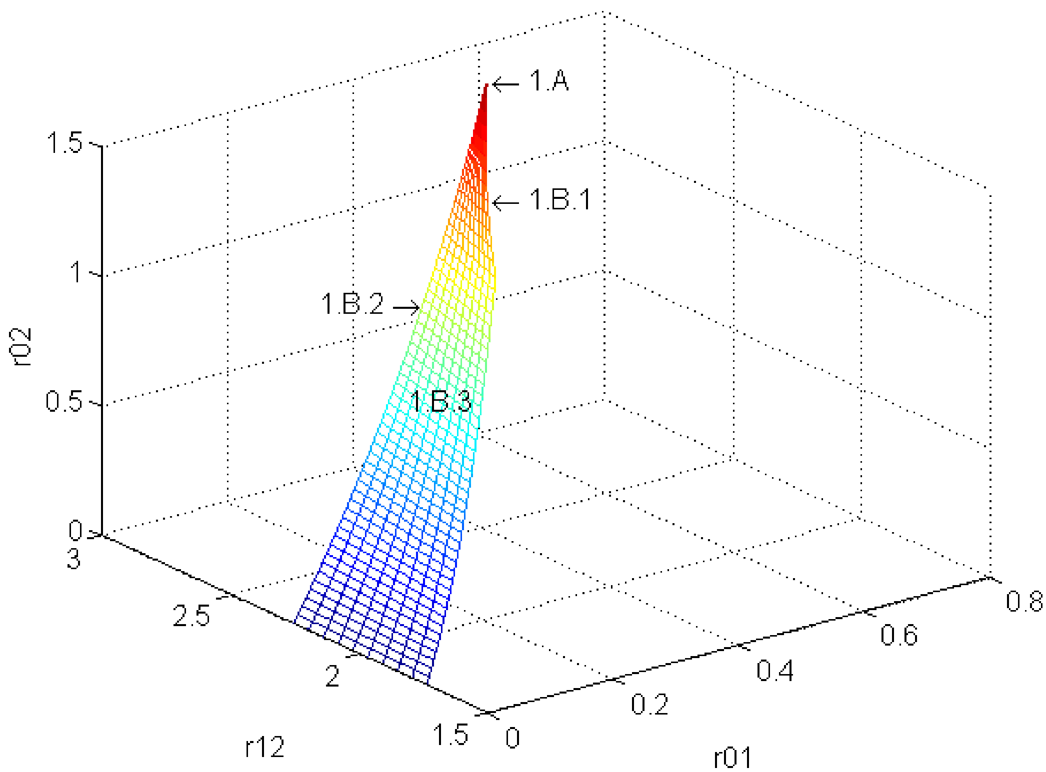

FIGURE 2.2: EQUILIBRIUM INTEREST RATES FOR CASES 1.A AND 1.B

Figure 2.2 represents the admissible interest rates in (r_{01}, r_{12}, r_{02}) space for the cases 1.A and 1.B[26]. Case 1.A interest rate vector is represented by the point at the tip of the surface in Figure 2.2. Case 1.B interest rates are represented by the surface itself. Case 1.B includes the situations where the international creditors are at the interior solution for all three debt instruments, but the banks want to borrow large amounts of debt for various maturities. This behavior is consistent with the figure as all three interest rates in case 1.B are smaller than their counterparts in case 1.A. Similar to case 1.A, case 1.B is also marked by the indeterminacy of the equilibrium amounts of debt traded. This indeterminacy seems to be the case whenever creditors are at an interior solution of their problem. Depending on differences in borrower behavior, there are three separate sets of equilibria under case 1.B.

Case 1.B.1 is observed when banks want to borrow large amounts of long-term debt at date zero and short-term debt at date one. On Figure 2.2, the interest rate vectors corresponding to this case are represented by the *smaller-r_{12} edge* of the sheet that extends down from the point 1.A until the kink at $r_{01} = s = 0.4$. The interest rates are on a curve; therefore this set of equilibria is locally unique.

Case 1.B.2 represents another set of locally unique equilibria. The interest rates are on the *larger-r_{12} edge* of the sheet extending down from point 1.A until the bottom of the sheet. Compared to 1.B.1, interest rates r_{12} and r_{02} are larger in the region where $r_{01} > s$. However, the short-term rate r_{01} could have very low values in this case.

Case 1.B.3 interest rates are represented by the sheet's *surface except its edges*. The interest rates are consistent with corresponding borrower behavior as the rates are between those of case 1.B.1 and case 1.B.2 except for the region where $r_{01} < s$.

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[26] The figure is drawn using the following parameter values: $\pi = 0.3, b = 12, n = 11, m = 10, \beta = 0.99, R = 1.5, g = 4, s = 0.4$

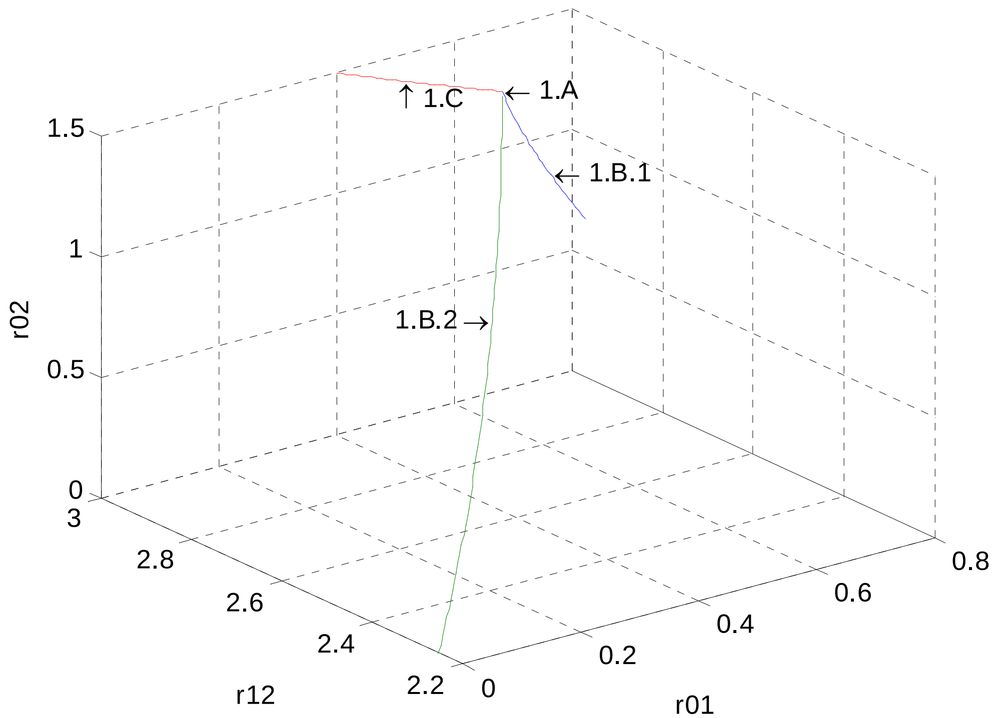

FIGURE 2.3: EQUILIBRIUM INTEREST RATES FOR CASE 1.C

Figure 2.3 illustrates the interest rates admitted by case 1.C. This case includes equilibria where banks (borrowers) are at the interior solution for all three assets. In this case, one can observe that the problem of quantity indeterminacy is solved when creditors choose not to lend short-term in the first date. This pins down the equilibrium short-term debt amount as zero and long-term debt amount as the maximum of *m* units. Compared to case 1.A, while value of the long-term rate is the same ($r_{02} = R$) in both cases, the date zero short-term rate (r_{01}) is smaller in 1.C. This tilts international creditors' preference toward long-term lending at date zero. As I will explain in detail in section II.5, the long-term maturity structure in this case seems to reduce vulnerability of the domestic economy to crises. This is because in this case the illiquidity condition (15) is unlikely to be satisfied.

II.4.2.2 Equilibria Where the Long-term Rate Is Larger

This section analyzes equilibria where the cost of (return on) two consecutive short-term loans is less than the cost of (return on) the long-term loan. Proposition 3 describes four such sets of equilibria.

Proposition 3: *When*

(i) the no arbitrage condition in the international debt markets does not hold and long-term debt is more expensive, i.e., $r_{02} > r_{01}r_{12}$ *and*

(ii) the long-term interest rate is equal to the return on the long-term asset, $r_{02} = R$ *,*

international creditors do not want to lend short-term debt at date zero ($d^s{}_{01} = 0$*), but they want to lend a finite amount of short-term debt at date one. As a result of four types of borrower (bank) behavior, four sets of equilibria are observed with no liquidation and no sudden stops. In each set, banks want to borrow a finite amount of long-term debt at date zero, but their behavior varies for other assets. Table 2.2 offers a summary.*

TABLE 2.2: SETS OF EQUILIBRIA WHEN LONG-TERM RATES ARE LARGER

Case	Interest rates	Demand F.O.C.	Supply F.O.C.	Quantities traded
2.A	$R = r_{02} > r_{01}r_{12}$	d^d_{01} *right corner*	$d^s_{01} = 0$	$d_{01}=0$
	Locally Unique	d^d_{02} *interior*	*N/A*	$d_{02}=m$
		d^d_{12} *interior*	d^s_{12} *interior*	$d_{12} = \frac{n\beta\pi g}{m+\pi(1+\beta)g+b/R}$
2.B	$R = r_{02} > r_{01}r_{12}$	d^d_{01} *right corner*	$d^s_{01} = 0$	$d_{01} = 0$
	Irregular	d^d_{02} *interior*	*N/A*	$d_{02}=m$
		d^d_{12} *right corner*	d^s_{12} *interior*	$d_{12} = \frac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$
2.C	$R = r_{02} > r_{01}r_{12}$	d^d_{01} *interior*	$d^s_{01} = 0$	$d_{01}=0$
	Locally Unique	d^d_{02} *interior*	*N/A*	$d_{02}=m$
		d^d_{12} *right corner*	d^s_{12} *interior*	$d_{12} = \frac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$
2.D	$R = r_{02} > r_{01}r_{12}$	$d^d_{01}=0$	$d^s_{01} = 0$	$d_{01}=0$
	Irregular	d^d_{02} *interior*	*N/A*	$d_{02}=m$
		d^d_{12} *right corner*	d^s_{12} *interior*	$d_{12} = \frac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$

Now I characterize each case in detail.

Case 2.A This case arises when banks want to borrow arbitrarily large amounts of short-term debt at date zero and a finite amount of short-term debt at date one. Then there exists a set of locally unique equilibria. In this set, the market interest rates are determined as $r_{02} = R$, $r_{12} = \frac{R[m+\pi(1+\beta)g]+b}{n\beta}$ and $\frac{n\beta}{m+\pi(1+\beta)g+b/R} > r_{01} > 0$. The maturity structure of debt is found as $d_{01} = 0, d_{02} = m$ *and* $d_{12} = \frac{n\beta\pi g}{m+\pi(1+\beta)g+b/R}$.

Case 2.B This case arises when banks want to borrow arbitrarily large amounts of short-term debt at dates zero and one. Then there exists a set of irregular equilibria. In this set, $r_{02} = R$, $r_{12} > r_{12}(r_{01})$ where the latter lower bound is defined as $r_{12}(r_{01}) = \dfrac{-B_2 + \sqrt{B_2^{\,2} - 4A_2C_2}}{2A_2}$ where

$A_2 = r_{01}\pi n\beta,\ B_2 = (1-\pi)Rn\beta - \pi r_{01}[mR + b + (1+\beta)Rg]$ and

$C_2 = -(1-\pi)R(mR+b)$. Also, $\dfrac{n\beta}{m + \pi(1+\beta)g + b/R} > r_{01} > s$. The maturity structure of debt is found as $d_{01} = 0, d_{02} = m\ and\ d_{12} = \dfrac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$.

Case 2.C This case arises when banks want to borrow a finite amount of short-term debt at date zero and arbitrarily large amounts of debt at date one. Then there exists a set of locally unique equilibria. In this set, the market interest rates are determined as $r_{02} = R$, $r_{12} = r_{12}(r_{01})$ and $\dfrac{n\beta}{m + \pi(1+\beta)g + b/R} > r_{01} > s$. The maturity structure of debt is determined as $d_{01} = 0,\ d_{02} = m,\ d_{12} = \dfrac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$.

Case 2.D This case arises when banks do not want to borrow any short-term debt at date zero, but arbitrarily large amounts of debt at date one. Then there exists a set of irregular equilibria. In this set, the market interest rates are determined as a surface that satisfies the following: $r_{02} = R$, $r_{12} < r_{12}(r_{01})$ and $r_{01}r_{12} < R$. The equilibrium amounts of debt traded are found as $d_{01} = 0, d_{02} = m\ and\ d_{12} = \dfrac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$.

I find that when the compounded short-term interest rates are smaller than the long-term rates, equilibrium debt contracted at date zero is exclusively long-term. In addition to case 2, such a long-term maturity structure was also found in case 1.C. One common property of both cases is that the equilibrium long-term interest rate is equal to the return on the long-term asset, $(r_{02} = R)$. Notice that R is the maximum possible value that this rate can possibly take. This implies that the domestic economy appears to have a long-term maturity structure of debt only in cases which it pays a large borrowing cost. This is consistent with the notion that borrowing long-term is expensive for the emerging market economies[27]. On the other hand, as I will show later in section II.5, having a long-term maturity structure decreases the likelihood of a bank run by making banks "more liquid". Therefore, there seems to be a tradeoff between a larger cost of long-term borrowing and a lower vulnerability to crises (runs). A similar tradeoff was demonstrated by Broner, Lorenzoni and Schmukler (2003) in the context of sovereign borrowing.

Figure 2.4 illustrates the sets of equilibria for the cases 1.A, 2.A and 2.C. In case 2.A, both r_{02} and r_{12} are uniquely determined in terms of parameters. Comparing this case to 1.A (a.k.a. the interior solution), one observes that r_{01} is not uniquely determined in 2.A, which it was in the interior solution. On the other hand, in the interior solution amounts of debt contracted could not be determined while in 2.A those are determined. In 2.A, banks want to borrow arbitrarily large amounts of d_{01}, because the interest rate on this asset is smaller than its value in the interior solution. For the same reason, international creditors do not want to lend any amount of this asset. Therefore all lending is long-term for date zero.

[27] Previous literature already pointed this out, but in reference to default risk. That is, there is a consensus that there is a larger risk premium on longer term debt (for example, see Broner, Lorenzoni and Schmukler 2003). The result that I find is that one does not have to have default risk in a model to get larger borrowing cost for longer term debt.

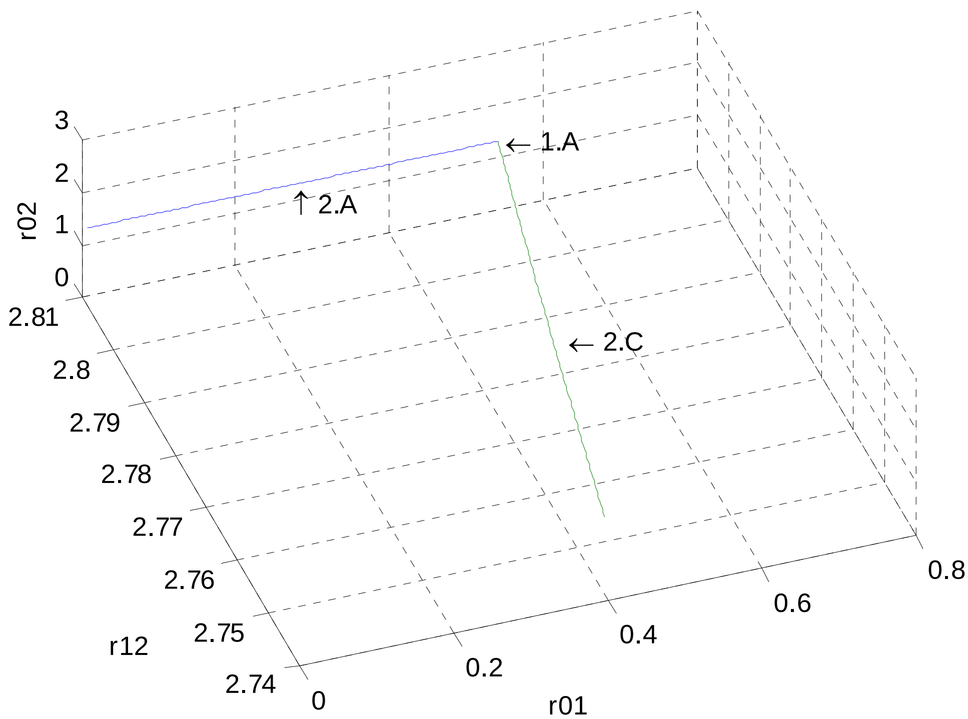

FIGURE 2.4: EQUILIBRIUM INTEREST RATES FOR CASES 2.A AND 2.C

Case 2.C implies smaller interest rates for borrowing at date one (r_{12}) than both the interior solution and case 2.A. Therefore banks want to borrow arbitrarily large amounts of d_{12}. International creditors exhibit the same lending behavior as in case 2.A.

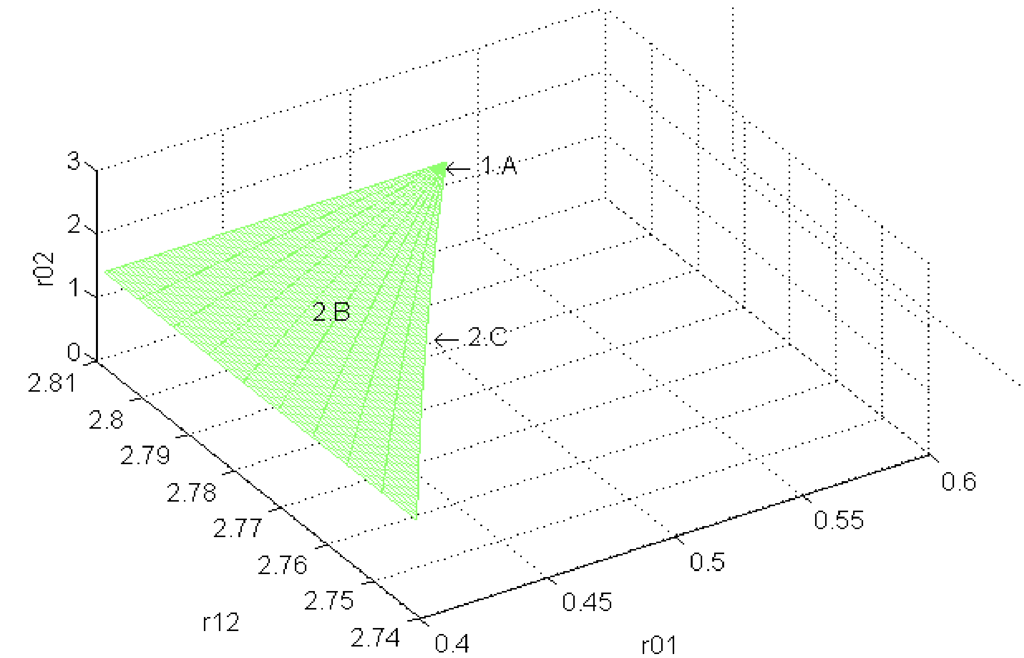

FIGURE 2.5: EQUILIBRIUM INTEREST RATES FOR CASES 2.B AND 2.C

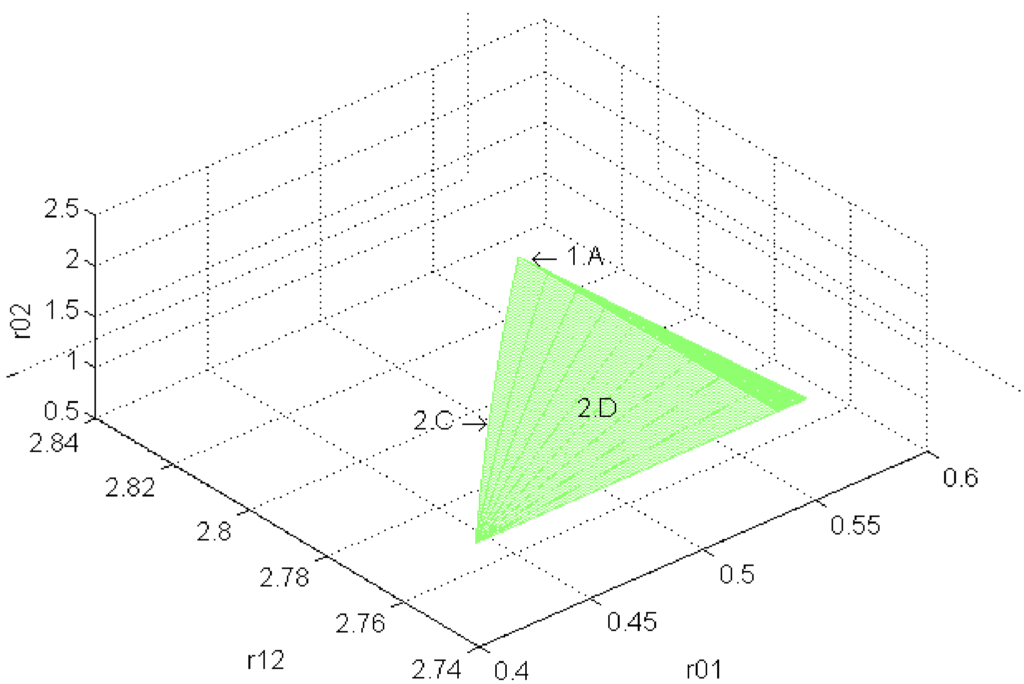

FIGURE 2.6: EQUILIBRIUM INTEREST RATES FOR CASE 2.D

In Figure 2.5, case 2.C rates coincide with the *larger-*r_{01} (or *smaller-*r_{12}) edge of the surface that shows case 2.B rates. That is, the latter case implies smaller short-term interest rates at date zero (r_{01}). Hence in case 2.B banks want to borrow arbitrarily large amounts of d_{01}, but they cannot do this because international creditors do not want to lend any of this asset. In summary, cases 2.B, 2.C and 2.D differ only in terms of borrowing behavior for this asset. In the same order, banks want to borrow less and less of this asset because its interest rate is rising. Figure 2.6 illustrates possible interest rates on a sheet for case 2.D, in which case banks' demand for this asset is zero.

The *smaller-*r_{01} edge of the sheet represents case 2.C rates. Note that the equilibrium amount of debt traded for d_{01} is determined by supply side as zero; hence it does not change across the cases 2.B, 2.C and 2.D.

II.4.2.3 Equilibria Where the Short-term Rates Are Larger

This section analyzes equilibria where the compounded rate on two consecutive short-term loans is larger than the rate on the long-term loan. Proposition 4 describes five sets of equilibria under this category.

Proposition 4: *When the no arbitrage condition in the international debt markets does not hold and short-term rates are larger, i.e.,* $r_{01}r_{12} > r_{02}$ *, international creditors do not want to lend long-term (*$d^{s}{}_{02} = 0$*). As a result of three types of borrower and two types of lender behavior, six sets of equilibria are observed with no liquidation and no sudden stops. Table 2.3 offers a summary.*

TABLE 2.3: SETS OF EQUILIBRIA WHEN SHORT-TERM RATES ARE LARGER

Case	Interest rates	Demand F.O.C.	Supply F.O.C.	Quantities traded
3.A.1	$R=r_{01}r_{12}>r_{02}$	$d^d{}_{01}$ *interior*	$d^s{}_{01}$ *interior*	$d_{01} = m$
	Locally Unique	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *interior*	$d^s{}_{12}$ *right corner*	$d_{12} = \frac{R(m+\pi g)}{r_{12}}$
3.A.2	$R=r_{01}r_{12}>r_{02}$	$d^d{}_{01}$ *interior*	$d^s{}_{01}$ *right corner*	$d_{01} = m$
	Locally Unique	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *interior*	$d^s{}_{12}$ *interior*	$d_{12} = \frac{n\beta(m+\pi g)}{m+\pi(1+\beta)g+b/R}$
3.B.1	$R > r_{01}r_{12} > r_{02}$	$d^d{}_{01}$ *interior*	$d^s{}_{01}$ *interior*	$d_{01} = m$
	Irregular	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *right corner*	$d^s{}_{12}$ *right corner*	$d_{12} = \frac{Rr_{01}(m+\pi g)}{(1-\pi)R+\pi r_{01}r_{12}}$
3.B.2	$R > r_{01}r_{12} > r_{02}$	$d^d{}_{01}$ *interior*	$d^s{}_{01}$ *right corner*	$d_{01} = m$
	Irregular	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *right corner*	$d^s{}_{12}$ *interior*	$d_{12} = \frac{Rr_{01}(m+\pi g)}{(1-\pi)R+\pi r_{01}r_{12}}$
3.C.1	$R > r_{01}r_{12} > r_{02}$	$d^d{}_{01}$ *right corner*	$d^s{}_{01}$ *interior*	$d_{01} = m$
	Irregular	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *interior*	$d^s{}_{12}$ *right corner*	$d_{12} = \frac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$
3.C.2	$R > r_{01}r_{12} > r_{02}$	$d^d{}_{01}$ *right corner*	$d^s{}_{01}$ *right corner*	$d_{01} = m$
	Irregular	$d^d{}_{02}$ *right corner*		$d_{02} = 0$
		$d^d{}_{12}$ *interior*	$d^s{}_{12}$ *interior*	$d_{12} = \frac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$

Now I describe each case in detail.

Case 3.A This case is observed when banks want to borrow arbitrarily large amounts of long-term debt at date zero but a finite amount of short-term debt at date zero and date one. There are two sub-cases that represent two types of creditor behavior.

Case 3.A.1 This case arises when

(i) international creditors want to lend arbitrarily large amounts of debt at date one, but a finite amount of short-term debt in date zero,

(ii) banks want to borrow arbitrarily large amounts of long-term debt at date zero but a finite amount of short-term debt at date zero and date one.

Then there exists a set of locally unique equilibria. In this set, $r_{01}r_{12} = R$ and $r_{02} = \dfrac{R[R(m+\pi g)+b]}{\beta(nr_{12} - \pi gR)}$. The amounts of debt traded are determined as $d_{01} = m, d_{02} = 0 \; and \; d_{12} = \dfrac{R(m+\pi g)}{r_{12}}$.

Case 3.A.2 This case arises when

(i) international creditors want to lend arbitrarily large amounts of short-term debt at date zero, but a finite amount of debt in date one,

(ii) banks want to borrow arbitrarily large amounts of long-term debt at date zero but a finite amount of short-term debt at date zero and date one.

Then there exists a set of locally unique equilibria. In this set, $r_{02} < R$, $r_{01} = \dfrac{n\beta}{m+\pi(1+\beta)g + b/R}$ and $r_{12} = \dfrac{R[m+\pi(1+\beta)g]+b}{n\beta}$. The amounts of debt traded are determined as $d_{01} = m, d_{02} = 0 \; and \; d_{12} = \dfrac{R(m+\pi g)}{r_{12}}$.

Case 3.B This case is observed when banks want to borrow arbitrarily large amounts of long-term debt at date zero and short-term debt at date one, but a finite amount of short-term debt at date zero. There are two sub-cases that represent two types of creditor behavior.

Case 3.B.1 This case arises when

(i) international creditors want to lend arbitrarily large amounts of debt at date one, but a finite amount of short-term debt at date zero,

(ii) banks want to borrow arbitrarily large amounts of long-term debt at date zero and short-term debt at date one, but a finite amount of short-term debt at date zero. Then there exists a set of irregular equilibria. In this set, $r_{01}r_{12} < R$ and $r_{12} > \underline{r_{12}}(r_{01}) = \dfrac{-B_1 + (B_1^{\,2} - 4A_1C_1)^{1/2}}{2A_1}$ where A_1, B_1 and C_1 are as defined in (23). Also, $r_{02} = \dfrac{r_{01}[r_{01}r_{12}R(m+\pi g)+\phi b]}{\beta[\phi(mr_{01}+n) - r_{01}R(m+\pi g)]}$ where $\phi = (1-\pi)R + \pi r_{01}r_{12}$. The amounts of debt traded are determined as $d_{01} = m,\ d_{02} = 0\ and\ d_{12} = \dfrac{Rr_{01}(m+\pi g)}{\phi}$.

Case 3.B.2 This case arises when

(i) international creditors want to lend arbitrarily large amounts of short-term debt at date zero, but a finite amount of debt in date one,

(ii) banks want to borrow arbitrarily large amounts of long-term debt at date zero and short-term debt at date one, but a finite amount of short-term debt at date zero. Then there exists a set of irregular equilibria. In this set, $r_{01}r_{12} < R$, $s < r_{01} < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$ and $r_{12} = r_{12}(r_{01}) = \dfrac{-B_1 + (B_1^{\,2} - 4A_1C_1)^{1/2}}{2A_1}$, where A_1, B_1 and C_1 are as defined in (23). Also, $r_{02} < r_{01}r_{12}$. The amounts of debt traded are determined as $d_{01} = m,\ d_{02} = 0\ and\ d_{12} = \dfrac{Rr_{01}(m+\pi g)}{\phi}$.

Case 3.C This case arises when banks want to borrow arbitrarily large amounts of long-term and short-term debt at date zero, but a finite amount of short-term debt at date one. There are two sub-cases that represent two types of creditor behavior.

Case 3.C.1 This case arises when

(i) international creditors want to lend arbitrarily large amounts of debt at date one, but a finite amount of short-term debt in date zero,

(ii) banks want to borrow arbitrarily large amounts of long-term and short-term debt at date zero, but a finite amount of short-term debt at date one.

Then there exists a set of irregular equilibria. In this set, $r_{01}r_{12} < R$, $r_{12} > \underline{r_{12}}(r_{01}) = \dfrac{\pi R(g+m)(1+\beta)+b}{r_{01}m[\pi(1+\beta)-1]+n\beta}$ and $0 < r_{01} < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$. Also, $r_{02} = \dfrac{r_{01}r_{12}[\pi R(g+m)+(1-\pi)mr_{01}r_{12}+b]}{\beta[r_{12}(\pi mr_{01}+n)-\pi R(g+m)]}$. The amounts of debt traded are determined as $d_{01} = m,\ d_{02} = 0\ and\ d_{12} = \dfrac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$.

Case 3.C.2 This case arises when

(i) international creditors want to lend arbitrarily large amounts of short-term debt at date zero, but a finite amount of debt at date one,

(ii) banks want to borrow arbitrarily large amounts of long-term and short-term debt at date zero, but a finite amount of short-term debt at date one.

Then there exists a set of irregular equilibria. In this set, $r_{01}r_{12} < R$, $r_{12} = \dfrac{\pi R(g+m)(1+\beta)+b}{r_{01}m[\pi(1+\beta)-1]+n\beta}$ and $0 < r_{01} < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$. Also, $r_{02} < r_{01}r_{12}$. The amounts of debt traded are determined as $d_{01} = m,\ d_{02} = 0\ and\ d_{12} = \dfrac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$.

I find that when the compounded short-term interest rates are larger than the long-term rates, equilibrium debt structure for date zero is completely short-term. I show in section II.5.1 that such a short-term debt maturity leaves banks more vulnerable to runs in case 3 than in other cases. In particular, I prove that in this case banks are always *internationally illiquid*, i.e. their potential liabilities exceed their potential assets at date one[28]. In other words, the model predicts that crisis episodes should be associated with larger short-term over long-term rates.

Another striking finding from case 3 is that it admits interest rates that are *less price determinate* than the other cases. This pattern is evident by the fact that in cases 1 and 2, there are one and two sets of irregular equilibria, respectively. In case 3 there are four such sets. The model seems to predict that situations where crises are more likely (banks are less liquid) should be associated with a greater indeterminacy of interest rates.

The above phenomena are consistent with empirical observation of crisis episodes by Broner, Lorenzoni and Schmukler (2003). They studied financial crisis episodes using data on sovereign bond spreads at different maturities since the early 1990s up to 2003. They estimated excess returns on emerging market bonds over risk-less US and German bonds. They found that before or during crisis episodes, average debt maturity shortens. This finding coincides with my results in the following sense: I find that in case 3 where runs (crises) are more likely, equilibrium debt maturity is short-term.

In case 3, there are six different sets of equilibria. Each represents a combination of three types of borrower and two types of lender behavior. Now I discuss each set of equilibria in detail.

[28] That is, (15) is always satisfied in case 3. A more detailed assessment of the illiquidity condition in each case is done in section II.5 below.

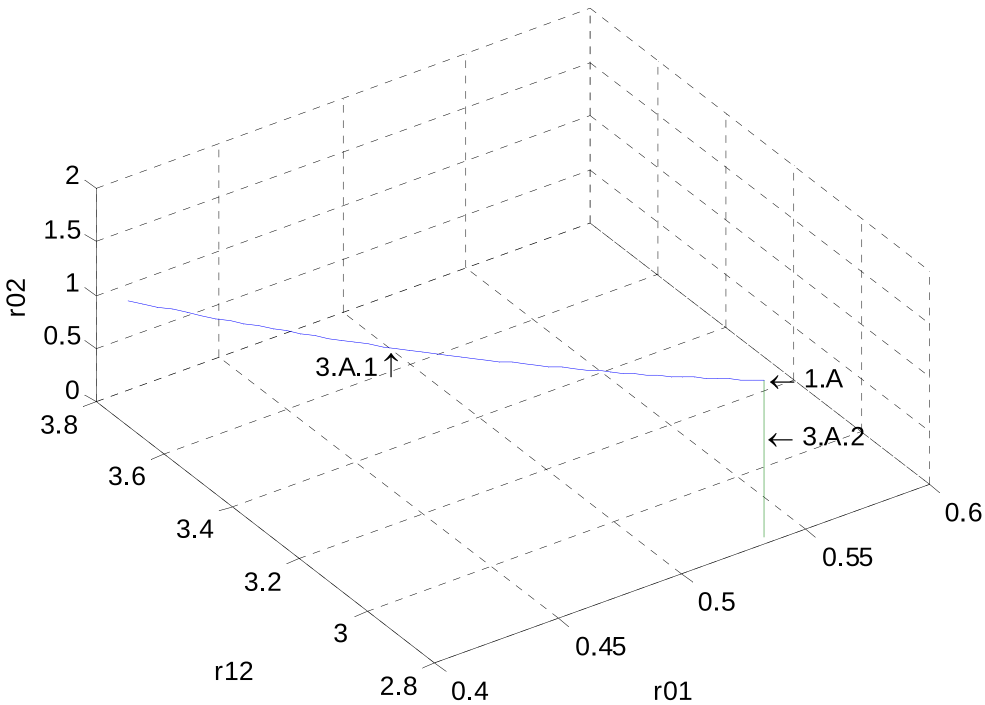

FIGURE 2.7: EQUILIBRIUM INTEREST RATES FOR CASE 3.A

Figure 2.7 illustrates the equilibrium interest rates admitted by cases 3.A.1 and 3.A.2. These two cases represent the same borrower but different lender behavior. At date zero, creditors' supply of short-term debt in the latter case is arbitrarily large while in the former case it is finite. At date one, creditors' supply is arbitrarily large in the former case while in the latter case it is finite. These behaviors are consistent with the equilibrium rates as the former case admits larger rates for r_{12} and smaller rates for r_{01} than the latter. While in both cases banks want to borrow long-term instead of short-term at date zero, equilibrium borrowing is short-term due to creditors' preference for short-term. This preference is driven by the condition $r_{01}r_{12} > r_{02}$.

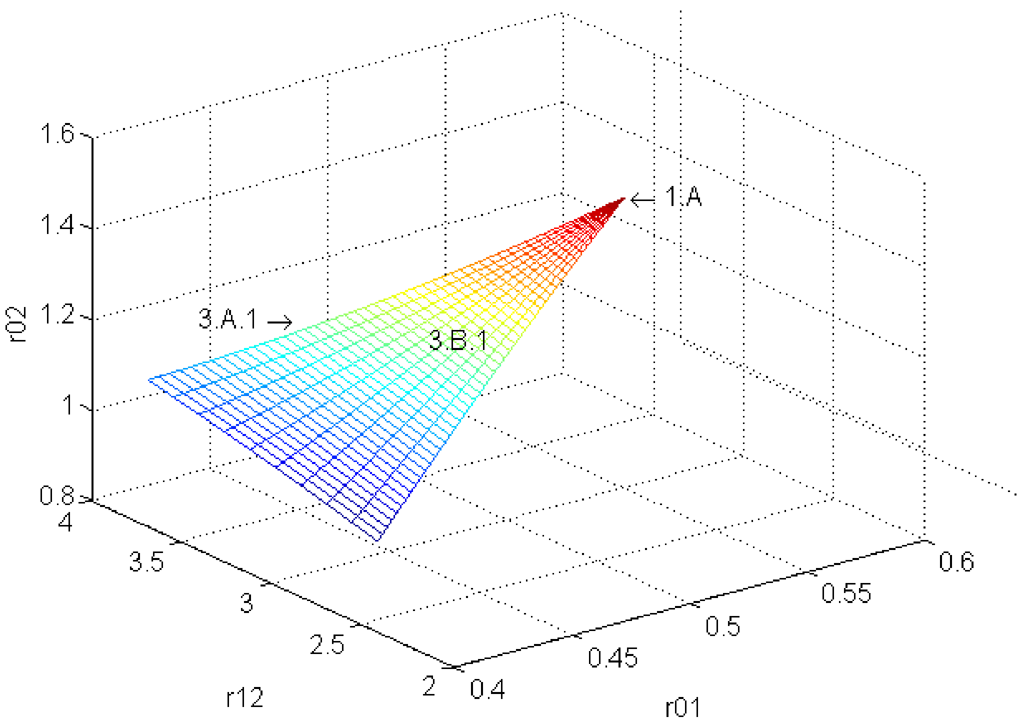

FIGURE 2.8: EQUILIBRIUM INTEREST RATES FOR CASE 3.B.1

In Figure 2.8, the sheet surface illustrates the equilibrium interest rates admitted by case 3.B.1. The *larger-*r_{12} edge of the surface illustrates equilibrium rates of case 3.A.1. Compared to case 3.A, banks want to borrow a lot more at date one in case 3.B.1. This borrowing behavior is consistent with interest rates as the latter case implies smaller interest rates (r_{12}) in this date. The lending behavior is the same in both cases.

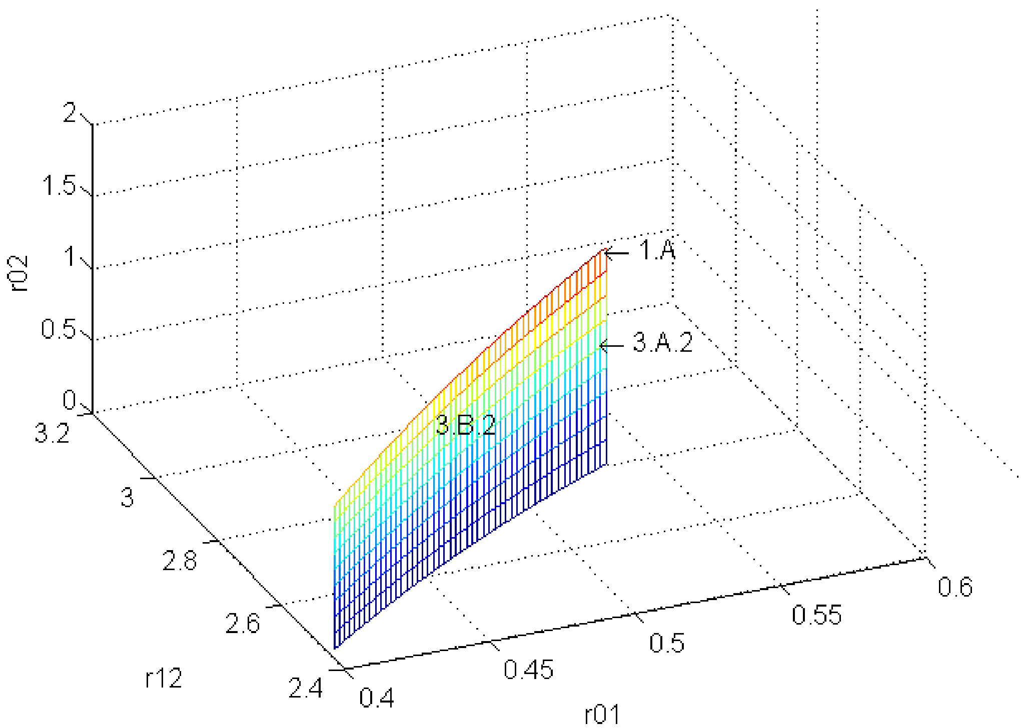

FIGURE 2.9: EQUILIBRIUM INTEREST RATES FOR CASE 3.B.2

The sheet in Figure 2.9 illustrates market interest rates for case 3.B.2. The top edge of this surface coincides with the *smaller-*r_{12} edge of the surface illustrated on Figure 2.8. This case represents the same borrower but different lender behavior compared to case 3.B.1. While in 3.B.1 lenders want to lend arbitrarily large amounts of debt at date one, in 3.B.2 their supply is finite. This is because (for a given r_{01}) interest rate at date one (r_{12}) is always smaller in the latter case. Moreover, the same rate is again smaller than that in case 3.A where banks' demand at date one is finite. As a result, similar to 3.B.1, in 3.B.2 banks have arbitrarily large demand for borrowing at date one.

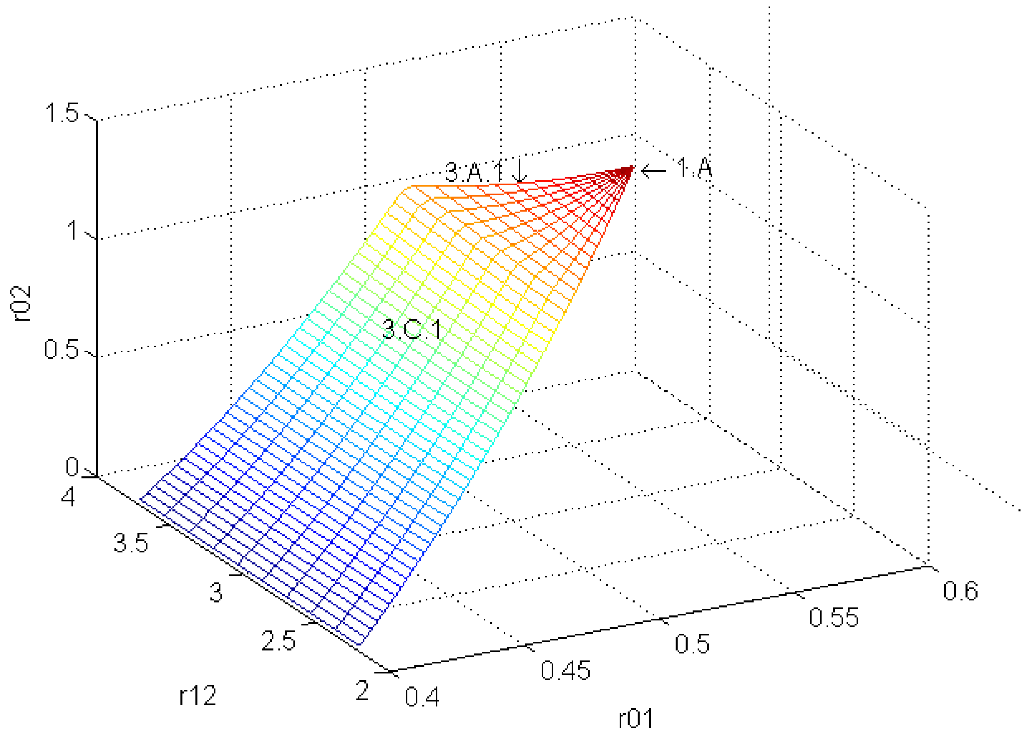

FIGURE 2.10: EQUILIBRIUM INTEREST RATES FOR CASE 3.C.1

The sheet in Figure 2.10 illustrates equilibrium market interest rates for the case 3.C.1. For $r_{01} > s$ ($s = 0.4$ in the figure), the *larger-*r_{12} edge coincides with the rates of case 3.A.1. Compared to case 3.A, here in 3.C banks want to borrow arbitrarily large amounts of short-term debt at date zero (d_{01}). Therefore interest rate on this asset is smaller in case 3.C[29].

[29] The comparison is strictly correct for all equilibria in cases 3.A.2 and 3.C.2. For 3.A.1 and 3.C.1, r_{01} is always smaller in the latter case for a given value of r_{12}.

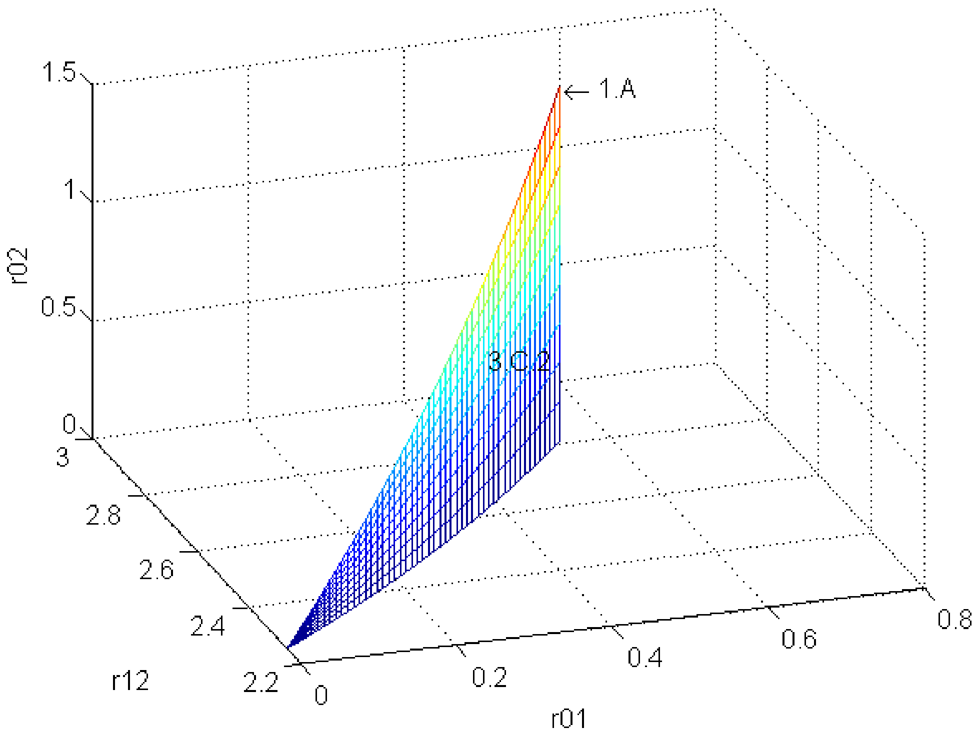

FIGURE 2.11: EQUILIBRIUM INTEREST RATES FOR CASE 3.C.2

Figure 2.11 shows the set of interest rates for case 3.C.2. The top edge of this sheet coincides with the *smaller*-r_{12} edge of the sheet on Figure 2.10. That is, for a given value of r_{01}, case 3.C.2 always implies a smaller r_{12} than case 3.C.1. This is due to the fact that international creditors want to lend arbitrarily large amounts of d_{12} in the latter case but a finite amount in the former case. On the other hand, for a given value of r_{12}, 3.C.2 implies a larger r_{01} because creditors want to lend arbitrarily large amounts of d_{01}. Their supply of this asset is finite in 3.C.1.

In section II.5 below, I allow for the possibility of crises in the form of bank runs. Then, I find the conditions under which a sudden stop may follow a bank run or not.

II.5 Equilibria with Runs and/or Sudden Stops

In the previous section I have assumed runs and hence financial crises are not probable and all agents believe that. In this section I allow for crises to take place. First, I identify the conditions of the environment under which banks are more vulnerable to runs. Second, assuming a bank run has taken place, I analyze possible equilibria. I am particularly interested in the insolvency conditions under which international creditors stop lending or otherwise bail the banks out.

II.5.1 System Liquidity and Vulnerability to Runs

> …it is a familiar point in the academic literature that Hong Kong-type speculative plays can work only if the economy is vulnerable to self-fulfilling crisis in the first place...
>
> –Paul Krugman (1999)

In section II.3, proposition 1 has shown that for any crisis to happen, banks must be illiquid. That is, (15) must hold. In the following, I analyze the implications of this condition for each case that was found in the previous section. The objective is to understand in which situations banks are more vulnerable to a run. Table 2.4 summarizes the implications of (15) for each case. In what follows, I evaluate (15) at each equilibrium.

TABLE 2.4: BANK'S VULNERABILITY TO RUNS

Case	Interest Rates	Amounts of Debt Traded	***Illiquid Banks If***
1.A	$r_{01}r_{12} = r_{02} = R$	Indeterminate	*If* $s \leq \underline{s}$, *all equilibria illiquid*[30]*.If* $s \in (\underline{s}, \bar{s})$ *then depends on the value of* d_{01} *or* d_{02}.
1.B.1	$r_{01}r_{12} = r_{02} < R$	Indeterminate	
1.B.2	$r_{01}r_{12} = r_{02} < R$	Indeterminate	
1.B.3	$r_{01}r_{12} = r_{02} < R$	Indeterminate	
1.C	$r_{01}r_{12} = r_{02} = R$	$d_{01} = 0, d_{02} = m$, $d_{12} = r_{01}\pi g$	*All equilibria liquid if* $s \in (\underline{s}, \bar{s})$.
2.A	$r_{01}r_{12} < r_{02} = R$	$d_{01} = 0, d_{02} = m,\ d_{12} = \dfrac{n\beta\pi g}{m+\pi(1+\beta)g+b/R}$	*Illiquid if and only if* $s \leq \underline{s}$
2.B,C,D	$r_{01}r_{12} < r_{02} = R$	$d_{01} = 0,\ d_{02} = m,\ d_{12} = \dfrac{n\beta r_{12} - mR - b}{(1+\beta)r_{12}}$	*More liquid than case* ***2.A***.
3.A.1,2	$R = r_{01}r_{12} > r_{02}$	$d_{01} = m, d_{02} = 0$, $d_{12} = \dfrac{R(m+\pi g)}{r_{12}}$	*All equilibria illiquid.*
3.B.1,2	$R > r_{01}r_{12} > r_{02}$	$d_{01} = m, d_{02} = 0, d_{12} = \dfrac{Rr_{01}(m+\pi g)}{\phi}$	
3.C.1,2	$R > r_{01}r_{12} > r_{02}$	$d_{01} = m, d_{02} = 0, d_{12} = \dfrac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$	

30 $\underline{s} = \dfrac{n\beta}{[m+\pi(1+\beta)g+b/R]}\dfrac{g}{(g+m)}$, $\bar{s} = \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$.

II.5.1.1 Cases Where the No Arbitrage Condition Holds ($r_{02} = r_{01}r_{12}$)

Case 1.A Banks are illiquid if and only if[31]

$$d_{02} \leq (g+m)\left[1-\frac{s}{r_{01}}\right] \tag{24}$$

where $r_{01} = \dfrac{\beta n}{\pi(1+\beta)g+m+b/R}$. To give an idea, for parameter values that I have used so far, banks are illiquid if $d_{02} \leq 3.51$ or $d_{01} \geq 6.48$[32]. I have found in section II.4 that in case 1.A, the equilibrium amounts of debt traded could not be determined, i.e. $d_{02} \in (0,m)$. Condition (24) implies that if the banks' long-term borrowing is below a threshold, then banks are vulnerable to runs. This result supports the conventional argument suggested in the literature that shortening of debt maturity increases vulnerability to financial crises[33].

A second implication is that as the liquidation value of the long-term asset (*s*) gets smaller especially relative to the long-term return from investment (*R*), banks become more vulnerable. For example, if $s \leq \underline{s} = \dfrac{n\beta}{[m+\pi(1+\beta)g+b/R]}\dfrac{g}{(g+m)}$, then banks are always illiquid regardless of the maturity structure of debt. If $s \in (\underline{s}, \bar{s})$, then debt maturity matters[34].

A third result is that as the fraction of impatient agents (π) increases, banks become less vulnerable. At first, this sounds counter-intuitive. However, this is expected because the extra amount that banks need to generate in case of a run by patient depositors is equal to $(1-\pi)x$. As the fraction of impatient agents increases, this amount gets smaller. To understand this, I can think of the extreme case of $\pi = 1$, i.e. all

---

[31] Or equivalently, using $d_{01} + d_{02} = m$, banks are illiquid if and only if $d_{01} \geq m-(g+m)\left[1-\frac{s}{r_{01}}\right]$.

[32] For parameter values, see footnote 18.

[33] Broner, Lorenzoni and Schmukler (2003) and Cole and Kehoe (1998) among others showed this result in the context of sovereign debt. Chang and Velasco (2000) assume away the choice of maturity structure of debt when they allow for crises. In particular, they assume $d_{01} = 0$ when crises are possible.

[34] Where $\bar{s} = \dfrac{n\beta}{[m+\pi(1+\beta)g+b/R]}$ was defined in assumption 1 in section II.2.

depositors are impatient. Then, there are no patient agents and hence no vulnerability to a run.

Lastly, all else equal, a larger return from long-term investment (*R*) increases banks' vulnerability. This is because a larger return increases payments promised to impatient agents in the original plan, i.e. *x* goes up. This increases banks' potential liabilities at date one (which is the left hand side of (15)). However, banks' potential assets (*sk*) do not change. Therefore, the financial system becomes more vulnerable to runs. This perfectly fits the story of the Asian crisis of 1997-98. The high (possibly perceived) rates of return on investment in these economies may have contributed to the severity of shock once confidence collapses.

Case 1.B.1 The reader should recall from section II.4 that in cases 1.B.1, 1.B.2 and 1.B.3 amounts of borrowing could not be determined. For $s < \underline{s}$, banks are always illiquid regardless of debt maturity. For $s \in (\underline{s}, \bar{s})$ and a given configuration of parameters[35], Figure 2.12 shows the illiquid and liquid regions in the space of (r_{01}, d_{01}). The graph plots the threshold amount of short-term borrowing above (below) which the banks become illiquid (liquid).

In this case, similar patterns are observed in terms of vulnerability. First, a shorter debt maturity implies higher vulnerability. Second, a smaller (larger) liquidation value (*s*) shifts the threshold curve downwards (upwards), hence makes banks more (less) vulnerable.

[35] Parameter values are given in footnote 22 on page 30.

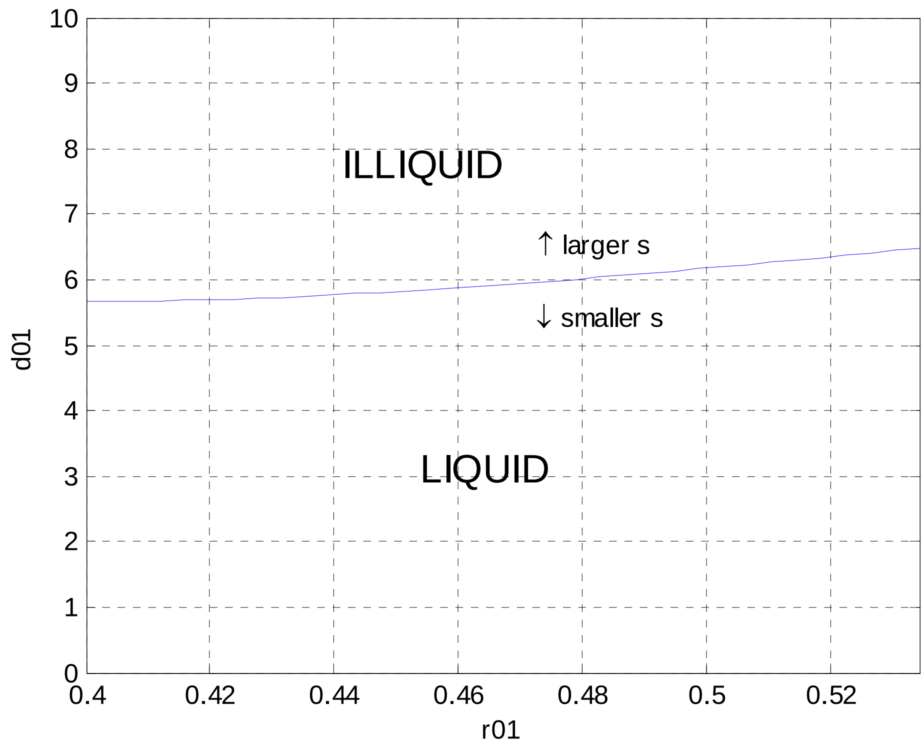

FIGURE 2.12: ILLIQUIDITY THRESHOLD FOR CASE 1.B.1

Case 1.B.2 Here, again for $s < \underline{s}$, banks are always illiquid regardless of debt maturity. For $s \in (\underline{s}, \bar{s})$, Figure 2.13 plots the threshold amount of short-term debt above which banks become illiquid.

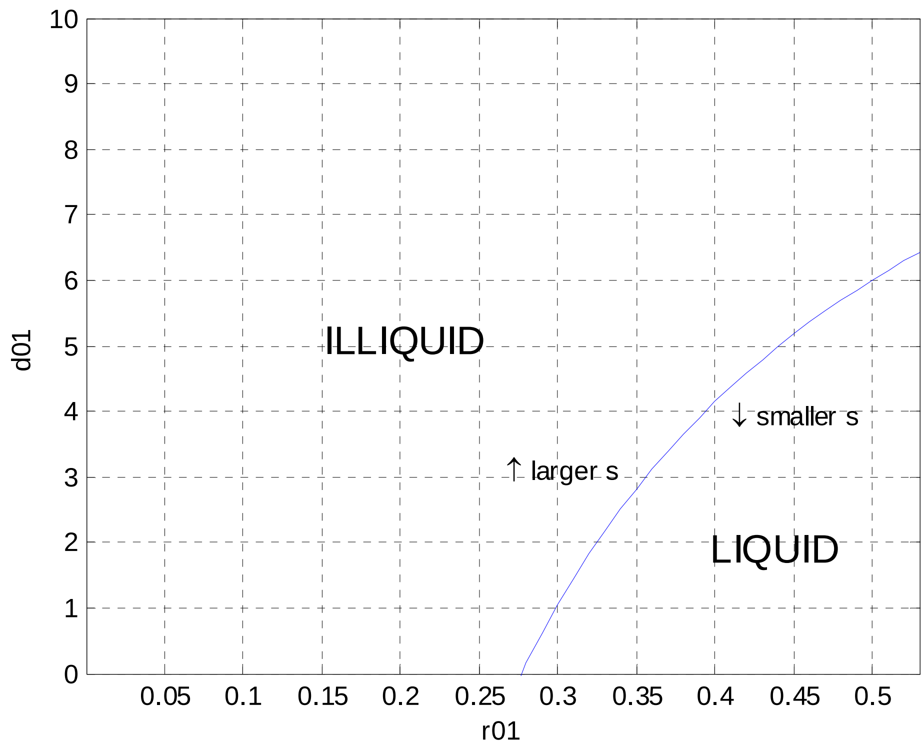

FIGURE 2.13: ILLIQUIDITY THRESHOLD FOR CASE 1.B.2

Case 1.B.3 Similar to previous cases, in this case for $s < \underline{s}$, banks are always illiquid regardless of debt maturity. For $s \in (\underline{s}, \bar{s})$, debt maturity determines illiquidity: a shorter debt maturity is more vulnerable and vice versa. Figure 2.14 plots the illiquidity threshold surface for combinations of possible interest rates (r_{01}, r_{12}) in the case when $s \in (\underline{s}, \bar{s})$. If short-term borrowing is above this surface, banks become illiquid. The figure reveals that as short-term interest rates rise, banks become less vulnerable. Casual observation of the simulations for cases 1.B.1, 1.B.2 and 1.B.3 seems to indicate a tradeoff between smaller interest rates and more vulnerability to runs. That is, the vulnerability seems to decrease as interest rates rise and vice versa.

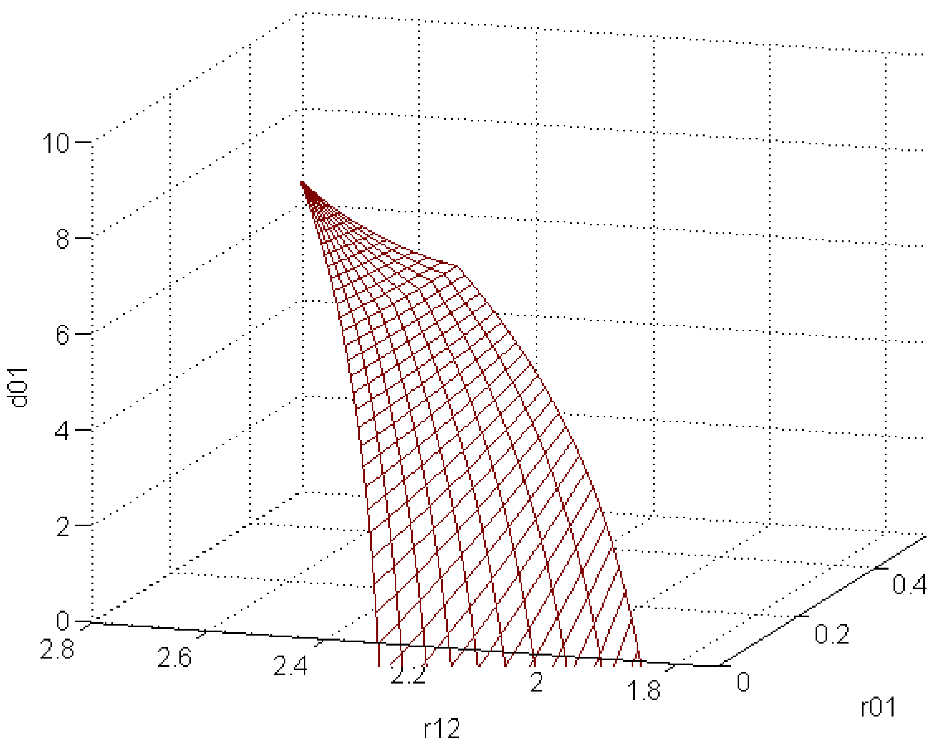

FIGURE 2.14: ILLIQUIDITY THRESHOLD FOR CASE 1.B.3

Case 1.C Banks are illiquid if $r_{01} \geq s\dfrac{(g+m)}{g}$. Notice that this condition does not depend on debt maturity since the latter is uniquely determined in this case: $d_{01} = 0, d_{02} = m$. This condition is unlikely to be satisfied, especially if the domestic economy is relatively small in size compared to the rest of the world. Since r_{01} is bounded from above, it is easy to check that banks are always liquid (equivalently, allocations are run-proof) if $s > \underline{s}$. That is, crises are possible in this case only if $s \leq \underline{s}$, while they were possible for $s \in (0, \overline{s})$ in previous cases. The less vulnerable environment brought about by this case is due to the equilibrium long-term maturity structure. Once more, there is a clear case for lengthening debt maturity of the financial system.

II.5.1.2 Cases Where Long-term Debt Is More Expensive ($r_{02} > r_{01}r_{12}$)

Case 2.A Banks are illiquid if and only if $s \leq \underline{s}$. This implies banks are in a safer liquidity position compared to 1.A and 1.B. Once more, this is due to the long-term maturity structure in this case: $d_{01} = 0, d_{02} = m$.

Cases 2.B, 2.C and 2.D In these cases, banks are illiquid if and only if

$$IB = r_{12}[n\beta - s(g+m)\pi(1+\beta)] - mR - b \geq 0 \tag{25}$$

The above implies that for $s \geq \dfrac{n\beta}{\pi(1+\beta)(g+m)}$, banks are always liquid. For $s < \dfrac{n\beta}{\pi(1+\beta)(g+m)}$, I find that in cases 2.B, 2.C and 2.D banks are less vulnerable (less likely to be illiquid) than in case 2.A[36].

In summary, case 2 allocations are less vulnerable to a crisis than cases 1.A and 1.B. This is due to the long-term debt maturity structure in case 2: $d_{01} = 0, d_{02} = m$.

II.5.1.3 Cases Where Short-term Debt Is More Expensive ($r_{02} < r_{01}r_{12}$)

Banks are illiquid *for all equilibria* in case 3 where short-term rates are larger than long-term rates[37]. This is a strong result and it is due to the fact that banks have a very short-term debt maturity: $d_{01} = m, d_{02} = 0$. The financial system is very fragile here since:

(i) the amount of debt that needs to be rolled over at date one is huge,

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[36] The interest rate r_{12} is not unique in these cases, but it has parametric boundaries, $r_{12} \in (\underline{r_{12}}, \overline{r_{12}})$ where $\overline{r_{12}} = \dfrac{b + R[m + \pi(1+\beta)g]}{n\beta}$ and $\underline{r_{12}} = \dfrac{-B_{2,s} + (B_{2,s}^{\,2} - 4A_{2,s}C_2)^{1/2}}{2A_{2,s}}$ where $A_{2,s} = s\pi n\beta,\ B_{2,s} = (1-\pi)Rn\beta - \pi s[mR + b + (1+\beta)Rg],\ C_2 = -(1-\pi)R(mR+b)$ is (26) evaluated at $r_{01} = s$. Notice that for $s < \dfrac{n\beta}{\pi(1+\beta)(g+m)}$, *IB* increases in r_{12}. Then, $IB \in (\underline{IB}, \overline{IB})$ where $\underline{IB} = IB(\underline{r_{12}})$ and $\overline{IB} = IB(\overline{r_{12}})$. This means (27) is most likely to hold when $r_{12} = \overline{r_{12}}$. This happens in case 2.A. In cases 2.B, 2.C and 2.D, $r_{12} < \overline{r_{12}}$, which means *IB* takes smaller values, i.e. banks are more liquid and less vulnerable.

[37] See Appendix A.5 for proofs.

(ii) costs of rolling over debt is high since short-term interest rates are larger than long-term rates.

II.5.1.4 Summary of Vulnerability to Bank Runs

The first implication of the analysis is that *debt maturity* is an important factor in determining vulnerability to bank runs. Case 3 represents the most vulnerable case as the debt is short-term in equilibrium. Then the next most vulnerable case is case 1 where debt maturity is indeterminate (except in case 1.C) and the no arbitrage condition holds. Unlike in case 3, vulnerability depends also on the particular parameter configuration in case 1. Case 2 is ranked as the least vulnerable case as a whole (except in case 1.C).

The second implication is that among other parameters, liquidation value of the long-term asset, s, is an important one in determining vulnerability of a financial system. A smaller value of this parameter relative to some functions of the other parameters of the environment implies a larger likelihood of a run. In particular, liquidity seems to be related to two parametric thresholds for s: $\underline{s} = \frac{n\beta}{[m + \pi(1+\beta)g + b/R]}\frac{g}{(g+m)}$ and $\bar{s} = \frac{n\beta}{[m + \pi(1+\beta)g + b/R]}$[38]. In cases 1 and 2 where illiquidity depends on the value of this parameter[39], it appears that the size of the domestic economy relative to the rest of the world $\left(\frac{g}{g+m}\right)$ also matter. If the domestic economy is relatively small, the interval $(\underline{s}, \bar{s})$ widens. This decreases the likelihood of a run by contracting the parameter space in which banks are illiquid. On the other hand, if the size of the domestic economy is larger, its financial sector is more vulnerable. This result makes sense because if the domestic economy is larger compared to the rest of the world, then in case of a liquidity crunch it needs a larger fraction of the world liquidity to pay its liabilities. This implies, for example, a financial crisis in Russia is more likely than a financial crisis in Thailand or Hong Kong, all else equal.

[38] Notice that by assumption 1, $s < \bar{s}$ throughout this chapter.

[39] In case 3 all equilibria are illiquid regardless of the parameter values.

I also find that a larger return on domestic long-term investment (R) increases banks' vulnerability to bank runs. This is because a larger return increases payments promised to impatient agents in the original plan, i.e. x goes up. This increases banks' potential liabilities at date one (which is the left hand side of (15)). However, banks' potential assets (sk) do not change. Then the ratio $\left(\frac{R}{s}\right)$ appears to be a good indicator of a financial system's vulnerability to bank runs. When this ratio is large, a financial system is more vulnerable to liquidity problems.

In the next section, I look at the cases where bank runs occur. Under these conditions, I look for the conditions under which international creditors are willing to bail the banks out.

II.5.2 When Do International Creditors Stop Lending to Domestic Banks?

In this section, I start by assuming that at date one:

(i) domestic depositors see a sunspot,

(ii) banks are illiquid, therefore system-wide bank runs take place in the domestic economy.

Under such circumstances, would the international creditors ever be willing to optimally bail the banks out? What would be the creditors' optimal response to a domestic bank run? Chang and Velasco (2000) argue that rational creditors would never lend to the banks when there is a run. However, in their model, creditors' choice is not explicitly considered. In this chapter, I will show that there are circumstances under which creditors find it optimal to bail the banks out. If the creditors find the banks insolvent, a sudden stop takes place and gross capital inflows are zero.

II.5.2.1 The Creditors' Re-optimization Problem

For simplicity, I assume that the actual interest rates after a bank run are equal to the anticipated rates before it. I admit that this assumption is an abstraction from reality. However, as I show below, this simplification proves to be helpful in tractability and still allows for valuable insights. I also assume that during a crisis, creditors and banks renegotiate the quantities of debt instruments d_{12} and d_{02}. The third debt instrument amount d_{01} is given to the re-optimization problem.

When creditors observe the bank runs in the domestic economy at date one, they reconsider some of their date zero decisions. In particular, they choose the amount of gross new lending they want to make at date one under the new circumstances. This amount is denoted by z_{12} and is not necessarily equal to the previously promised amount d_{12}. In addition, I allow creditors to renegotiate the amount of long-term debt that was contracted at date zero. One reason for such a renegotiation could be the following. Notice that in the case of a run, if the banks survive to date two, they no longer have any obligation to depositors. Creditors are the only claimants of the remaining bank assets at this date. Therefore, bailout may be rational for creditors if they could increase the value of the long-term debt. This would be expected especially if the return from long-term investment R is large. Given that the interest rates are assumed to be constant, this means creditors would choose a large amount of the long-term debt. Table 2.5 introduces the new variables:

TABLE 2.5: CREDITOR RE-OPTIMIZATION

	No Crisis-Anticipated	**Crisis-Actual**
Gross New Lending at $t=1$:	d_{12}	z_{12}
Long-term Debt:	d_{02}	z_{02}

Notice that the domestic banks cannot re-optimize when a run hits. All depositors consume x that was originally promised to impatient depositors. Banks' borrowing demand is perfectly elastic; they are willing to borrow any amounts of z_{12} and z_{02} that are supplied. Therefore, it is only the solution of the representative international creditor's problem that determines whether a sudden stop or a bailout is going to take place.

The representative creditor's new budget constraint at date one becomes:

$$u + z_{12} \leq n + r_{01}d_{01} \tag{26}$$

Her budget constraint at date two is expressed as:

$$v \leq b + r_{12}z_{12} + r_{02}z_{02} \tag{27}$$

There is a possibility of a bailout only if the banks are going to be able to meet their obligations. Otherwise, creditors will not lend any money that the banks will not be able to repay. Then, the following conditions must be satisfied in any bailout equilibrium:

$$x + r_{01}d_{01} \leq z_{12} + sl \tag{28}$$

$$r_{12}z_{12} + r_{02}z_{02} \leq R(k - l) \tag{29}$$

The first condition states that banks are able to meet payment obligations to their depositors at date one. The second condition ensures that the banks are able to repay their debt to creditors at date two.

Finally, the following non-negativity constraints need to be satisfied:

$$u, v, z_{12}, z_{02}, l \geq 0 \tag{30}$$

The representative creditor chooses $\{u, v, z_{12}, z_{02}, l\}$ in order to maximize (2) subject to (26)-(30) taking $\{d_{01}, r_{01}, r_{02}, r_{12}, x, n, b, s, R, k\}$ as given.

At the interior solution of the creditors' re-optimization problem, first order conditions yield the following:

$$z_{12} = r_{01}d_{01} + \frac{1}{(1+\beta)}\left[x + \beta n - s\left(k + \frac{b}{R}\right)\right] \tag{31}$$

$$l = \frac{1}{s(1+\beta)}\left[\beta(x - n) + s\left(k + \frac{b}{R}\right)\right] \tag{32}$$

$$z_{02} = \frac{R}{r_{02}}k - \frac{r_{01}r_{12}}{r_{02}}d_{01} - \frac{1}{r_{02}(1+\beta)}\left[x\left(r_{12} + \frac{R\beta}{s}\right) + \beta n\left(r_{12} - \frac{R}{s}\right) + (R - r_{12}s)\left(k + \frac{b}{R}\right)\right] \tag{33}$$

Also, notice that a bailout or a sudden stop can only happen if there is a bank run in the first place. Then, for a bailout or a sudden stop equilibrium to occur, banks must be illiquid. The latter is captured by condition (15). Then, there is a lower bound on z_{12}

and an upper bound on z_{02}. Plugging (15) in (31) and (33), I get (34) and (35) respectively:

$$z_{12} \geq \frac{1}{1+\beta}\left\{s\left(\beta k - \frac{b}{R}\right) - \beta x + \beta n\right\} \tag{34}$$

$$z_{02} \leq \frac{1}{r_{02}}\left(r_{12} - \frac{R}{s}\right)\frac{\beta}{(1+\beta)}\left[x - n - s\left(k - \frac{b}{\beta R}\right)\right] \tag{35}$$

II.5.2.2 The Insolvency Condition

In this section, I investigate insolvency conditions under which international creditors decide whether to lend to domestic banks at $t = 1$ or not. Proposition 5 proves that (16) is a sufficient condition for insolvency. Under this condition, a sudden stop takes place and banks fail at $t = 1$. Proposition 6 derives the necessary and sufficient insolvency condition from the creditors' re-optimization problem.

Proposition 5: *If*

(i) a bank run has happened, and

(ii) *the sufficient insolvency condition (16) holds,*

Then, $z_{12} = z_{02} = 0$ *in equilibrium.*

Proof: Assume (16) holds. Let us consider the incentives of an individual creditor. Since each creditor is small, she takes the above state of the bank as given. She knows she cannot change it with *her* lending. At this point, it is obvious to this creditor that the bank will default completely on both z_{02} and z_{12}. This is because it cannot even fulfill its date one obligations after they liquidate everything. There is no reason she could be lending any amount that is not going to be repaid. Then, she sets $z_{12} = z_{02} = 0$. Then, all creditors set $z_{12} = z_{02} = 0$ and this is the equilibrium. QED.

Alternatively, one can use the first order conditions of the creditors' re-optimization problem to find an insolvency condition. In this way, I can link the insolvency condition to the fundamentals. Proposition 6 below derives the *necessary and sufficient* insolvency condition under which creditors' optimal response to a bank run is a sudden stop.

Proposition 6: *Assume that bank runs are observed in the domestic economy and (15) holds. Creditors do not bail the banks out and a sudden stop is observed if and only if*

$$\beta \frac{R}{s} \frac{1}{b + \frac{R}{s}\left(sk - x - r_{01}d_{01}\right)} < \frac{1}{n + r_{01}d_{01}}. \tag{36}$$

Proof: *Sufficiency:* If the international creditors do not want to lend at all at date one (a corner solution), the derivative of the Lagrangian of the creditors' re-optimization problem with respect to this variable is strictly negative. This implies:

$$\beta \frac{R}{s} \frac{1}{b + \frac{R}{s}\left(z_{12} + sk - x - r_{01}d_{01}\right)} < \frac{1}{n - z_{12} + r_{01}d_{01}} \tag{37}$$

Also, the non-negativity constraint for z_{12} binds: $z_{12} = 0$ optimally. Plugging these conditions into (37) yields (36).

Necessity: On the other hand, if (37) does not hold, then it must be that creditors are willing (or indifferent in case of equality) to increase $t = 2$ and decrease $t = 1$ consumption. This is possible only by increasing the value of z_{12} so that $z_{12} > 0$. Then, a sudden stop is not observed when (36) does not hold. QED.

In a sudden stop, the banks are not able to fully repay the loan with amount $r_{01}d_{01}$. The actual amount of payment is equal to what is left of the complete liquidation of the long-term asset. If nothing is left after the banks pay all its depositors (i.e. if $sk - x < 0$), then banks pay nothing to the creditors. Combining the two possibilities, in a sudden stop, gross outflows of capital from domestic economy is equal to $\max\{0, sk - x\}$. Also, notice that date two consumption of the creditors in a sudden stop is equal to their endowment b at this date.

I find that creditors are not willing to bail the banks out and a sudden stop occurs if their marginal utility at $t = 1$ exceeds their (weighted) marginal utility at $t = 2$. Notice that the right hand side of (37) is the marginal utility of $t = 1$ consumption of the creditor. The left hand side expresses the marginal utility of $t = 2$ consumption of the creditor weighted by two factors. The first factor is the discount rate (β). If the creditor sharply discounts date two consumption, a sudden stop is more likely because the creditor is too impatient to give up $t=1$ consumption and wait for $t=2$ return. The second factor is the ratio of $t=1$ and $t=2$ yields from long term investment $\left(\frac{R}{s}\right)$. If the return from allowing the bank to keep its investment until date two (and get *R*) instead of forcing the bank to liquidate early (and get *s*) is large enough, then a sudden stop is less likely. This same factor also appears in the denominator of the marginal utility of $t=2$ consumption. Since (15) holds, a larger factor of $\left(\frac{R}{s}\right)$ implies a smaller denominator and a larger marginal utility of $t=2$ consumption. Therefore, sudden stops are less likely.

Intuitively, if the creditor's $t=1$ endowment (*n*) is small, then a sudden stop is more likely because creditors have scarce resources and they are reluctant to lend at this date. A larger $t=2$ endowment (*b*) on the other hand makes a sudden stop more likely as creditors do not need to save for date two, they already have enough to consume.

One important insight I gain from the above analysis is that insolvency of the domestic financial system is not only determined by the fundamentals of the domestic economy, but also by the fundamentals of the rest of the world. Taking the behavior of international creditors seriously changes the way we understand sudden stops. I find that preferences and endowments of the international creditors are of utmost relevance to whether a sudden stop takes place or not.

Below, as an example, I show the existence of a bailout equilibrium for the case of 1.A before the bank run. For other cases, solutions are available upon request from the author.

II.5.2.3 Bailout Equilibrium at the Interior Solution

In this section, I assume that a bank run is precipitated when the economy is at case 1.A of the general equilibrium problem in section II.4. Proposition 7 below shows the existence of an equilibrium where creditors find it optimal to bail the banks out.

Proposition 7: *Assume that bank runs occur in the domestic economy at the equilibrium of case 1.A. If the condition* $s \geq \underline{\underline{s}}$ *where* $\underline{\underline{s}} = \left(1 - \frac{g\beta}{\pi(1+\beta)g + m + b/R}\right)\left(\frac{n\beta}{g+m+b/R}\right)$ *is satisfied, there exists an equilibrium where creditors bail the banks out. At this equilibrium,* $l = \frac{1}{s(1+\beta)}\left\{\beta g r_{01} - \beta n + s\left(g + m + \frac{b}{R}\right)\right\}$,

$z_{12} = r_{01}d_{01} + \frac{1}{(1+\beta)}\left[g r_{01} + \beta n - s\left(g + m + \frac{b}{R}\right)\right]$ *and*

$z_{02} = g + m - d_{01} - \frac{1}{1+\beta}\left[\left(\frac{\beta}{s} + \frac{1}{r_{01}}\right) g r_{01} + \left(\frac{1}{r_{01}} - \frac{1}{s}\right)\beta n + \left(1 - \frac{s}{r_{01}}\right)\left(g + m + \frac{b}{R}\right)\right]$ *where*

$r_{01} = \frac{\beta n}{\pi(1+\beta)g + m + b/R}$.

Proof: From case 1.A in section II.4, plug in $x = g r_{01}$, $r_{01} = \frac{n\beta}{m + \pi(1+\beta)g + b/R}$ and $r_{02} = r_{01} r_{12} = R$ into (31)-(33). The non-negativity constraint $l \geq 0$ implies $s \geq \underline{\underline{s}}$. The other non-negativity constraints $u, v, z_{12}, z_{02} \geq 0$ do not bind. QED.

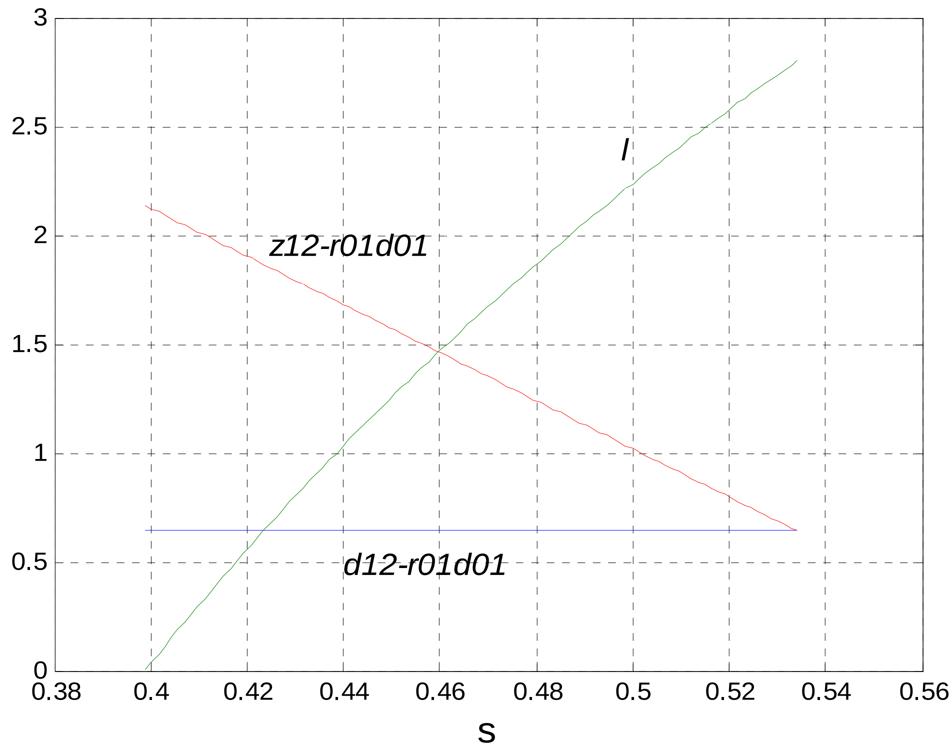


FIGURE 2.15: SIMULATION RESULTS OF BAILOUT EQUILIBRIUM

Figure 2.15 shows simulation results for $s \in (\underline{\underline{s}}, \bar{s})$ [40]. I find that if there is a bailout, actual net lending during a crisis $z_{12} - r_{01}d_{01}$ is always larger than the anticipated net lending $d_{12} - r_{01}d_{01}$. This is an expected result because in the case of a crisis, banks have to pay x in the aggregate instead of the anticipated smaller amount of $\pi x = d_{12} - r_{01}d_{01}$. The banks must raise the unanticipated extra liquidity $(1-\pi)x$ via a combination of additional borrowing and liquidation. The liquidation value parameter determines how much of the either source is optimally used. This means that in any bailout equilibrium, creditors must extend unanticipated funds over and above what was originally planned. Why would the creditors do such a thing, especially considering the assumption that interest rates cannot be bid upward during the crisis? They do this

[40] I remind the reader that $s < \bar{s}$ throughout the chapter by assumption 1. Also, it is easy to show that $\underline{\underline{s}} < \bar{s}$ always holds.

because they have the opportunity to boost their consumption at the last date. Their outside option is a sudden stop where banks close down and the representative creditor's consumption in the last date is equal to her endowment *b*. Her choice of a bailout or not depends on the tradeoff between a smaller consumption at date one and a larger consumption at date two. Table 2.6 compares her consumption vectors for each possibility:

TABLE 2.6: CREDITOR'S CHOICE OF BAILOUT OR SUDDEN STOP

	u	v
No Crisis	$n + r_{01}d_{01} - d_{12}$	$b + r_{12}d_{12} + r_{02}d_{02}$
Bailout	$n + r_{01}d_{01} - z_{12}$	$b + r_{12}z_{12} + r_{02}z_{02}$
Sudden Stop (No Bailout)	$n + \max\{0, sk - x\}$	b

Note: Recall that *u* and *v* represent the amounts of the good that an investor consumes at date one and two respectively.

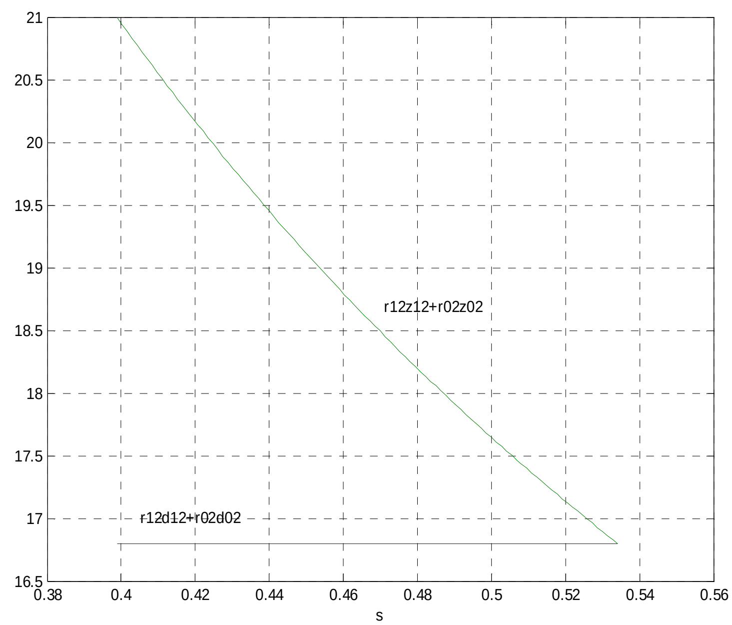


FIGURE 2.16: TOTAL INDEBTEDNESS IN NO CRISIS AND BAILOUT CASES

Figure 2.16 compares total indebtedness in no crisis and bailout cases. These are $r_{12}d_{12} + r_{02}d_{02}$ and $r_{12}z_{12} + r_{02}z_{02}$ respectively. The total value of debt that creditors will accept for a bailout can be quite large, especially if the liquidation value is small. It is evident from the figure that a bailout could impose a heavy debt burden on the domestic economy. Here, there can be some confusion about how the banks are able to repay such a large amount of debt, given that their total resources are smaller in a bailout case than the no crisis case: $R(k-l) \leq Rk$ for $l \geq 0$. However, it should be recalled that the bank has no domestic liabilities at the last date in the case of a run: $r_{12}z_{12} + r_{02}z_{02} = R(k-l)$. This is in contrast with the no crisis case in section II.4 where the bank has to make payments of y to each patient depositor: $r_{12}d_{12} + r_{02}d_{02} = Rk - (1-\pi)y$.

II.5.3 A Comparison of Closed and Open Financial Systems

When I compare my results to those of the closed economy applications of the Diamond and Dybvig (1983) setup, I understand that we can gain important insights. In particular, the model helps us understand the implications of allowing a financial system to borrow funds from a free global capital market. In this section, an "open" financial system refers to the banks' ability to borrow funds from the rest of the world. In closed economy versions[41], two properties are observed:

Property 1: Whenever banks play a welfare improving role, they are always illiquid and vulnerable to a self-fulfilling run (Wallace 1996).

Property 2: Whenever such a run happens, some depositors are always left without consumption. I call this a "very bad outcome" in the sense that depositors' welfare is even smaller than it would be without any banks (autarky). The possibility of a very bad outcome is mentioned in the original Diamond and Dybvig (1983) paper. Therefore, in closed economy models, the condition that determines whether a run will occur or not and the condition that determines whether a very bad outcome will occur or not are one and the same.

The first advantage of a liberalized financial system is regarding the illiquidity condition (15). In my model, equilibria with banks dominate autarky if Assumption 1 holds. However, in contrast to closed economy models' first property, the same assumption does not always imply illiquidity of banks. In particular, in cases 1 and 2, illiquidity requires a stronger condition than Assumption 1. This means that with an open financial system, it is possible to avoid illiquidity while still benefiting from welfare advantages of a financial equilibrium over autarky.

The second advantage of a liberalized financial system appears after a bank run. In my open economy model, when there is an economy-wide run on the banks and creditors stop lending, there may be cases in which some depositors are left without consumption. In this chapter, such an outcome is observed when (18) and (36) hold at the same time. Condition indicates that the bank cannot fulfill its obligations to some depositors who are left without consumption. It applies when there is a bank run *and* a sudden stop. For a sudden stop to occur, the insolvency condition (36) must hold. Therefore, for a very bad outcome to occur, both conditions must hold. Notice that satisfaction of both of the conditions is much less likely than satisfaction of the illiquidity condition (15). This means that vulnerability to a bank run does not always

[41] Diamond and Dybvig (1983), Wallace (1996), Cooper and Ross (1998) and Ennis and Keister (2004) among others.

imply vulnerability to a very bad outcome in a liberalized financial system. This is in contrast with the second property of closed economy models wherein a bank run automatically leads to a very bad outcome which yields welfare levels lower than autarky.

The above comparison of results suggests that a liberalized financial system has several desirable properties over a closed one. Access to global capital markets seem to serve like a cushion against bank runs or very bad outcomes.

II.6 Conclusion

In this chapter, I construct a model of a large open economy where foreign debt with different maturities is available. In the model, financial crises in the form of bank runs and/or sudden stops can arise endogenously. I take a world general equilibrium approach where the behavior of international creditors is modeled explicitly. This approach seems to deliver important insights into understanding the relationship between financial crises, foreign debt maturity and the term structure of interest rates on foreign debt.

There are two opposing viewpoints in the literature on financial crises. One view is that fundamentals of an economy play an important role in precipitating a crisis. Especially after the Asian crisis of 1997-98, this view lost some ground in academic circles. Five Asian economies seemed to have sound policies and macroeconomic indicators before the crisis. In order to explain what went wrong, among other things, self-fulfilling nature of the confidence crisis was emphasized in the literature. Even if the economy has sound macroeconomic policies and a sustainable debt structure *ex ante*, a confidence crisis can easily cause large liquidation and welfare losses.

This chapter has some support for both views. Fundamentals before the crisis determines whether the financial system is liquid or not. System liquidity depends on two factors. First, it depends on the maturity structure of debt that the banks take on. A shorter debt maturity increases illiquidity. Second, it depends on the nature of the investment technology in the domestic economy. A larger cost of liquidating the long-term asset increases system illiquidity. Degree of illiquidity, in turn, determines the degree of risk of a domestic bank run; a crisis is more likely if banks are illiquid. In this sense, the model supports the “fundamentalist” view. However, I find that illiquidity is not a sufficient condition for a crisis (bank run) to take place. Given illiquid banks, a confidence crisis or a sunspot completely unrelated to the fundamentals can only convince the domestic depositors to run on the banks. Therefore, the self-fulfilling element is essential to how a crisis takes place. In this sense, the model supports the “self-fulfilling” view.

One of the important contributions of this chapter is that it is a first step in designing a framework that is rich enough to allow for both domestic and foreign sources of adverse expectations about a financial system. I have studied the case of sunspots of domestic depositors as the original source of a crisis. An important and natural extension of this chapter is to study sunspots of international creditors as the original source. Also, an important question is whether I can design a policy that selects “healthy” equilibria from among the equilibria that I have discovered in this chapter.

In chapter III below, I study financial fragility of a small open economy using a monetary model. The objective is to investigate the merits of alternative monetary policies with respect to the risk of a financial and a currency crisis.

CHAPTER III

FINANCIAL FRAGILITY AND THE CHOICE OF MONETARY POLICY

III.1 Introduction

In this chapter, I investigate the merits of alternative monetary policies with respect to financial fragility and currency crises. I study a small open economy and explicitly model a financial system in which banks arise to provide liquidity. I present a variation of an open economy version of the Diamond and Dybvig's (1983) illiquid investment technology when modeling my financial system. In particular, I study an overlapping-generations-model with an infinite sequence of two-period lived generations. As stated by Schreft and Smith (1997), previous neoclassical models that study explicit financial markets have mostly been real economies. In contrast, I study a monetary economy in this chapter; I take seriously the definition of fiat money as an object without any intrinsic value. I consider the presence of two fiat currencies (domestic and foreign) that can circulate simultaneously in my general equilibrium framework. In particular, I carefully build the environment such that money is not treated as a consumption good that generates utility[42] or an investment good that generates output.

I motivate the demand for two intrinsically useless currencies by the spatial separation and limited communication of agents. The latter method has been extensively used by Townsend (1980) and others to explain the existence of a monetary equilibrium in closed economies. In this chapter, the domestic economy consists of two symmetric islands. At the end of every period, a fraction of young agents are required to move to a location where only currency (domestic or foreign) is accepted as a means of payment. In addition, there is a Central Bank (CB henceforth) that has the monopoly of domestic currency creation. It also conducts alternative monetary policies. Having such a

[42] Chang and Velasco (2000) use a money-in-the-utility function in their model.

monetary model allows me to study the effects of monetary policy on the efficiency and fragility of the financial markets.

III.2 Environment

Consider a small open economy that consists of an infinite sequence of two-period lived, overlapping generations. Time is discrete and indexed by $t = 0,1,2,...$. The domestic economy consists of two symmetric locations: island A and island B. In each period and at each island, a continuum of agents with unit mass is born. Therefore in any given period, there is a population of young agents and a population of old agents at each island. Also in each period, there is a single tradable consumption/investment good which is homogenous across countries. This good can be freely traded across the border and there are no trade barriers.

III.2.1 Endowments, Preferences, Assets and the Information Structure

Each agent is endowed with w units of the good when young, but does not receive any endowments when old. Agents derive utility *only* from consuming when old. Therefore, here I do not have the *preference shock* that the Diamond and Dybvig (1983) utilize. However, agents face a *relocation shock*. Young agents face an uncertain outcome such that with probability π, each young agent will be required to move to the other island at the end of her youth. Then, as of the end of her youth, each agent is of one of two types: a *mover* or a *non-mover*. Type realization is an i.i.d. process across young agents. Then, by the law of large numbers, π is also the fraction of movers in each generation. The fraction of movers is exogenously given and is public information at all times. Hence, while there is individual uncertainty in this economy, there is no aggregate uncertainty. Also, the information regarding a particular individual's type is private, and her consumption and investment activities cannot be observed or verified by others.

I assume that when movers are relocated to the other island, they can only transport currency[43]. I am allowing both domestic and foreign currencies to be carried to the other island. Also, I am not legally restricting the use of any one of the currencies as a means to purchase the consumption good at any location. Let p_t^* and p_t denote the

[43] The investment good or the consumption good cannot be transported across islands.

price of the good at time t in terms of foreign currency and domestic currency, respectively. Since the good is freely traded in the world market and I have a small open economy, I assume that p_t^* is exogenous and taken as given. More precisely, I assume that $\frac{p_t^*}{p_{t+1}^*} = \frac{1}{1+\sigma^*}$ where σ^* is a constant parameter that represents the world inflation rate (WIR). Let e_t denote the nominal exchange rate at time t such that e_t units of the domestic currency can be used to purchase one unit of the foreign currency.

Let $\hat{c}_{t+1}$ and $\widetilde{c}_{t+1}$ denote the consumption amounts of an old agent that was born at time t if she is a mover and a non-mover, respectively. For simplicity, I use a logarithmic utility function such that $u(c) = \log(c+\gamma)$ where γ is a given parameter[44]. Then, as of her youth, an agent's expected utility can be written as

$$E_t[U(\hat{c}_{t+1}, \widetilde{c}_{t+1})] = \pi \log(\hat{c}_{t+1} + \gamma) + (1-\pi)\log(\widetilde{c}_{t+1} + \gamma)\,. \tag{38}$$

Following Diamond and Dybvig (1983), there is an illiquid technology available to agents and financial institutions of the domestic economy. One unit of the good invested at the beginning of period t before types are realized can be transformed into capital that yields R units of the consumption good in period $t+1$. However, this is an illiquid asset in the sense that once one unit of the good is invested at the beginning of period t, an early liquidation after types are realized yields a return of s units of the good. Investment decisions must be made before types are realized. I assume that $R > s$, $R > s^2$, $R > \frac{p_t}{p_{t+1}}$ and $R > \frac{1}{1+\sigma^*}$. The first two of these assumptions imply that early liquidation of long-term investment is costly. The last two assumptions imply that the rate of return from long-term investment dominates the rates of returns from holding either the domestic or the foreign currencies between young and old age.

As it is standard in the literature, one can easily show that in the environment described, coalitions of domestic agents organized as banks can achieve superior outcomes relative to autarky where agents make consumption and investment decisions

[44] This particular functional form has some useful properties. One of those is that utility is bounded from below and above.

by themselves. Once again, this is because of the fact that while there is individual uncertainty in this economy, there is no aggregate uncertainty.

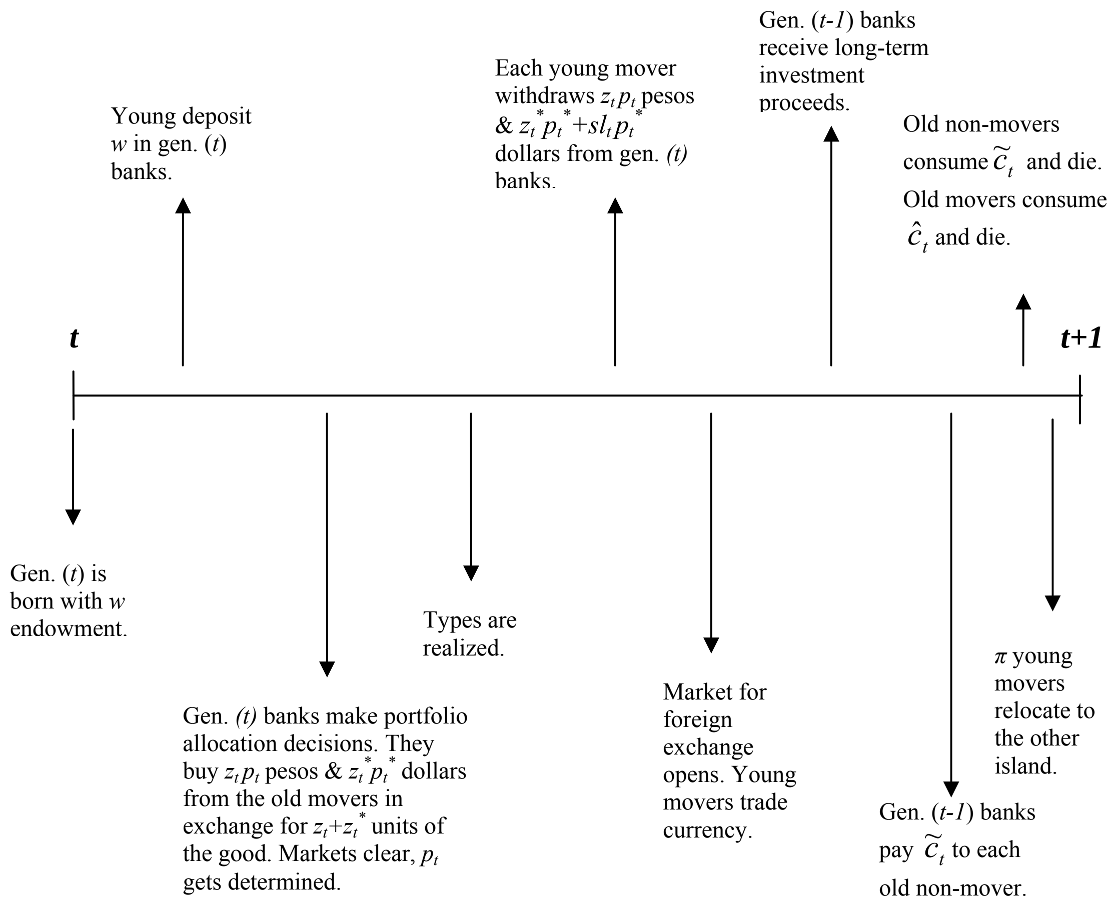
III.2.2 The Representative Domestic Bank's Problem

The banking arrangement in this environment is described as follows. At time t, each bank[45] offers a demand deposit contract that promises the following payments to its depositors in exchange for depositing w units of good when they are young: The agents who report themselves as movers are promised a payment of a portfolio of currencies that can buy x_t units of the good in period t. The agents who report themselves as non-movers are entitled to a payment of $\tilde{c}_{t+1}$ units of the good at $t+1$. Accepting this contract, agents deposit their entire endowment of w units of the good with the bank when they are young. The bank can invest these deposits in three available assets. It chooses to invest k_t units of the good in the long-term asset. Also, it purchases m_t and m_t^* units of the domestic and foreign currency, respectively. Then, the resource constraint faced by the bank before the types are realized is:

$$k_t + z_t + z_t^* \leq w \tag{39}$$

for all t where $z_t \equiv \dfrac{m_t}{p_t}$ and $z_t^* \equiv \dfrac{m_t^*}{p_t^*}$ are holdings of real domestic and foreign currency balances respectively. Figure 3.1 illustrates the timeline of events in this economy.

[45] "bank" henceforth stands for the representative bank owned by the generation that was born at time t.



Note: Gen. stands for "generation".

FIGURE 3.1: TIMELINE OF EVENTS

After the types are realized in period t, the bank has to pay reported movers a combination of domestic and foreign currency balances that are equivalent in sum to x_t units of the good in real terms. At this time, the bank's resources include currency balances carried from the beginning of the period. If those balances are not sufficient to meet the payment obligations, the bank could liquidate l_t units of the long-term asset before maturity. Then, the bank exchanges the proceeds from liquidation for foreign currency and completes its payments to reported movers in foreign currency. In separating equilibrium, number of depositors who withdraw at this period is equal to the number of movers. Therefore, the bank's resource constraint is[46]:

$$\pi x_t \leq z_t + z_t^* + sl_t \text{ for all } t. \tag{40}$$

Notice that the reported movers are going to exchange fiat currency holdings for goods at period *t+1*. The amount of consumption that each mover can buy at *t+1* can be expressed as:

$$\pi \hat{c}_{t+1} = z_t \frac{p_t}{p_{t+1}} + z_t^* \frac{p_t^*}{p_{t+1}^*} + sl_t \frac{p_t^*}{p_{t+1}^*}. \tag{41}$$

When period *t+1* arrives, the bank receives the proceeds from the non-liquidated part of the long-term investment. The bank has obligations of $\tilde{c}_{t+1}$ units of good with each depositor that withdraws at this period. Then,

$$(1-\pi)\tilde{c}_{t+1} \leq R(k_t - l_t), \forall t \geq 0 \tag{42}$$

becomes the bank's resource constraint at this period.

For the separating equilibrium to be incentive compatible, the bank has to give the right incentives to non-movers so that they do not misrepresent their type. If a non-mover pretends as a mover and withdraws currency when young, the best she can do is to exchange the currency for goods when old. By (41), the amount of consumption goods that she can buy when old is equal to $\hat{c}_{t+1}$. To discourage misrepresentation of type by non-movers, the following incentive compatibility condition must hold:

$$\tilde{c}_{t+1} \geq \hat{c}_{t+1} \tag{43}$$

Finally, the following non-negativity constraints apply:

$$z_t, z_t^*, l_t \geq 0 \quad \text{and } k_t, x_t > 0 \text{ for all } t. \tag{44}$$

---

[46] Notice that this constraint is written in real terms. The actual payments to reported movers are made in fiat currency. That is, payment to each reported mover includes $z_t p_t$ units of domestic currency, $z_t^* p_t^*$ units of foreign currency, and if there is any liquidation, $sl_t p_t^*$ units of foreign currency. Since the law of one price holds, that is, $e_t = \frac{p_t}{p_t^*}$ at all times, the resource constraint can be expressed as (40).

In summary, the representative bank owned by generation t chooses $\{\hat{c}_{t+1}, \tilde{c}_{t+1}, k_t, z_t, z_t^*\}$ in order to maximize (38) subject to (39)-(44) taking $\{p_t, p_t^*, w, \pi, R, s\}$, $t = 0, 1, 2...$ as given.

III.2.3 Restrictions on Parameter Space

Assumption III.1 restricts the parameter space so that a financial system can provide some insurance against liquidation of the long-term asset. This assumption is maintained throughout the chapter.

Assumption III.1: *The following condition is necessary and sufficient to ensure that zero liquidation of the long-term asset is optimal:*

$$\frac{(\gamma + \tilde{c}_{t+1})}{(\gamma + \hat{c}_{t+1})} < \frac{R}{s}\left(1 + \sigma^*\right) \tag{45}$$

Proof: The first order condition of the bank's problem with respect to l_t being strictly negative yields (45).

The intuition with (45) is that the opportunity cost of liquidating the long-term asset, $\left(\frac{R}{s}\right)$ needs to be large enough so that financial intermediation increases social welfare relative to financial autarky by avoiding liquidation. Notice that I had a similar condition in chapter II as well.

III.3 Steady-State Equilibria with No Crises

In this section, as a first step, I find the steady-state equilibria of the model with no crises. I find two sets of steady-state monetary equilibria. In the first set, both domestic and foreign currencies are held in positive amounts in equilibrium. In the second set, only foreign currency is held in equilibrium. Which of the two sets is observed is determined by domestic monetary policy. If the growth rate of domestic money supply and hence the steady-steady domestic inflation rate is equal to international inflation rate, both domestic and foreign currencies are held in equilibrium. If, on the other hand, growth rate of domestic money supply is larger than foreign inflation, only foreign currency is held in equilibrium. Below, I present these sets of equilibria.

III.3.1 Market Clearing Conditions

The domestic currency market clearing condition can be expressed as

$$2\pi z_t = \frac{M_t}{p_t}. \tag{45}$$

Above, M_t denotes the total nominal supply of domestic currency in period t. The demand for real domestic currency balances *per depositor* is equal to z_t. Notice that in separating equilibrium, only movers demand domestic currency. Since there are 2π movers in this economy, total demand for real domestic currency balances is $2\pi z_t$. The price level gets determined through the market clearing condition. Using (45), the domestic inflation rate can be expressed as

$$\frac{p_{t+1}}{p_t} = \frac{M_{t+1}}{M_t}\frac{z_t}{z_{t+1}}. \tag{46}$$

For simplicity, assume that the Central Bank follows the policy of a constant growth rate of domestic money supply (σ) such that $\frac{M_{t+1}}{M_t} = (1+\sigma)$. Notice that I have assumed a fixed foreign price level and rate of inflation. Therefore, the market for foreign currency automatically clears at all times[47]. These assumptions imply that I have a floating exchange rate regime with the exchange rate being determined through the law of one price: $e_t = \frac{p_t}{p_t^*}$.

III.3.2 Steady-State Equilibria and Implications

If both domestic and foreign currencies are to be held in positive amounts in equilibrium, the following no arbitrage condition must hold:

$$\frac{p_{t+1}}{p_t} = \frac{p_{t+1}^*}{p_t^*}. \tag{47}$$

Using (46), (47) and the first order conditions of the bank's problem, I obtain the following dynamic system:

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[47] Demand for foreign currency $2\pi z_t^*$ is instantly satisfied by the perfectly elastic international supply at the exogenous foreign price level.

$$z_{t+1}\left[\frac{\gamma}{R}+\frac{1}{(1-\pi)}w-\frac{1}{\pi(1-\pi)}z_t-\frac{1}{(1-\pi)}z_t^*\right]=z_t\left[\gamma(1+\sigma)+\frac{1}{\pi}\frac{(1+\sigma)}{(1+\sigma^*)}z_t^*\right] \quad (48)$$

$$z_{t+1}-z_t=z_t\left[\frac{(1+\sigma)}{(1+\sigma^*)}-1\right] \quad (49)$$

A steady-state equilibrium can be defined as a set of allocations $\{\hat{c}_{t+1},\tilde{c}_{t+1},k_t,z_t,z_t^*\}_{t=0}^{\infty}$ such that:

(i) (48) and (49) are satisfied, and

(ii) $z_t=z_{t+1}=z,\ z_t^*=z_{t+1}^*=z^*,\ k_t=k_{t+1}=k,$

$\hat{c}_{t+1}=\hat{c}_{t+2}=\hat{c},\ \tilde{c}_{t+1}=\tilde{c}_{t+2}=\tilde{c},\ \forall t\geq 0$.

I find two sets of steady-state equilibria. The first set (equilibrium I) is the interior solution with $z, z^*>0$ and $\sigma=\sigma^*$. This equilibrium is illustrated on Figure 3.2 as the points on the line with $z+z^*=g(\sigma^*)$ where $g(\sigma^*)=\pi w-\pi(1-\pi)\gamma\left[(1+\sigma^*)-\frac{1}{R}\right]$. The consumption vector is unique across combinations of domestic and foreign real currency holdings along this line:

$$\hat{c}=\frac{1}{\pi(1+\sigma^*)}g(\sigma^*) \text{ and } \tilde{c}=\frac{R}{(1-\pi)}\left[w-g(\sigma^*)\right]. \quad (50)$$

Also, social welfare is constant along the same line. If I denote the social welfare of a representative future[48] generation by $\theta(\sigma^*)=\pi\hat{c}+(1-\pi)\tilde{c}$, then

$$\theta(\sigma^*)=\left[\frac{1}{(1+\sigma^*)}-R\right]g(\sigma^*)+Rw. \quad (51)$$

The second set (equilibrium II) is a unique point, a corner solution with $z=0,\ z^*=g(\sigma^*)$ and $\sigma>\sigma^*$. That is, if the growth rate of domestic money supply is larger than the international inflation rate, domestic currency holdings are completely substituted by foreign currency holdings at the steady-state. However, as stated above,

[48] I am not considering the initial old generation at this point.

the consumption vector and hence the social welfare level is the same as with the first equilibrium.

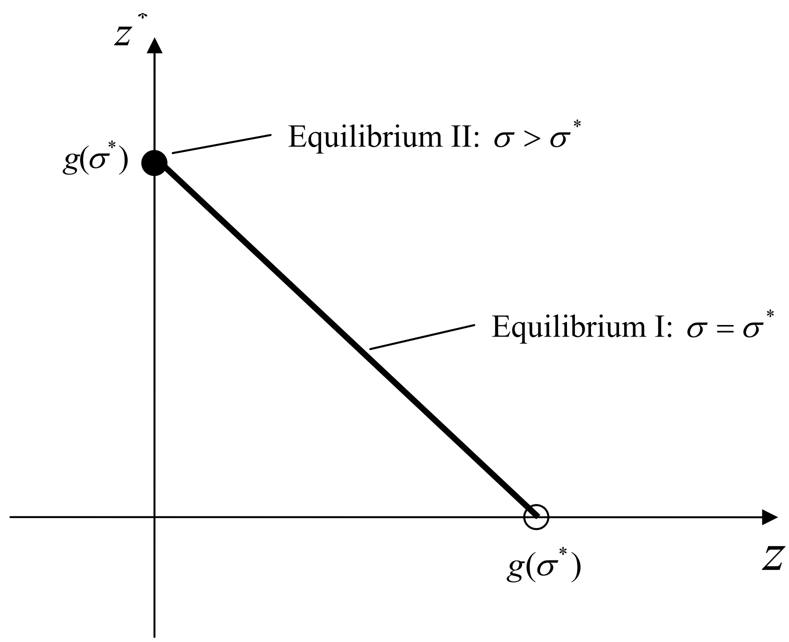

FIGURE 3.2: STEADY-STATE EQUILIBRIA

I find that given the international rate of inflation (σ^*), domestic monetary policy is *neutral* with respect to welfare. There are two alternative monetary policy regimes: (i) growth rate of domestic money supply can be set equal to the international rate of inflation ($\sigma = \sigma^*$), or (ii) the former rate can be set to be larger than the latter, ($\sigma > \sigma^*$). Under both regimes, the steady-state consumption amounts are constant and given by (50). Consequently, the welfare level is also constant and given by (51). In cases where $\sigma < \sigma^*$, there is no steady-state equilibrium.

The international rate of inflation has a negative effect on total real currency balances held in equilibrium. At both the first and the second steady-state equilibria, total real currency holdings are given by $z + z^* = g(\sigma^*)$ where $g(\sigma^*)$ is a decreasing function of the world inflation rate (WIR). The implication is that when the WIR increases (decreases), the line in Figure 3.2 shifts inward (outward). As a consequence, steady-state total real currency holdings decrease (increase).

There is an interesting relationship between the international inflation rate and domestic welfare. Consider the consumption amounts of movers and non-movers given a rise in the international inflation rate. By (50), movers consume less, non-movers consume more. The total effect is ambiguous and depends on the initial level of σ^*. It is easy to show that $\theta''(\sigma^*) > 0$. If the initial level of the international inflation rate is smaller (larger) than some critical level, then a rise in σ^* decreases (increases) welfare. Let me call this critical level the "turning point" and denote it by σ_T^*. By (51), the turning point level is given by:

$$\left(1+\sigma_T^*\right) = \frac{1}{R}\left[1 + \frac{Rw}{(1-\pi)\gamma}\right]^{\frac{1}{2}} \tag{52}$$

This result is interesting in the sense that there is a possibility that the domestic economy may benefit from a larger world inflation rate if the initial inflation rate is already large. In this case, the positive effect from non-movers' utility dominates the negative effect from movers' utility on welfare, increasing total domestic welfare.

III.4 Conclusion

In this chapter, I study a small open economy with two fiat currencies (domestic and foreign) and an explicit banking system that is vulnerable to runs from its depositors. Deviating from previous literature, I treat fiat currencies as intrinsically useless. They are used merely as a means to carry value across two islands that make up the domestic economy. I assume spatial separation and limited communication of agents. As a first step, I present steady-state equilibria with no crises. I find that domestic monetary policy in the form of a constant growth rate of domestic money supply is *neutral* with respect to welfare. For both domestic and foreign currencies to be held in equilibrium, growth rate of domestic money supply must be equal to the world inflation rate (WIR). If the former rate is larger than the latter, domestic money is not held in equilibrium. The total (domestic and foreign) real money balances held is negatively related to the WIR. The relationship between the WIR and domestic welfare is not trivial and depends on the initial level of WIR. If the initial level of the WIR is larger (smaller) than some critical level, then domestic welfare is positively (negatively) related with WIR. The implication is that in some cases a small open economy may benefit from a larger international inflation rate.

There are some interesting directions in which this chapter can be extended. For example, one can allow the possibility of a bank run by introducing a sunspot. If the sunspot is observed, then depositors check the liquidity position of banks. This liquidity condition would depend on fundamentals and possibly would interact with the domestic and international price levels. One of the challenges of such a study is the question of how prices are determined after the sunspot. Prices might be indeterminate and multiple equilibria could be observed. Another interesting question is the following. Once a bank run happens, what are the conditions under which a central bank (CB) should extend credit to troubled banks? Radelet and Sachs (2000) criticize the abrupt bank closures based on IMF prescriptions in the Asian crisis. At least in the short-term, it could be welfare improving if the CB could extend credit to illiquid banks instead of closing them down.

CHAPTER IV

CONCLUSION

In this dissertation, I study international financial crises in emerging market economies. Specifically, I focus on Mexican (1995), Asian (1997) and Turkish (2001) financial crises. There are some characteristics common to all of these crisis episodes. First, many analysts believe that they were largely unanticipated by market participants. Second, they involved a rapid rise in foreign liabilities of the commercial banking system up until the crisis during which international creditors suddenly refused to rollover debt. Third, the banking systems in the crisis economies were newly liberalized but did not have effective regulatory and supervisory mechanisms in place (Radelet and Sachs 1998, 2000; Sachs, Tornell and Velasco 1996).

In Chapter II, I study a world general equilibrium model of international creditors on the supply side and domestic banks on the demand side of the international capital markets. Banks are allowed to borrow at various maturities and issue dates. In the first step, I present and discuss equilibria where no crises take place. One characteristic of those equilibria is multiplicity and indeterminacy. I observe two types of indeterminacy: in terms of (i) prices and (ii) quantities of debt borrowed. Interestingly, there is an apparent tradeoff between price indeterminacy and quantity indeterminacy. When the prices are more determinate, quantity vector is less determinate and vice versa. In the second step, I present and discuss equilibria where crises are allowed to take place. In my model, crises are triggered by a sudden shift of expectations. I assume that domestic depositors may observe a bad signal about the banking system. If they do, whether a bank run takes place or not depends on the liquidity condition of banks. According to this condition, banks are illiquid if and only if their potential liabilities (as opposed to actual) exceed their potential assets. If banks are illiquid, all depositors run to the banks for withdrawal and banks may fail. Potential liabilities of the banking system increase if banks have a larger stock of short-term debt due in period one. Banks' potential assets are given by the early-liquidation value of the illiquid investment. Then, liquidity crises are more likely if the equilibrium debt maturity is relatively short-term. Therefore, policies that are aimed at inducing a longer term maturity of foreign liabilities are supported[49]. Next, given debt maturity structure, a relatively large cost of liquidating the long-term asset before maturity implies a more fragile banking system. In the third step, given a domestic bank run, I consider international creditors' optimal response. Facing a domestic liquidity crisis, they re-evaluate their original lending plans. If they find the banks insolvent, they stop lending and a sudden stop occurs. In this setting, the risk of a sudden stop depends on three parameters. First, if the international creditors highly discount future consumption over current consumption, a sudden stop is more likely. Second, if the creditors' current income is small relative to their future income, they are more likely to stop lending. Third, if the cost of liquidating the long-term asset is small, then a sudden stop is more likely because the creditors choose to ask for immediate repayment instead of waiting for the long-term returns. The reason that I am able to assess the risk of a sudden stop is that there is the possibility of a rational bailout equilibrium under favorable conditions.

In Chapter III, I model an explicit banking system in the presence of two fiat currencies. My objective is to assess the role of monetary policy in a setting where banks are vulnerable to self-fulfilling runs. The most critical contribution of this model is the way it treats fiat currencies. To motivate demand for a fiat currency, the previous literature has assumed that fiat currency generates utility or output. Deviating from previous literature, I treat fiat currencies as intrinsically useless. They are used merely as a means to carry value across islands in my model. I assume spatial separation and limited communication of agents. I allow a domestic and a foreign currency to be freely traded in my model. As a first step, I present steady-state equilibria with no crises. I find that domestic monetary policy in the form of a constant growth rate of domestic money supply is *neutral* with respect to welfare. For both domestic and foreign currencies to be held in equilibrium, gowth rate of domestic money supply must be equal to the world

[49] One example is Chilean style taxes on short-term capital flows.

inflation rate (WIR). If the former rate is larger than the latter, domestic money is not held in equilibrium. The total (domestic and foreign) real money balances held is negatively related to the WIR. The relationship between the WIR and domestic welfare is not trivial and depends on the initial level of WIR. If the initial level of the WIR is larger (smaller) than some critical level, then domestic welfare is positively (negatively) related with WIR. The implication is that in some cases a small open economy may benefit from a larger international inflation rate.

Below, I discuss some interesting extensions of the models studied in this dissertation.

IV.1 Possible Extensions

In the model presented in Chapter II, I have studied sunspots that are domestically originated. Domestic depositors observe the bad signal about the health of the banking system. Then, according to the liquidity position of banks they run or do not run for withdrawal. An interesting extension would be to study sunspots that are internationally originated. International creditors would observe the bad signal and stop lending if they find domestic banks unable to pay its obligations given that all creditors refuse to rollover debt. In that case, domestic depositors would re-evaluate their original decisions and run if they find the banks unable to meet their obligations.

There is a common dilemma that was faced by the Central Bank of Turkey, Bank of Mexico and Bank of Thailand when there is a run on the commercial banking system caused by a fear of devaluation. There are two courses of action available to the central banker at this point. The central bank (CB) may act as a lender of last resort and extend credit to the commercial banking system. Then the withdrawals are going to be used to purchase foreign exchange from the CB. Then, under a fixed exchange rate regime, the CB may run out of reserves and face a balance of payments crisis and devaluation. Or alternatively, the CB may leave illiquid banks to their fate and face a financial meltdown. Under which set of fundamentals and situations should the CB choose to extend credit to domestic banking system? This policy question was emphasized by Akyüz and Boratav (2003) for the Turkish (2001) and Sachs, Tornell and Velasco (1996) for the Mexican (1995) crises. One of the extensions of the model in Chapter III can be to endogenize the choice of the central bank acting as a lender of last resort or not. When making this decision, the CB can be assumed to maximize social welfare. The decision of the CB can be linked to the fundamentals and the current situation of the economy. I believe such a study would provide interesting policy implications.

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APPENDIX A

A.1 First Order Conditions for the No Crises Case

We first write the first order conditions (FOC's) of the representative bank's and international creditor's problems respectively. The expression next to the endogenous variable is the partial derivative of the Lagrangian with respect to that variable. If the expression is equal to zero, the solution is the "interior" one. Then the corresponding variable has a nonnegative finite value. If the expression is less than zero, then the corresponding variable is equal to zero. Lastly, if the expression is positive, then the corresponding variable has an arbitrarily large value.

Bank's Problem FOC's:

$$d_{01}{}^{d}: \qquad -\frac{r_{01}}{x}+\frac{R}{y} \tag{A1}$$

$$d_{02}{}^{d}: \qquad \frac{R-r_{02}}{y} \tag{A2}$$

$$d_{12}{}^{d}: \qquad \frac{1}{x}-\frac{r_{12}}{y} \tag{A3}$$

$$l: \qquad \frac{s}{x}-\frac{R}{y} \tag{A4}$$

where $x=\frac{1}{\pi}(d_{12}{}^{d}+sl-r_{01}d_{01}{}^{d})$ and

$y=\frac{1}{1-\pi}\left[Rg+Rd_{01}{}^{d}+(R-r_{02})d_{02}{}^{d}-Rl-r_{12}d_{12}{}^{d}\right]$. Notice that in the no crisis case, $l=0$ by assumption 1. The necessity or sufficiency of assumption 1 depending on the case will be proven for each case below.

International Creditor's Problem FOC's: First notice that since $d_{02}{}^{s} = m - d_{01}{}^{s}$, there is no FOC for $d_{02}{}^{s}$.

$$d_{01}{}^{s}: \qquad \frac{r_{01}}{u} - \frac{\beta r_{02}}{v} \tag{A5}$$

$$d_{12}{}^{s}: \qquad -\frac{1}{u} + \frac{\beta r_{12}}{v} \tag{A6}$$

Where $u = r_{01}d_{01}{}^{s} + n - d_{12}{}^{s}$ and $v = r_{12}d_{12}{}^{s} + r_{02}m - r_{02}d_{01}{}^{s}$.

A.2 Proof of Proposition 2

This proposition solves for the cases where long-term interest rates are equal to the compounded two short-term rates: $r_{01}r_{12} = r_{02}$.

Case 1.A: I start with solving for the supply side as interior solution. Taking (A5) and (A6) as equalities, I find $r_{01}r_{12} = r_{02}$ and $d_{12}{}^{s} = \dfrac{(1+\beta)r_{01}r_{02}d_{01}{}^{s} + r_{02}n\beta - r_{01}r_{02}m - r_{01}b}{r_{01}r_{12} + \beta r_{02}}$.

Combining the two, I get:

$$d_{12}{}^{s} = r_{01}d_{01}{}^{s} + \frac{n\beta}{1+\beta} - \frac{mr_{01}}{1+\beta} - \frac{b}{(1+\beta)r_{12}} \tag{A7}$$

Now, I solve the demand side problem as interior solution. Using (A3), I get $d_{01}{}^{d} = \dfrac{r_{12}d_{12}{}^{d} - \pi Rg}{\pi R + (1-\pi)r_{01}r_{12}}$. Combining (A1)-(A3), I find $r_{01}r_{12} = r_{02} = R$. Plugging the latter into former, I get:

$$d_{01}{}^{d} = \frac{r_{12}}{R}d_{12}{}^{d} - \pi g \tag{A8}$$

Notice that (A8) implies $x = r_{01}g$ and $y = Rg$.

Using market clearing conditions (20)-(22) and $r_{01}r_{12} = r_{02} = R$, I combine (A7) and (A8). I find $r_{01} = \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$ and $r_{12} = \dfrac{R[m + \pi(1+\beta)g] + b}{n\beta}$. Amounts of debt d_{ij} cannot be determined.

- No liquidation condition $(l=0)$ requires that (A4) be strictly negative. This implies $s < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$ must hold.

- Incentive compatibility (IC) condition (6) requires $R \geq \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$.

  This implies that $R \geq \dfrac{n\beta - b}{m+\pi(1+\beta)g}$ is a sufficient condition for IC.

Case 1.B.1: Here, the supply side is interior similar to case 1.A. Therefore, again $r_{01}r_{12}=r_{02}$ and (A7) must hold.

Now, I turn to demand side problem. Since $d_{01}{}^{d}$ is interior, (A1) is equal to zero. This implies

$$d_{12}{}^{d} = r_{01}d_{01}{}^{d}\frac{[(1-\pi)R+\pi r_{02}]}{[(1-\pi)R+\pi r_{01}r_{12}]}+\frac{\pi r_{01}[R(g+m)-mr_{02}]}{[(1-\pi)R+\pi r_{01}r_{12}]} \tag{A9}$$

Combining with the other two conditions (A2) and (A3) by taking them strictly positive (they are both at right corner), I get $R > r_{02}$ and $R > r_{01}r_{12}$. Notice that equilibrium amounts of debt d_{ij} cannot be determined.

By market clearing conditions, I combine (A7) and (A9) using $r_{01}r_{12}=r_{02}$. I get the polynomial: $A_1 r_{12}{}^{2} + B_1 r_{12} + C_1 = 0$ where

$A_1 = \pi\beta r_{01}(mr_{01}+n) \quad B_1 = (1-\pi)R\beta n - r_{01}[\pi b + Rm(1+\beta\pi)+R\pi g(1+\beta)] \quad C_1 = -(1-\pi)Rb$

. This implies that $r_{12}(1,2) = \dfrac{-B_1 \mp \sqrt{B_1{}^2 - 4A_1C_1}}{2A_1}$. The simulation results (available from author) show that the first root, $r_{12}(1) = \dfrac{-B_1 - \sqrt{B_1{}^2 - 4A_1C_1}}{2A_1}$ is negative for a wide range of reasonable parameter values. Therefore, I pick $r_{12}(2) = \dfrac{-B_1 + \sqrt{B_1{}^2 - 4A_1C_1}}{2A_1}$ as a function of r_{01}. This shows a curve in the space of interest rates, i.e. regular equilibria. Normalized vector of interest rates is unique (see section 4.2). I also find that r_{12} is an increasing function of r_{01}. By $R > r_{01}r_{12}$ and the fact that this curve passes through the unique interest rate vector of case 1.A (interested reader can easily verify this), I find that $r_{01} < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$ and $r_{12} < \dfrac{R[m+\pi(1+\beta)g]+b}{n\beta}$.

- No liquidation $(l=0)$ condition implies $s < r_{01}$. This is satisfied only if $s < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$ holds.
- The IC condition requires $r_{01} \le R$. By $r_{01} < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$, a sufficient condition for IC to be satisfied is $\dfrac{n\beta}{m+\pi(1+\beta)g+b/R} \le R$. The latter implies that $R \ge \dfrac{n\beta-b}{m+\pi(1+\beta)g}$ is a sufficient condition for IC.

Case 1.B.2: Here, the supply side is again at interior solution. Therefore, again $r_{01}r_{12} = r_{02}$ and (A7) must hold.

The demand side problem has d_{02}^{d} right corner, which implies $R > r_{02}$. Combining d_{01}^{d} right corner and d_{12}^{d} interior conditions, I get $R > r_{01}r_{12}$. The latter condition implies:

$$r_{12}d_{12}^{\ d} = \pi R(g+m) - \pi m r_{02} + d_{01}^{\ d}[\pi r_{02} + (1-\pi)r_{01}r_{12}] \tag{A10}$$

By market clearing conditions, I combine (A7) and (A10). Again, equilibrium amounts of debt cannot be determined, but interest rates are found to be on a curve in space of *(r_{01}, r_{12}, r_{02})*. Assuming $\pi(1+\beta) \ne 1$, I find

$r_{01} = \dfrac{1}{m[\pi(1+\beta)-1]}\left[\dfrac{\pi R(g+m)(1+\beta)+b}{r_{12}} - n\beta\right]$ or equivalently,

$r_{12} = \dfrac{\pi R(g+m)(1+\beta)+b}{r_{01}m[\pi(1+\beta)-1]+n\beta}$. I find that r_{12} is an increasing (decreasing) function of r_{01} if $\pi(1+\beta) < 1$ ($\pi(1+\beta) > 1$).

- No liquidation condition implies $r_{12} < \dfrac{R}{s}$. A sufficient condition for no liquidation is found by imposing the latter condition for the maximum possible value of r_{12}.

If $\pi(1+\beta)<1$ (r_{12} is increasing in r_{01}), then the sufficient condition for $(l=0)$ is $\frac{b+R[m+\pi(1+\beta)g]}{n\beta}<\frac{R}{s}$ which implies $s<\frac{n\beta}{m+\pi(1+\beta)g+b/R}$. If $\pi(1+\beta)>1$ (r_{12} is decreasing in r_{01}), then the sufficient condition becomes $\frac{b+R\pi(1+\beta)(g+m)}{n\beta}<\frac{R}{s}$ which implies $s<\frac{n\beta}{\pi(1+\beta)(g+m)+b/R}$. Therefore, a sufficient condition can be written as $s<\min\left\{\frac{n\beta}{m+\pi(1+\beta)g+b/R},\frac{n\beta}{\pi(1+\beta)(g+m)+b/R}\right\}$.

- The IC condition becomes $r_{12}\geq 1$. A sufficient condition can be found by checking the minimum value of r_{12}. If $\pi(1+\beta)<1$, then the sufficient condition is $\frac{b+R\pi(1+\beta)(g+m)}{n\beta}\geq 1$ which implies $R\geq\frac{n\beta-b}{\pi(1+\beta)(g+m)}$. If $\pi(1+\beta)>1$, then the sufficient condition is $\frac{b+R[m+\pi(1+\beta)g]}{n\beta}\geq 1$ which implies $R\geq\frac{n\beta-b}{m+\pi(1+\beta)g}$. Then I can write the sufficient condition as $R\geq\max\{\frac{n\beta-b}{m+\pi(1+\beta)g},\frac{n\beta-b}{\pi(1+\beta)(g+m)}\}$.

Case 1.B.3: The supply side is again at interior solution. Therefore, again $r_{01}r_{12}=r_{02}$ and (A7) must hold.

Turning to demand side problem, I have $d_{01}{}^{d}$ right corner. This implies

$$d_{12}{}^{d}>r_{01}d_{01}{}^{d}\frac{[(1-\pi)R+\pi r_{02}]}{[(1-\pi)R+\pi r_{01}r_{12}]}+\frac{\pi r_{01}[R(g+m)-mr_{02}]}{[(1-\pi)R+\pi r_{01}r_{12}]}. \tag{A11}$$

By $d_{02}{}^{d}$ right corner, $r_{02}<R$. By $d_{12}{}^{d}$ right corner, $d_{12}{}^{d}<d_{01}{}^{d}\frac{[\pi r_{02}+(1-\pi)r_{01}r_{12}]}{r_{12}}+\frac{\pi R(g+m)}{r_{12}}-\frac{m\pi r_{02}}{r_{12}}$.

(A12) Using market clearing conditions and $r_{01}r_{12}=r_{02}$, I combine (A7) with

(A11) and get $A_1 r_{12}^{\ 2} + B_1 r_{12} + C_1 > 0$ where $A_1 = \pi\beta r_{01}(mr_{01} + n)$ $\quad B_1 = (1-\pi)R\beta n - r_{01}[\pi b + Rm(1+\beta\pi) + R\pi g(1+\beta)]$ $\quad C_1 = -(1-\pi)Rb$

. Notice that the above is the same polynomial that was found in case 1.B.1, except here I have an inequality. This implies $r_{12} < r_{12}(1) = \dfrac{-B_1 - \sqrt{B_1^{\ 2} - 4A_1C_1}}{2A_1}$ or $r_{12} > r_{12}(2) = \dfrac{-B_1 + \sqrt{B_1^{\ 2} - 4A_1C_1}}{2A_1}$. Since $r_{12}(1) < 0$, only the latter condition is relevant. Therefore, case 1.B.1's r_{12} values become a lower bound for r_{12} here.

Again using market clearing conditions and $r_{01}r_{12} = r_{02}$, I combine (A7) and (A12) and get $r_{12} < \dfrac{\pi R(g+m)(1+\beta)+b}{r_{01}m[\pi(1+\beta)-1]+n\beta}$. Notice that this is the same function found in case 1.B.2, except here I have the right hand side as an upper bound for r_{12}. In summary, case 1.B.3 interest rates fill the area between rates of cases 1.B.1 and 1.B.2.

- No liquidation (NL) condition imposes a second lower bound on r_{12}: $r_{12} > \dfrac{-B_2 + \sqrt{B_2^{\ 2} - 4A_2C_2}}{2A_2}$ where $A_2 = \beta\pi s(mr_{01} + n)$, $B_2 = -\{\{\pi s[R(g+m)(1+\beta)+b] - (1-\pi)Rn\beta\} + r_{01}(1-\pi)Rm\}$ and $C_2 = -(1-\pi)Rb$. This curve intersects the first lower bound $r_{12}(2)$ at $r_{01} = s$. This implies that the condition $s < \min\left\{\dfrac{n\beta}{m+\pi(1+\beta)g + b/R}, \dfrac{n\beta}{\pi(1+\beta)(g+m)+b/R}\right\}$ is necessary for zero liquidation.

Also, I found that this curve has a smaller slope than $r_{12}(2)$. This implies that for $r_{01} < s$, NL condition binds. For $r_{01} > s$, $r_{12}(2)$ binds.

- Notice that by "$d_{12}{}^{d}$ right corner" condition, $\left(\frac{y}{x} > r_{12}\right)$. For IC condition $\left(\frac{y}{x} \geq 1\right)$ to be satisfied, a sufficient condition is $r_{12} \geq 1$. For $r_{12} \geq 1$, a sufficient condition is $b \geq n\beta$.

Case 1.C: Here, demand side is at the interior solution. Taking (A1)-(A3) as equal to zero, I find $r_{01}r_{12} = r_{02} = R$ and (A8) holds. So far, this case is the same as case 1.A. However, here the supply side resolves the indeterminacy of d_{ij}. Supply chooses $d_{01}{}^{s} = 0$ which implies $d_{02}{}^{s} = m$. By $d_{01}{}^{s} = 0$, I get

$$d_{12}{}^{s} < \frac{n\beta r_{02} - m r_{01} r_{02} - r_{01} b}{r_{01} r_{12} + \beta r_{02}}. \tag{A13}$$

By the condition $d_{12}{}^{s}$ *right corner*, I get

$$d_{12}{}^{s} < \frac{n\beta r_{12} - m r_{02} - b}{r_{12}(1+\beta)}. \tag{A14}$$

By market clearing conditions, $d_{01} = 0, d_{02} = m$. By (A8), I get $d_{12} = \frac{R\pi g}{r_{12}}$. Then, (A13) implies $r_{01} < \frac{n\beta}{m + \pi(1+\beta)g + b/R}$. (A14) implies $r_{12} > \frac{R[m + \pi(1+\beta)g] + b}{n\beta}$.

- NL condition implies $r_{12} < \frac{R}{s}$. This is possible only if $s < \frac{n\beta}{m + \pi(1+\beta)g + b/R}$.
- IC condition implies $r_{12} \geq 1$. A sufficient condition can be found by plugging in the minimum value of r_{12}: $\frac{b + R[m + \pi(1+\beta)g]}{n\beta} \geq 1$. Then, $R \geq \frac{n\beta - b}{m + \pi(1+\beta)g}$ is sufficient for IC to hold.

A.3 Proof of Proposition 3

This proposition solves for case 2 where long-term rates are larger than compounded short-term rates: $r_{01} r_{12} < r_{02}$.

Case 2.A: I start with solving the supply side problem. Taking (A6) as equal to zero, I get

$$d_{12}{}^{s} = \frac{n\beta r_{12} - mr_{02} - b}{(1+\beta)r_{12}} \quad \text{(A15)}$$

Taking (A5) as strictly less than zero (since $d_{01}{}^{s} = 0$) and combining with (A6), I get $r_{01}r_{12} < r_{02}$.

Turning to demand side problem, I take (A2) equal to zero and get $r_{02} = R$. Next, I take (A3) equal to zero and get

$$d_{01}{}^{d} = \frac{r_{12}d_{12}{}^{d} - \pi Rg}{\pi R + (1-\pi)r_{01}r_{12}}. \quad \text{(A16)}$$

Taking (A1) strictly positive and combining with (A3), I get $R > r_{01}r_{12}$.

By market clearing conditions, $d_{01} = 0, d_{02} = m$. Plugging these into (A16) and combining with (A15) and the fact that $r_{02} = R$, I get $r_{12} = \frac{R[m+\pi(1+\beta)g]+b}{n\beta}$. Then, $R > r_{01}r_{12}$ implies $r_{01} < \frac{n\beta}{m+\pi(1+\beta)g+b/R}$. Also, plugging the value of r_{12} into (A15), I get $d_{12} = \frac{n\beta\pi g}{m+\pi(1+\beta)g+b/R}$.

- NL condition implies $r_{12} < \frac{R}{s}$, which becomes $s < \frac{n\beta}{m+\pi(1+\beta)g+b/R}$.
- IC condition implies $r_{12} \geq 1$, which becomes $R \geq \frac{n\beta - b}{m+\pi(1+\beta)g}$.

Case 2.B: Since the supply side problem is the same as case 2.A, (A15) and $r_{01}r_{12} < r_{02}$ holds. Now I turn to demand side problem. Taking (A2) as equal to zero, I get $r_{02} = R$. Taking (A3) strictly positive, I get

$$d_{01}{}^{d} > \frac{r_{12}d_{12}{}^{d} - \pi Rg}{\pi R + (1-\pi)r_{01}r_{12}}. \quad \text{(A17)}$$

Taking (A1) strictly positive I get

$$d_{12}{}^{d} > \frac{d_{01}{}^{d}Rr_{01} + \pi Rgr_{01}}{\pi r_{01}r_{12} + (1-\pi)R} \quad \text{(A18)}$$

Also, combining with (A3) strictly positive, $R > r_{01}r_{12}$ is obtained.

By market clearing conditions, $d_{01} = 0, d_{02} = m$ and $r_{02} = R > r_{01}r_{12}$. Combining (A15) and (A17), I get

$$r_{12} < \frac{R[m + \pi(1+\beta)g] + b}{n\beta}. \tag{A19}$$

Combining (A15) and (A18), I get $A_3 r_{12}^{\ 2} + B_3 r_{12} + C_3 > 0$ where $A_3 = \pi n\beta r_{01}$, $B_3 = (1-\pi)Rn\beta - \pi r_{01}[mR + b + (1+\beta)Rg]$ *and* $C_3 = -(1-\pi)R(mR+b)$.

Simulation results (available from the author) show that for a wide range of parameter values, the first root $\left(\frac{-B_3 - \sqrt{B_3^{\ 2} - 4A_3C_3}}{2A_3}\right)$ is negative and the second root $\left(\frac{-B_3 + \sqrt{B_3^{\ 2} - 4A_3C_3}}{2A_3}\right)$ is positive. Therefore, the relevant condition is

$$r_{12} > \frac{-B_3 + \sqrt{B_3^{\ 2} - 4A_3C_3}}{2A_3}. \tag{A20}$$

(A19) and (A20) together determine the set of equilibrium interest rates as depicted on Figure 5. These two conditions imply that r_{12} is an increasing function of r_{01}. Also, they imply that $r_{01} < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$.

- NL condition implies $\frac{y}{x} < \frac{R}{s}$. This is very similar to the condition of "$d_{01}^{\ d}$ right corner": $\frac{y}{x} < \frac{R}{r_{01}}$. The latter condition implied (A20). The NL condition turns out to be the same as (A20) with $r_{01} = s$. That is, NL condition acts as a constant lower bound for r_{12}: $r_{12} > \dfrac{-B_4 + \sqrt{B_4^{\ 2} - 4A_4C_3}}{2A_4}$ where $A_4 = \pi n\beta s$ *and* $B_4 = (1-\pi)Rn\beta - \pi s[mR + b + (1+\beta)Rg]$. This means that

$r_{01} > s$ is a sufficient condition for NL. For $r_{01} > s$, $s < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$ is necessary.

- IC condition implies an upper bound for r_{12}: $r_{12} \le \dfrac{-B_5 + \sqrt{B_5{}^2 - 4A_5C_5}}{2A_5}$ where $A_5 = \pi n\beta,\ B_5 = (1-\pi)n\beta - \pi[mR + b + (1+\beta)Rg]\ and\ C_5 = -(1-\pi)(mR+b)$.

  This upper bound never binds (IC condition is always satisfied) if the other upper bound (A19) is always smaller than this one. This is the case if $R \ge \dfrac{n\beta - b}{m + \pi(1+\beta)g}$, which is a sufficient condition.

Case 2.C: Again, supply side problem is the same as in 2.A and 2.B. Therefore, (A15) and $r_{01}r_{12} < r_{02}$ holds.

Now I turn to demand side problem. Taking (A2) as equal to zero, I get $r_{02} = R$. Taking (A1) as equal to zero, I get

$$d_{12}{}^{d} = \frac{d_{01}{}^{d} R r_{01} + \pi R g r_{01}}{\pi r_{01} r_{12} + (1-\pi)R} \tag{A21}$$

Combining this condition with "$d_{12}{}^{d}$ right corner" (i.e. (A3) strictly positive), I get $R > r_{01}r_{12}$.

Next, market clearing conditions imply $d_{01} = 0, d_{02} = m$ and $r_{02} = R > r_{01}r_{12}$. Plugging these into (A21) and combining with (A15), I get $A_3 r_{12}{}^2 + B_3 r_{12} + C_3 = 0$. This is the same function that was found in case 2.B, although here I have equality: $r_{12} = \dfrac{-B_3 + \sqrt{B_3{}^2 - 4A_3C_3}}{2A_3}$. These conditions determine equilibrium interest rates on a curve in the space of (r_{01}, r_{12}, r_{02}) as depicted on Figure 4.

- NL condition requires $r_{01} > s$. A necessary condition for the latter is $s < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$.

- IC condition requires $r_{01} \leq R$. A sufficient condition for the latter is $R \geq \dfrac{n\beta - b}{m + \pi(1+\beta)g}$.

Case 2.D: Again, supply side problem is the same as in 2.A-2.C. Therefore, (A15) and $r_{01}r_{12} < r_{02}$ hold.

Now I turn to demand side problem. Taking (A2) as equal to zero, I get $r_{02} = R$. Taking (A1) as strictly negative, I get

$$d_{12}{}^{d} < \frac{d_{01}{}^{d} Rr_{01} + \pi Rgr_{01}}{\pi r_{01}r_{12} + (1-\pi)R}. \tag{A22}$$

Market clearing conditions imply $d_{01} = 0, d_{02} = m$, $d_{12} = \dfrac{n\beta r_{12} - mr_{02} - b}{(1+\beta)r_{12}}$ and $r_{02} = R > r_{01}r_{12}$. Using these conditions, (A3) being strictly positive implies (A19).

Combining market clearing conditions and (A22), I get $A_3 r_{12}{}^2 + B_3 r_{12} + C_3 < 0$. This is the same curve that was found in case 2.B. In this case, this curve becomes an upper bound for r_{12}. Notice that this upper bound together with $r_{01}r_{12} < R$ imply (A19). Therefore (A19) does not bind. These relationships describe an irregular set of equilibria as illustrated on Figure 6. The lower bound for r_{12} comes from the zero liquidation condition as explained below:

- No liquidation condition c12ombined with market clearing conditions implies a constant lower bound for r_{12}. This lower bound is the value of r_{12} on the same curve found in case 2.B when $r_{01} = s$. For zero liquidation, I find that $s < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$ is necessary because as s approaches the right hand side from below, r_{12} approaches $\dfrac{R[m + \pi(1+\beta)g] + b}{n\beta}$ from below.
- IC condition implies an upper bound for r_{12}. This is found from the roots of the function $A_6 r_{12}{}^2 + B_6 r_{12} + C_6 \leq 0$ where $A_6 = \pi n\beta$,

$B_6 = (1-\pi)n\beta - \pi[mR + b + (1+\beta)Rg]$ and $C_6 = -(1-\pi)(mR+b)$. This upper bounds binds if and only if $R < \dfrac{n\beta - b}{m + \pi(1+\beta)g}$. On the other hand, if $R \geq \dfrac{n\beta - b}{m + \pi(1+\beta)g}$, this upper bound does not bind.

A.4 Proof of Proposition 4

Case 3.A.1: I start with solving for the supply side. Notice that $r_{01}r_{12} > r_{02}$ implies $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$. Using this and taking (A5) as equality, I get

$$d_{12}{}^{s} = \frac{\beta r_{02}(mr_{01} + n) - r_{01}b}{r_{01}r_{12} + \beta r_{02}}. \tag{A23}$$

Using (A23) and taking (A6) strictly positive, I get $r_{01}r_{12} > r_{02}$.

Turning to demand side problem, taking (A2) strictly positive, I get $r_{02} < R$. Taking both (A1) and (A3) as equal to zero, I get $r_{01}r_{12} = R$ and

$$d_{12}{}^{d} = \frac{R(m + \pi g)}{r_{12}}. \tag{A24}$$

Market clearing conditions allow us to combine (A23) and (A24) and get

$$r_{02} = \frac{R[R(m + \pi g) + b]}{\beta(nr_{12} - \pi gR)} \tag{A25}$$

Also, notice that $r_{02} < R$ and (A25) imply $r_{12} > \dfrac{R[m + \pi(1+\beta)g] + b}{n\beta}$. As a result, $r_{01} < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$ must also hold. These relationships identify a locally unique set of equilibria as illustrated on Figures 7 and 8.

- By (A1) and (A3), zero liquidation condition implies $s < r_{01}$. Since $r_{01} < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$, a necessary condition for zero liquidation is $s < \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$.
- From demand side problem, $\dfrac{y}{x} = r_{12}$. Then, the IC condition is equivalent to $r_{12} \geq 1$. This condition binds only if the other lower bound for r_{12}, $\dfrac{R[m+\pi(1+\beta)g]+b}{n\beta}$ is smaller than 1. Therefore, the IC condition does not bind if $R \geq \dfrac{n\beta - b}{m+\pi(1+\beta)g}$. The latter condition is a sufficient one for IC.

Case 3.A.2: On the supply side, by $r_{01}r_{12} > r_{02}$, $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$. Taking (A6) as equal to zero, I get

$$d_{12}{}^{s} = \frac{\beta r_{12}(mr_{01}+n)-b}{(1+\beta)r_{12}} \tag{A26}$$

Taking (A5) strictly positive, I verify $r_{01}r_{12} > r_{02}$.

Turning to demand side, taking (A2) strictly positive, I get $r_{02} < R$. Taking (A1) and (A3) equal to zero, I get $r_{01}r_{12} = R$ and

$$d_{01}{}^{d} = \frac{r_{12}}{R} d_{12}{}^{d} - \pi g \tag{A27}$$

Market clearing conditions imply $d_{01} = m, d_{02} = 0, R > r_{02}, R = r_{01}r_{12}$. Plugging these conditions in and combining (A27) and (A26), I get $r_{12} = \dfrac{R[m+\pi(1+\beta)g]+b}{n\beta}$ and $r_{01} = \dfrac{n\beta}{m+\pi(1+\beta)g+b/R}$. Two of the three interest rates are uniquely determined. The equilibria are on the line described by $r_{02} < R$. This is illustrated on Figure 7. Also, by (A27), $d_{12} = \dfrac{R(m+\pi g)}{r_{12}}$.

- Zero liquidation condition implies $s < r_{01}$, for which a necessary and sufficient condition is $s < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$.
- IC condition holds if and only if $r_{12} \geq 1$, which holds if and only if $R \geq \dfrac{n\beta - b}{m + \pi(1+\beta)g}$.

Case 3.B.1: Supply behavior is the same as case 3.A.1. Therefore, $r_{01}r_{12} > r_{02}$, $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$ and (A23) holds.

Turning to demand side problem, by (A2) positive, I have $r_{02} < R$. Since $d_{01}{}^{d}$ is interior, (A1) is equal to zero. This implies (A9). Taking (A1) equal to zero and (A3) positive, I get $R > r_{01}r_{12}$.

By market clearing conditions, $d_{01} = m,\ d_{02} = 0,\ R > r_{01}r_{12} > r_{02}$. Plugging these into (A9), and then combining with (A23), I get

$$r_{02} = \frac{r_{01}[r_{01}r_{12}R(m+\pi g) + \phi b]}{\beta[\phi(mr_{01} + n) - r_{01}R(m+\pi g)]} \text{ where } \phi = (1-\pi)R + \pi r_{01}r_{12}. \qquad \text{(A28)}$$

Combining the market clearing condition $r_{01}r_{12} > r_{02}$ and (A28), I find the following lower bound for r_{12}: $r_{12} > r_{12}(2) = \dfrac{-B_1 + \sqrt{B_1{}^2 - 4A_1C_1}}{2A_1}$ where $A_1 = \pi\beta r_{01}(mr_{01} + n)$, $B_1 = (1-\pi)R\beta n - r_{01}[\pi b + Rm(1+\beta\pi) + R\pi g(1+\beta)]$ and $C_1 = -(1-\pi)Rb$. This lower bound is the same function that was found to be equal to r_{12} in case 1.B.1. The upper bound for r_{12} comes from $R > r_{01}r_{12}$. These conditions identify this case as depicted on Figure 8. Also, by (A9), I get $d_{12} = \dfrac{Rr_{01}(m+\pi g)}{\phi}$ where $\phi = (1-\pi)R + \pi r_{01}r_{12}$.

- The zero liquidation condition becomes $r_{01} > s$. Since $r_{01} < \frac{n\beta}{m+\pi(1+\beta)g+b/R}$, a necessary condition for zero liquidation is $s < \frac{n\beta}{m+\pi(1+\beta)g+b/R}$.
- The IC condition holds if and only if $r_{01} \le R$. Since $r_{01} < \frac{n\beta}{m+\pi(1+\beta)g+b/R}$, a sufficient condition for IC to be satisfied is $R \ge \frac{n\beta}{m+\pi(1+\beta)g+b/R}$. The latter implies $R \ge \frac{n\beta-b}{m+\pi(1+\beta)g}$.

Case 3.B.2: Supply behavior is the same as case 3.A.2. Therefore, $r_{01}r_{12} > r_{02}$, $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$. Also, taking (A6) as equal to zero, I get (A26). Taking (A5) strictly positive, I verify $r_{01}r_{12} > r_{02}$.

Turning to demand side, by (A2) positive, I have $r_{02} < R$. Since $d_{01}{}^{d}$ is interior, (A1) is equal to zero. This implies (A9). Taking (A1) equal to zero and (A3) positive, I get $R > r_{01}r_{12}$.

By market clearing conditions, $d_{01} = m,\ d_{02} = 0,\ R > r_{01}r_{12} > r_{02}$. Plugging these into (A9), and then combining with (A26), I get the same polynomial that determines r_{12} as the one found in case 1.B.1. That is, $r_{12} = r_{12}(2) = \frac{-B_1+\sqrt{B_1^2-4A_1C_1}}{2A_1}$ where $A_1 = \pi\beta r_{01}(mr_{01}+n)$, $B_1 = (1-\pi)R\beta n - r_{01}[\pi b + Rm(1+\beta\pi) + R\pi g(1+\beta)]$ and $C_1 = -(1-\pi)Rb$. The extra indeterminacy of interest rates in this case comes from the fact that I cannot determine r_{02}. I only have $r_{01}r_{12} > r_{02}$. This identifies an irregular set of equilibria as depicted on Figure 9. Also, by (A9), I get $d_{12} = \frac{Rr_{01}(m+\pi g)}{\phi}$ where $\phi = (1-\pi)R + \pi r_{01}r_{12}$.

- Zero liquidation condition is satisfied if and only if $r_{01} > s$. Since $r_{01} < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$, a necessary condition for zero liquidation is $s < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$.
- The IC condition holds if and only if $r_{01} \le R$. Since $r_{01} < \dfrac{n\beta}{m + \pi(1+\beta)g + b/R}$, a sufficient condition for IC to be satisfied is $R \ge \dfrac{n\beta - b}{m + \pi(1+\beta)g}$.

Case 3.C.1: Supply behavior is the same as case 3.A.1. Therefore, $r_{01}r_{12} > r_{02}$, $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$ and (A23) holds. Using (A23) and taking (A6) as strictly positive, I verify $r_{01}r_{12} > r_{02}$.

Turning to demand side problem, by (A2) positive, I have $r_{02} < R$. The demand side behavior is the same as case 1.B.2. Combining $d_{01}{}^{d}$ right corner and $d_{12}{}^{d}$ interior conditions, I get $R > r_{01}r_{12}$. The latter condition implies (A10).

Market clearing conditions imply $d_{01} = m, d_{02} = 0, R > r_{01}r_{12} > r_{02}$. Plugging these into (A10) and combining with (A23), I get r_{02} as a function of the other two interest rates:

$$r_{02} = \frac{r_{01}r_{12}[\pi R(g+m) + (1-\pi)mr_{01}r_{12} + b]}{\beta[r_{12}(\pi m r_{01} + n) - \pi R(g+m)]}. \tag{A29}$$

Now, I need to plug (A29) into $r_{01}r_{12} > r_{02}$. When I do, I get a lower bound for r_{12}; $r_{12} > \dfrac{\pi R(g+m)(1+\beta) + b}{r_{01}m[\pi(1+\beta) - 1] + n\beta}$. Notice that the lower bound above is what I found as the value of r_{12} in case 1.B.2. The upper bound for r_{12} comes from two sources: $R > r_{01}r_{12}$ and the zero liquidation condition. Also, by (A10) and market clearing conditions, I get $d_{12} = \dfrac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$.

- Zero liquidation condition is satisfied if and only if $r_{12} < \frac{R}{s}$. A necessary condition for the latter condition is $s < \min\left\{ \frac{n\beta}{m + \pi(1+\beta)g + b/R}, \frac{n\beta}{\pi(1+\beta)(g+m) + b/R} \right\}$ since $r_{12} > \min\left\{ \frac{R[m + \pi(1+\beta)g] + b}{n\beta}, \frac{R\pi(1+\beta)(g+m) + b}{n\beta} \right\}$ in this case.
- The IC condition is satisfied if and only if $r_{12} \geq 1$. Since $r_{12} > \min\left\{ \frac{R[m + \pi(1+\beta)g] + b}{n\beta}, \frac{R\pi(1+\beta)(g+m) + b}{n\beta} \right\}$, a sufficient condition for the IC condition is $R \geq \max\left\{ \frac{n\beta - b}{m + \pi(1+\beta)g}, \frac{n\beta - b}{\pi(1+\beta)(g+m)} \right\}$.

Case 3.C.2: Supply behavior is the same as case 3.A.2. Therefore, $r_{01}r_{12} > r_{02}$, $d_{01}{}^{s} = m, d_{02}{}^{s} = 0$. Also, taking (A6) as equal to zero, I get (A26). Taking (A5) strictly positive, I verify $r_{01}r_{12} > r_{02}$.

The demand side behavior is the same as case 1.B.2. Taking (A2) strictly positive, I get $r_{02} < R$. Combining $d_{01}{}^{d}$ right corner and $d_{12}{}^{d}$ interior conditions, I get $R > r_{01}r_{12}$. Taking (A3) equal to zero implies (A10).

Market clearing conditions imply $d_{01} = m, d_{02} = 0, R > r_{01}r_{12} > r_{02}$. Plugging these into (A10) and combining with (A26), I get $r_{12} = \frac{\pi R(g+m)(1+\beta) + b}{r_{01}m[\pi(1+\beta) - 1] + n\beta}$. This is the same curve found in case 1.B.2. The only difference with that case is the fact that r_{02} is not determined here; $r_{01}r_{12} > r_{02}$. These conditions identify this case as a set of irregular equilibria depicted on Figure 11. Also, by (A10) and market clearing conditions, I get $d_{12} = \frac{\pi R(g+m)}{r_{12}} + (1-\pi)mr_{01}$.

- Zero liquidation condition is satisfied if and only if $r_{12} < \frac{R}{s}$. Since $r_{12} > \min\left\{\frac{R[m+\pi(1+\beta)g]+b}{n\beta}, \frac{R\pi(1+\beta)(g+m)+b}{n\beta}\right\}$, a necessary condition for zero liquidation is $R \geq \max\left\{\frac{n\beta - b}{m+\pi(1+\beta)g}, \frac{n\beta - b}{\pi(1+\beta)(g+m)}\right\}$.
- The IC condition is satisfied if and only if $r_{12} \geq 1$. Since $r_{12} > \min\left\{\frac{R[m+\pi(1+\beta)g]+b}{n\beta}, \frac{R\pi(1+\beta)(g+m)+b}{n\beta}\right\}$, a sufficient condition for the IC condition is $R \geq \max\left\{\frac{n\beta - b}{m+\pi(1+\beta)g}, \frac{n\beta - b}{\pi(1+\beta)(g+m)}\right\}$.

A.5 Proofs of Illiquidity of Case 3 Equilibria

For cases 3.A.1 and 3.A.2, $x = r_{01}g$. Illiquidity condition (15) holds if and only if $r_{01} \geq s$, which had already been assumed by no liquidation assumption, $r_{01} > s$ (assumption 1). Therefore all equilibria are illiquid in these cases.

For cases 3.B.1 and 3.B.2, (15) implies

$$r_{01}\{\frac{R}{\phi}g + [1+\frac{1}{\pi}(\frac{R}{\phi}-1)]m\} \geq s(g+m) \tag{A7}$$

where $\phi = (1-\pi)R + \pi r_{01}r_{12}$. Notice that since $r_{01}r_{12} < R$, $\frac{R}{\phi} > 1$. Also, $1+\frac{1}{\pi}(\frac{R}{\phi}-1) > 1$. Therefore, the left hand side of (A7) is larger than $r_{01}(g+m)$. Since $r_{01} > s$, by no liquidation assumption, (A7) is satisfied for all equilibria in these cases. In fact, I have just shown that in these cases, banks are *more vulnerable* than in cases 3.A.1 and 3.A.2. This is because the left hand side which indicates banks' liabilities is larger.

For cases 3.C.1 and 3.C.2, illiquidity condition implies $\frac{R}{s} \geq r_{12}$, which is already satisfied by the previously derived conditions $r_{01} > s$ and $r_{01}r_{12} < R$. Therefore, all equilibria in case 3 are illiquid.

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