ABSTRACT

Title of dissertation:	BORROWING CONSTRAINTS AND THE BUSINESS CYCLE IN EMERGING MARKETS
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The global financial crisis of 2008/09 has reminded both policymakers and academics of the powerful effect of sudden changes in the direction of capital flows. A tightening of borrowing constraints was an important contributor to these sudden changes and forced many borrowers into rapid deleveraging. Based on their experience in the 1990s, a number of emerging market economies had prepared for such shocks by accumulating foreign reserves. This dissertation analyzes the effects of such credit shocks and the optimal precautionary response in emerging economies.

Chapter 1 is a brief introduction that motivates the topic and overviews main results of the subsequent chapters.

Chapter 2 takes the view of a small open economy. It develops a formal model of why emerging markets simultaneously hold external debt and external reserves. Reserves may be held simultaneously with debt even when their return is lower because they are valuable for self-insurance. Two key assumptions generate this finding. First, the economy may experience a sudden stop in its access to new foreign

debt issuance. Second, debt has longer maturity than reserves. When a sudden stop occurs, the maturity difference allows the agent to repay the debt gradually, giving a liquidity advantage to reserves. I numerically show that the model economy optimally chooses simultaneous holding for most periods. The model also generates contrasting responses of reserves to the sudden stop shock and the endowment shock, consistent with the data.

Chapter 3 takes the view of a firm in an emerging economy. It investigates the relationship between credit shocks and firm financing patterns. After empirically establishing that banking crises are followed by stagnation in credit and that investment is financed less by debt and more by internal fund or equity at the time of banking crises, I develop a dynamic model of the firm consistent with this finding. In the model, the firm increases its reliance on retained earnings or equity issuance in response to a negative credit shock. In the long-run distribution, the introduction of a credit shock leads to a lower average debt and higher volatility in equity payout, debt, and capital. An extended period of negative credit shocks leads to a creditless recovery where investment is financed not by debt but by retained earnings or equity issuance.

BORROWING CONSTRAINTS AND THE BUSINESS CYCLE IN EMERGING MARKETS

by

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Dedication

To my parents.

Acknowledgments

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Chapter 1

Introduction

The global financial crisis of 2008/09 has reminded both policymakers and academics of the powerful effect of sudden changes in the direction of capital flows. A tightening of borrowing constraints was an important contributor to these sudden changes and forced many borrowers into rapid deleveraging. Based on their experience in the 1990s, a number of emerging market economies had prepared for such shocks by accumulating foreign reserves. This dissertation analyzes the effects of such credit shocks and the optimal precautionary response in emerging economies.

1.1 Small Open Economies and Credit Shocks

Chapter 2 models a small open economy. Distinct features of this model are that it distinguishes between external reserves and external debt, and that the model includes an exogenous credit shock. I use this model to analyze external balance sheet adjustments of a small open economy. An important result is that the model can rationalize that emerging market economies simultaneously hold external reserves and external debt. The simultaneous holding of exernal reserves and external debt is a prominent feature of external balance sheets of emerging markets (Lane and Milesi-Ferretti, 2007), yet it is a puzzle because given the interest rate difference between the saving interest and borrowing interest rate it is costly (Rodrik, 2006 and Stiglitz, 2006). The chapter shows that two assumptions are crucial to generating this simultaneous holding result. First, the economy may experience a sudden stop in its access to new foreign debt issuance. Second, debt has longer maturity than reserves. Under these assumptions, when a sudden stop occurs, the maturity difference allows the agent to repay the debt gradually, giving a liquidity advantage to reserves. I calibrate the model to a sample of emerging markets and compare the model performance to the data. The model economy optimally chooses simultaneous holding for most periods. The model also generates contrasting responses of reserves to the sudden stop shock and the endowment shock, consistent with the data. Reservers decrease sharplly in response to a sudden stop shock, but it does not in response to a negative endowment shock.

1.2 Firms and Credit Shocks

Chapter 3 analyzes the effect of credit shock on firm's choice of investment, debt issuance, and equity payout. First the chapter shows stylized facts on the relationship between business cycle and credit. Using aggregate data I confirm that banking crisis incidence leads to stagnant credit developments in the subsequent years. At the firm level, I show that firms that are located in the countries that are experiencing banking crises tend to rely less on bank financing and more on other sources, such as retained earnings or equity issuance. Using a firm level survey for a broad range of emerging markets and developing economies, I show that firms experiencing banking crises have lower proportion of bank financing and higher proportion of equity financing/owner's self financing of fixed asset investment. Then I use a dynamic model of the firm consistent with these stylized facts. Main departure from existing models is that the credit shock is included. I show analytical results on substitution of financing sources in response to a credit shock. Simulated long-run distribution of the firm shows that the introduction of the credit shock leads to a much lower average debt and higher volatility in equity payout, debt, and capital. I also show that that the firm can recover its output after the initial shock in response to extended periods of negative credit shocks. Thus this model can replicate "creditless recovery" phenomenon, a recovery in output after financial crises without an accompanying recovery in credit, observed for both emerging markets and industrial economies but especially strong for the former.

Chapter 2

Sudden Stops and External Balance Sheet Management in Emerging Markets

2.1 Introduction

Emerging market economies simultaneously hold external reserves and external debt. Figure 2.1 shows the reserves to GDP ratio and gross debt to GDP ratio for 15 emerging market economies in 2007.[1] All countries hold a substantial level of reserves while retaining a positive level of debt. This appears to be an inefficient use of resouces because emerging markets generally face higher borrowing interest rates than lending interest rates in the international financial market.

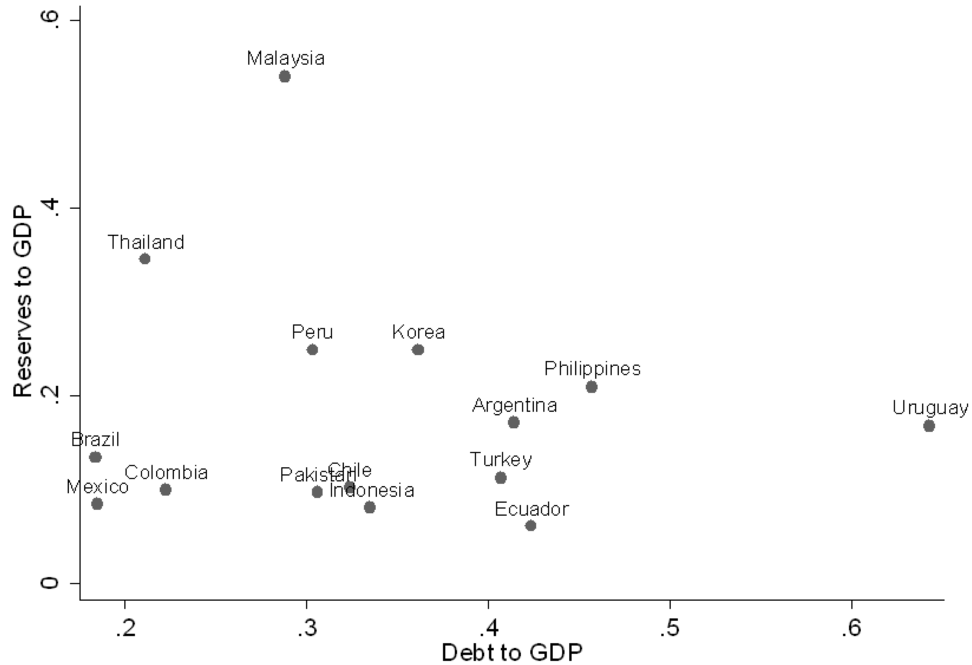
Academic literature has paid a lot of attention to the asset side of emerging markets' external balance sheet, i.e. the surge in international reserves.[2] The concurrent question of why they accumulate reserves and debt simultaneously has been less explored and has not been formally modeled, however.[3] Rodrik (2006) and Stiglitz (2006) point out that the accumulation of low-yielding international reserves

[1]The sample consists of countries that experienced the sudden stop of capital flows in the 1990's and early 2000's, excluding Hong Kong. This sample is used later in the quantitative analysis. The appendix lists data sources.

[2]An incomplete list includes Aizenman and Lee (2007), Rodrik (2006), Durdu, Mendoza, and Terrones (2009), Obstfeld, Shambaugh, and Taylor (2010), Jeanne (2007), Jeanne and Ranciere (2009), Caballero, Farhi, and Gourinchas (2008), Mendoza, Quadrini, and Rios-Rull (2009), and Devereux and Sutherland (2009), and Korinek and Luis (2010).

[3]One of the only papers that attempt to study the simultaneous holding of the reserves and external debt is Alfaro and Kanczuk (2009). In their model, the distinction between reserves and debt is default risk. They find that it is never optimal to hold reserves and debt simultaneously, contradicting the evidence presented in figure 2.1.

Figure 2.1: Emerging Markets' Reserves and Gross External Debt



by emerging markets entails large opportunity costs, but do not rationalize it by a formal model. The vast majority of open economy models do not make a distinction between reserves and debt but track only net foreign assets. I take a first step in modeling this simultaneous holding.

I study a small open economy that models differences between reserves and external debt in the emerging markets. First, I assume that the economy's ability to issue new debt may suddenly be lost exogenously (henceforth called a sudden stop). This assumption captures experiences of emerging market countries that suffered the sudden stop of external capital inflows. Second, I assume that reserves have shorter maturity than debt. This assumption captures the fact that a large part of emerging markets' reserves are held in the form of U.S. Treasury debts, which have a deep and liquid secondary market that continues to function even during financial crises.[4]

These assumptions motivate the economy to hold reserves alongside debt for liquidity purposes. When an economy incurs the sudden stop, it cannot smooth consumption by issuing new external debt. Having set aside reserves in advance is beneficial in this context. On the one hand, the economy can repatriate both principal and interest from the reserves even during the sudden stop. On the other hand, only a fraction of existing debt stock has to be repaid each period. Thus reserves holding financed by debt creates a source of self-insurance against the sudden stop because of the difference in maturities between the reserves and debt. This reserve accumulation can be interpreted as holding of an asset with high market liquidity as insurance against debt with an occasional funding liquidity problem.[5]

I find that my model generates simultaneous holding of reserves and debt in equilibrium. The model's decision rule is similar to the standard model when the optimal portfolio choice results in a strong net foreign asset position. In this case, the agent chooses zero debt and generates positive reserves. When the optimal portfolio choice results in a weak net foreign asset position, however, the decision rule differs from that in the standard model. In the standard precautionary model, the agent would choose a positive level of debt with no reserves. In my model, in contrast, the agent would maintain reserves along with debt. Moreover, a choice of higher debt is accompanied by higher reserve holding because higher debt risks

[4]Krishnamurthy and Vissing-Jorgenssen (2010) present empirical evidence on the special role of U.S. Treasury bonds as liquidity provider.

[5]Market liquidity refers to the ease with which an asset an agent holds can be sold, and funding liquidity refers to the ease with which an agent can issue new debt. See Brunnermeier and Pedersen (2008) and IMF (2008) for further description.

larger capital outflow if no new borrowing is allowed next period.

For sensitivity analysis, I first vary two parameters in the model, namely, the interest rate spread and the probability of the sudden stop. The size of the simultaneous holding is inversely related to the interest rate spread. A higher probability of the sudden stop results in a higher level of reserves per unit of debt on the one hand, but deters debt holding on the other hand because the need for higher reserves increases the cost of debt. Second, I endogenize of the probability of the sudden stop by making it a decreasing function of the reserve to short-term debt ratio. This results in the optimal reserves and debt varying little compared with the benchmark case. This result is in contrast with that in Jeanne and Ranciere (2009), who find that the optimal reserves generally increase when the sudden stop probability is a decreasing function of the reserve to short-term debt ratio. The reason for the difference is because my model features occasionally-binding constraints, leading to accumulation of reserves financed by debt issuance during non-sudden stop periods.

Comparison of numerical results from the model with data from a sample of emerging markets provides us with a sense of the quantitative fit of the model. I find that both the model and the data show constrasting responses to different types of shocks. The economy uses up reserves in response to the sudden stop shock, but does not do so in response to a low endowment shock. When I compare the size of the responses and the ergodic distribution, however, I find that the volatility of reserves and debt relative to endowment volatility is much higher in the model than in the data.

The first contribution of this paper is to develop a formal model of why emerging markets simultaneously hold external debt and external reserves. In particular, my model generates a substantial level of simultaneous holding of reserves and debt for reasonable parameters, the first to do so. My model also generates adjustments of external balance sheets in response to sudden stop and endowment shocks that are consistent with data.

2.1.1 Literature Review

This paper generates the holding of liquid, return-dominated short-term assets by assuming different liquidity properties among assets and a liquidity shock. In this sense, my model is closest in spirit to Kiyotaki and Moore (2008). They construct a closed-economy general equilibrium model that endogenously generates money holding as insurance against market illiquidity of existing equity and funding illiquidity of new equity issuance. When constraints on equity financing are sufficiently stringent, entrepreneurs obtain money when they do not have investment opportunities to be used when they have investment opportunities in the future. While their model and mine have common characteristics as mentioned above, there are also important differences. First, asset prices are endogenously determined and the holding of liquidity is endogenously generated in their closed-economy setting. In my model, the small open economy takes the price of both assets as given. The implied assumption is that the emerging markets are small players in both international saving and borrowing. Second, they limit their focus around the steady state, resulting in an always binding constraint, whereas my study allows for an occasionally-binding constraint and numrically solves the problem by a global approximation method.

There are a small number of papers that model endogenous choice of multiple assets. Alfaro and Kanczuk (2009) construct a small open economy model with risk-free reserves and defautable debt. They assume that the sovereign can retain reserves even when it defaults, giving the reserves a consumption-smoothing role when access to new borrowing is curtailed after defaults. However, this benefit of reserves conflicts with the incentive to repay the defaultable debt, making debt more expensive because the probability of default increases with reserves. In the end, the optimal choice in their model is to hold no reserves for reasonable parameter values. Their model and mine differ in what is modeled as the difference between emerging economies' reserves and debt. They assume differences in default risk, while we model differences in liquidity. Our model generates co-existence of saving and debt for reasonable parameter values. Gamba and Triantis (2008) construct a dynamic model of a firm that separately chooses one-period saving and issuance of a consol bond. Their interest is in modeling optimal cash retention coexisting with debt to obtain "financial flexibility". Retaining cash helps the firm adjust flexibly in response to exogenous productivity shocks when debt and equity issuance entails transaction costs and physical capital is not perfectly irreversible. It also helps avoiding financial distress when productivity is low and the firm is highly leveraged. Both of these models feature a liquid asset coexisting with other assets because of the costs and restrictions on financing with the other assets as in my model, but neither involves a liquidity shock. Telyukova and Wright (2008) rationalize households' simultaneous holding of liquid saving and credit card debt by extending the search model of money. In their model, there are three segmented markets. In addition to the centralized Walrasian market and decentralized market with search frictions and agents' anonymity, which makes money essential as means of payments, there is a third market in which there are search frictions but there is no anonymity. An agent can make payment by either debt or money in this third market. Knowing the future need in the decentralized market, the agent chooses to make payments by debt and preserves money holding. As a result, money saving and debt optimally coexist in the households' balance sheets. While their model emphasizes market segmentation, my model emphasizes the liquidity shock. My model could be an alternative explanation of simultaneous holding of households' saving and debt if shocks to access to new borrowing are important for households' portfolio decisions.

As stated in introduction, there is a long list of papers that studies reserve accumulation by the emerging market economies. This study is most closely related to those that explore the issue using a small open economy model with financial frictions. Jeanne and Ranciere (2009) construct a stylized model in order to obtain a formula for the optimal reserve level against sudden stops where the debt level, insurance premium and probability of a sudden stop are exogenously given. My model does not take the debt level as given, but jointly determines reserves and debt while allowing for occasionally binding constraints. This feature in particular leads to a different result than their model in the extension of the model that endogenizes the probability of sudden stops. Durdu, Mendoza, and Terrones (2009) measure the effect of business cycle volatility, financial globalization, and sudden stops on reserve accumulation in the context of small open economy model with financial frictions. Their model tracks only net foreign assets, and their measure of reserve accumulation is the level of precautionary saving or the difference in the level of net foreign assets between different setups of the model. The emphasis in our model is separation and joint determination of saving and debt.

A number of multi-country general equilibrium models, such as Caballero, Farhi, and Gourinchas (2008), Mendoza, Quadrini, and Rios-Rull (2009), and Devereux and Sutherland (2009) endogenously generate emerging market economies holding debts issued by industrial economies. They all assume some kind of asymmetry in financial development between industrial economies and developing economies to obtain this result. The current study has a different focus than theirs. While they are interested in trends of global financial imbalances due to structural properties of domestic or international financial markets, I focus on business cycle movements by comparing filtered data and simulation results from the model that does not include trends.

The rest of the paper is organized as follows. Section 2 presents the model and describes the conditions for simultaneous holding of reserves and debt. Section 3 summarizes the calibration and numerical solution method. Section 4 describes the decision rule. Section 5 compares the model with data. Section 6 describes extensions of the model. Section 7 concludes.

2.2 The Model

2.2.1 Problem

The main features of our model are the following.

- There is an infinitely lived risk-averse representative agent subject to an endowment shock and an exogenous shock that prohibits new borrowing.
- Agents smooth consumption using non-state contingent reserves and debt, whose prices are determined in the international financial market.
- Debt has a longer maturity and higher return than reserves.

The model's assumptions on the differences between reserves and debt reflect the asymmetric environment that emerging markets' reserves and debt face. A substantial part of emerging markets' reserves is invested in industrial economies' sovereign bonds, inter alia, U.S. Treasury Bonds. The U.S. Treasury Bond market is deep and liquid, and continues to function with low transaction costs through times of financial crises in emerging markets. This constitutes the basis for the different maturity assumption. Regarding the emerging market economies's debt, they periodically face periods in which they find it difficult to issue new bonds. Thus my model focuses on liquidity as the distinction between the saving and debt instruments of the emerging economies. These differences in liquidity are reflected in the different interest rates between the reserves and the debt.[6]

[6] There is also a technical reason for the assumption of the difference in interest rates. In the stochastic endowment economy with incomplete financial market for consumption smoothing, assuming $\beta(1 + r^s) = 1$ where r^s the saving interest rate results in non-stationarity of the model. I avoid this by assuming $\beta(1 + r^s) < 1$. See Chamberlain and Wilson (2000).

These assumptions differ from other papers. Alfaro and Kanczuk (2009) consider default as the distinguishing feature between reserves and debt. Jeanne and Ranciere (2009) assume that reserves are an insurance contract with net insurance payment at the time of the sudden stop.

The model is formally expressed as the following.

$$\max_{c_t, a_{t+1}, b_{t+1}} E \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{2.1}$$

s.t.

$$c_t = y_t + (1+r^s)a_t - a_{t+1} - (1+r)b_t + b_{t+1} - A \tag{2.2}$$

$$b_{t+1} \leq \begin{cases} (1-\lambda)b_t & \text{if } \overline{b_t} = 0, \\ \\ b^h & \text{if } \overline{b_t} = 1 \end{cases} \tag{2.3}$$

$$a_{t+1} \geq 0 \tag{2.4}$$

$$b_{t+1} \geq 0 \tag{2.5}$$

The inclusion of A, exogenously given absorption to take account of government expenditure and investment missing in the model, follows Durdu et al. (2009). The assumption of the interest rate spread and the need to ensure stationarity of the model leads β, r^s, r to satisfy the conditions $r^s < r$, $\beta(1+r) = 1$. For the utility function, we assume

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$

The exogenous shocks are modeled as the following.

- Endowment shock

$$\ln(y') = \rho_y \ln(y) + \epsilon_y \tag{2.6}$$

- The borrowing limit takes two discrete values $\overline{b_t} \in [0, 1]$, with transition matrix

$$\begin{bmatrix} P_{ll} & P_{lh} \\ P_{hl} & P_{hh} \end{bmatrix} \tag{2.7}$$

$\overline{b_t}$ is a shock to access to new borrowing. It takes two values, 1 and 0. If $\overline{b_t} = 1$, the agent can issue new debt freely subject only to conditions that are non-binding in equilibrium, analogous to the natural debt limit modified to reflect the possibility of sudden stop next period.[7] If $\overline{b_t} = 0$, the agent cannot obtain any new borrowing. This, however, does not mean $b_{t+1} = 0$. Only the fraction λ of the current debt stock has to be repaid, and the agent can maintain the rest of the debt stock. We will see that this maturity difference generates simultaneous holding of reserves and debt. In the special case $\lambda = 1$, the two debt constraints are equivalent and the model is reduced to the one-period debt case. In another special case to the other direction, $\lambda = 0$, the debt is a consol bond.

[7] In Aiyagari (1994), a risk-averse agent that has perfect access to risk-free asset every period faces the debt limit that ensures repayment with non-negative consumption even if the agent faces the worst endowment indefinitely. This is called the natural debt limit. Taking into account the interest rate spread, the natural debt limit in my model is $b_t \leq \frac{\underline{y} - A}{r} + \frac{1+r^s}{1+r} a_t + (\frac{1+r^s}{1+r} - 1) \sum_{i=1}^{\infty} (\frac{1}{1+r})^i a_{t+i}$. My model requires an additional debt limit. An agent faces the debt limit that ensures repayment with non-negative consumption even if the agent faces the worst endowment and the sudden stop next period. This gives the debt limit $b_t \leq \frac{\underline{y} + (1+r^s) a_t - A}{r + \lambda}$.

I can recursively express the problem as the following.

$$V(a,b;y,\overline{b}) = \max_{a',b',c} \left\{ u(c) + \beta E(V(a',b';y',\overline{b'}) \right\} \tag{2.8}$$

The first-order conditions are the following.[8] μ, ψ, η^a, η^b are Lagrange multipliers for (2.2), (2.3), (2.4), (2.5), respectively.

$$\beta E V_1(a',b',y',\overline{b'}) - \mu + \eta^a = 0 \tag{2.9}$$

$$\beta E V_2(a',b',y',\overline{b'}) + \mu + \eta^b - \psi = 0 \tag{2.10}$$

The envelope conditions are the following:

$$V_1(a,b;y,\overline{b}) = (1+r^s)\mu \tag{2.11}$$

$$V_2(a,b;y,\overline{b}) = -(1+r)\mu + \psi I \tag{2.12}$$

where I is an indicator function

$$I = \begin{cases} 0 & \text{if } \overline{b_t} = 1, \\ (1-\lambda) & \text{if } \overline{b_t} = 0 \end{cases} \tag{2.13}$$

[8]The appendix describes the detailed derivation.

Combining the above optimality conditions, we obtain the following.

$$u'(c) = \beta(1 + r^s)Eu'(c') + \eta^a \tag{2.14}$$

$$u'(c) + (\eta^b - \psi) = \beta(1 + r)Eu'(c') - \beta E\psi' I' \tag{2.15}$$

(2.14) and (3.13) are the Euler equations for reserves and debt, respectively.

Equilibrium 1. *Prices* $\{r^s, r\}$*, allocations* $\{c_t, a_t, b_t\}_{t=0}^{\infty}$ *and exogenous shocks* $\{y_t, \overline{b_t}\}_{t=0}^{\infty}$ *are such that:*

(i) given $\{r^s, r\}$ *and* $\{y_t, \overline{b_t}\}_{t=0}^{\infty}$*,* $\{c_t, a_t, b_t\}_{t=0}^{\infty}$ *solve the representative agent's optimization problem.*

2.2.2 Characterization of Solution (Perfect Foresight Version)

I first describe the model dynamics using the perfect foresight version of the model. I use the perfect foresight version because our results on the conditions for the simultaneous holding of reserves and debt carry over to the stochastic version, and because the perfect foresight version allows me to illustrate more clearly the different portfolio adjustments with and without sudden stops.

Below I show that both the existence of the sudden stop and the maturity difference between reserves and debt are necessary in order for the economy to optimally choose simultaneous holding. I first show the analytical results and then describe them in the context of a general description of the optimal decision rule.

2.2.2.1 Endowment Shock Only

As a benchmark, suppose that there is no shock to borrowing. Then the Euler equations are the following.

$$\frac{u'(c_t)}{\beta u'(c_{t+1})} = 1 + r^s + \frac{\eta_t^a}{\beta u'(c_{t+1})} \tag{2.16}$$

$$\frac{u'(c_t)}{\beta u'(c_{t+1})} = 1 + r - \frac{\eta_t^b}{\beta u'(c_{t+1})} \tag{2.17}$$

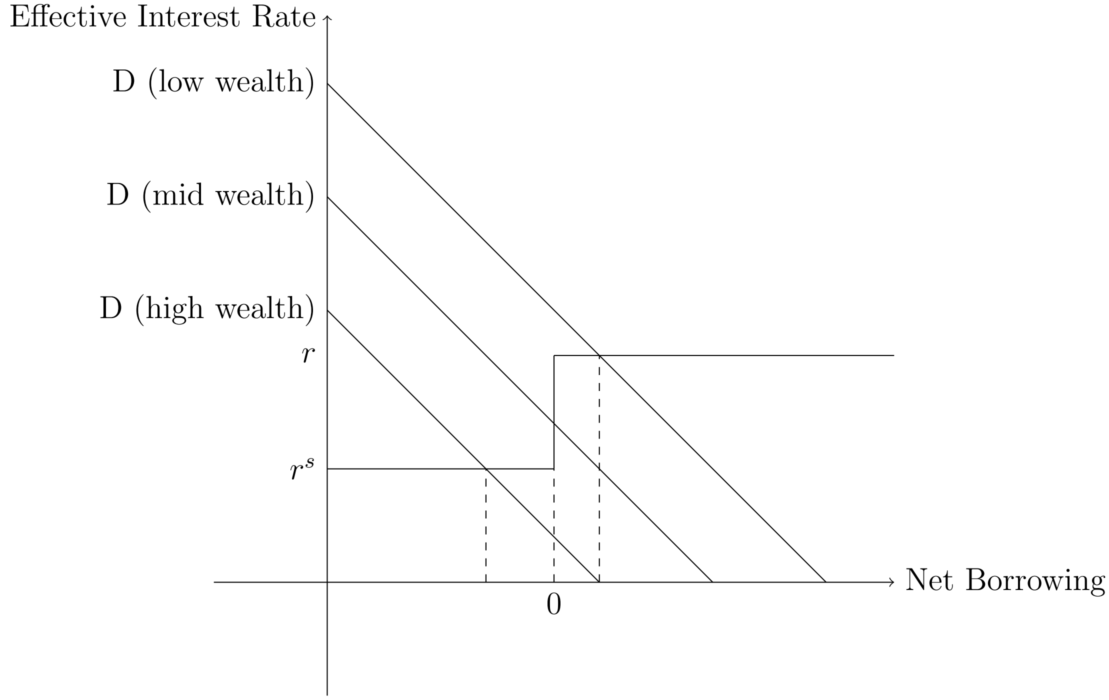
The optimal level of reserves and debt are determined so that the effective interest rates from (2.16) and (2.17) are equalized. The following proposition is obtained from these Euler equations.

Proposition 1 (No simultaneous holding with endowment shock only). *If the endowment shock is the only exogenous shock, the economy never chooses to hold reserves and debt simulataneously.*

Proof. Set $\eta_t^a = \eta_t^b = 0$. Then the system of equations (2.16) and (2.17) do not have a solution. □

When there is no sudden stop shock, the simultaneous holding of reserves and debt would just result in the opportunity cost due to $r^s < r$ without any apparent benefit. Thus the economy never chooses it. For high wealth (high initial net assets and high current period endowment), the economy chooses $a_{t+1} > 0$, $b_{t+1} = 0$. In this case, $\eta_t^a = 0$, $\eta_t^b > 0$, and the effective interest rate for the economy is r^s. For low wealth (low initial net assets and low current period endowment), the economy chooses $a_{t+1} = 0$, $b_{t+1} > 0$. In this case, $\eta_t^a > 0$, $\eta_t^b = 0$, and the effective interest

Figure 2.2: Supply and Demand for Borrowing



rate for the economy is r. Reflecting the opportunity cost of reserve holding, there is an intermediate region in which the economy chooses $a_{t+1} = 0$, $b_{t+1} = 0$. The effective interest rate for the economy is between r^s and r. Figure 2.2 illustrates the three cases.

In the special case $r = r^s$, the optimal portfolio is indeterminate. The model in fact reduces to a standard saving problem. This suggests that when there is only the endowment shock, there is little point in distinguishing between reserves and debt.

2.2.2.2 Introduction of Sudden Stop Shock

The Euler equations are the following.

$$\frac{u'(c_t)}{\beta u'(c_{t+1})} = 1 + r^s + \frac{\eta_t^a}{\beta u'(c_{t+1})} \tag{2.18}$$

$$\frac{u'(c_t)}{\beta u'(c_{t+1})} = 1 + r - \frac{\beta \psi_{t+1}(1-\lambda) - \psi_t + \eta_t^b}{\beta u'(c_{t+1})} \tag{2.19}$$

Again the optimal level of reserves and debt are determined so that the effective interest rates from (2.18) and (2.19) are equalized. The following proposition is obtained.

Proposition 2 (**Simultaneous holding with binding next period sudden stop**). *If $\lambda < 1$ and the economy faces both the endowment shock and the sudden stop shock, the economy may choose to hold reserves and debt simultaneously only if the borrowing constraint from the next period sudden stop shock is binding.*

Proof. Suppose that the next period borrowing constraint is not binding. Then $\psi_{t+1} = 0$. If we also assume $\eta_t^a = \eta_t^b = 0$, the system of equations (2.18) and (2.19) does not have a solution. The system of equations could possibly have a solution with $\eta_t^a = \eta_t^b = 0$ only when the third term in (2.19) is positive, which requires $\psi_{t+1} > 0$. □

When the next period borrowing constraint is binding, the economy cannot borrow as much as it would like next period. In that case, it is sometimes beneficial for the economy to borrow in long-term debt and allocate resources to short-term reserves. The fact that the entire reserves will be available next period while the debt has to be repaid only partially helps smooth consumption the next period. The economy thus has an incentive to borrow and simultaneously save in one-period saving as self-insurance.

Given there is a sudden stop next period, when does it actually bind? It binds when the current period states are unfavorable, which leads the economy to choose low net foreign assets at the start of next period. In this case, choosing $a_{t+1} = 0$, $b_{t+1} > 0$ as in the endowment shock only case could lead to a sharp decrease in the next period consumption due to the sudden stop. Choosing $a_{t+1} > 0$, $b_{t+1} > 0$ would mitigate the effect. Solutions to (2.18) and (2.19) exist for $\eta_t^a = 0$, $\eta_t^b = 0$ and the effective interest rate is $1+r^s$. In contrast, when the current period states allow the economy to choose a strong net foreign asset position at the start of next period, $a_{t+1} > 0$, $b_{t+1} = 0$ continues to be optimal, as in the endowment shock only case. Even if there is a sudden stop next period, running down the reserves is sufficient for consumption smoothing. If the economy experiences the binding sudden stop both in the current period and the next period, the incentive for reserve accumulation is lessened everything else being constant. In this case, $\psi_t > 0$ implies that the relative price of current period consumption is high, leading to an increase in the effective interest rate in terms of (2.19). Then the system of equations (2.18) and (2.19) is more likely to be solved by $a_{t+1} = 0$, $\eta_{t+1}^a > 0$ and an effective interest rate higher than $1 + r^s$.

When borrowing is allowed next period or when the sudden stop shock is not binding, the economy would not choose to simultaneously hold reserves and debt. This is apparent because in this case the system of equations (2.18) and (2.19) again would not have a solution with $\eta_t^a = \eta_t^b = 0$. When the borrowing constraint does not bind next period, allowing for partial repayment of debt does not hold any extra value.

Even if the economy faces the risk of sudden stops, there will be no simultaneous holding if reserves and debt have the same maturity ($\lambda = 1$). Because the debt does not provide a liquidity advantage during the sudden stop, there is no incentive for the economy to maintain debt and invest in reserves at the same time. This result confirms that both the sudden stop and the difference in maturity are required to generate simultaneous holding.

Proposition 3 (**No simultaneous holding with same maturity**). *If* $\lambda = 1$, *there will be no simultaneous holding even if the economy faces both an endowment shock and the sudden stop shock.*

Proof. Set $\lambda = 1$. Then the system of equations (2.18) and (2.19) does not have a solution for $\eta_t^a = \eta_t^b = 0$. $\square$

2.2.2.3 Numerical example

I graphically illustrate and contrast results from the model with and without sudden stop shocks. I consider a perfect-foresight economy with exogenous shocks to endowments and to access to external borrowing. In the numerical examples below, the economy starts with initial reserves $a_0 = 0.04$ and initial debt $b_0 = 0.3$. The endowment is either $y^h = 1.1$ or $y^l = 0.9$. The reserve interest rate is $r^s = 0.032$, borrowing interest rate is $r = 0.052$, and β is set to satisfy $\beta(1 + r) = 1$. $\lambda = 0.2$

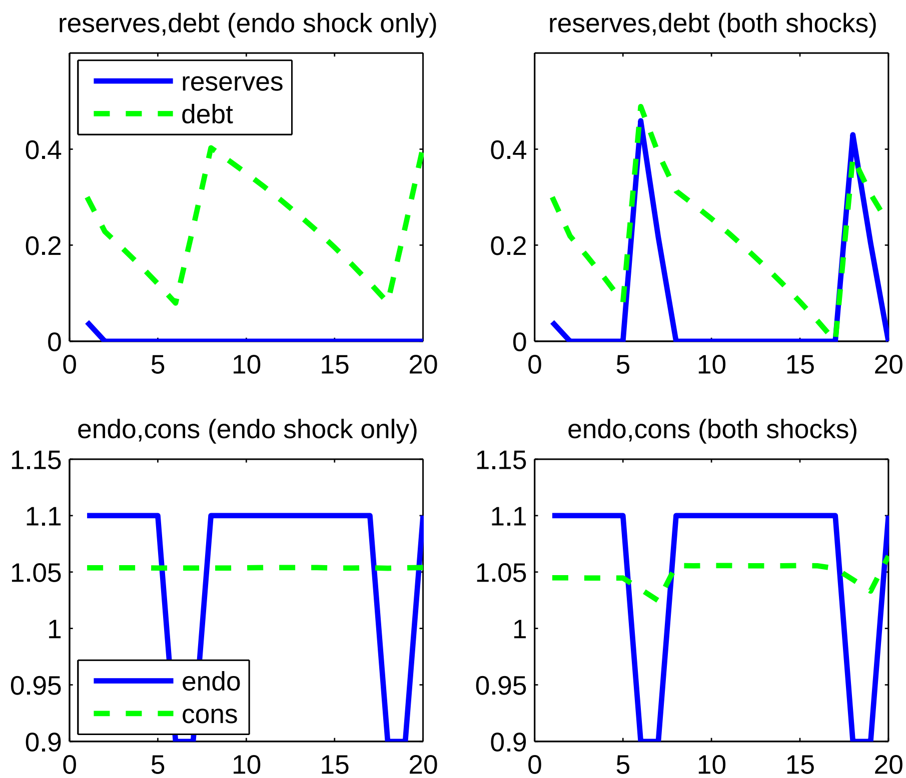
implies 20 percent of the principal of current period debt has to repaid next period. The limit to external debt $\bar{b}_t$ takes two values, 0 or 1. When debt limit = 0, no new borrowing is allowed. The debt limit never binds in equilibrium when $\bar{b}_t = 1$. The parameter values are similar to the benchmark calibration I describe below.

I simulate an economy that lasts $T = 100$ periods. The economy experiences high endowment in $t = 1$ to $t = 5$. Then it experiences low endowment in $t = 6$ and $t = 7$. After that, it permutates a pattern of 10 periods of high endowment and 2 periods of low endowment. In scenario 1, this completes the description of the economy. That is, this is an endowment shock only economy. In scenario 2, the economy also incurs a sudden stop shock when the endowment is low. I show the first 20 periods of both scenarios in figure 2.3.

The left panels illustrate the dynamics for scenario 1. The economy deleverages during the high endowment times between $t = 1$ and $t = 5$. When the endowment is low in $t = 6$, it increases debt and further in $t = 7$, the second period of low endowment. Between $t = 8$ and $t = 17$, the economy gradually decreases debt while reserves remains at 0. In $t = 18$ and $t = 19$, the economy increases debt again in response to the second round of low endowment. This series of balance sheet adjustments is essentially equivalent to a standard consumption smoothing result using a single non-state contingent asset. Notice that there is no simultaneous holding of the reserves and debt in any period of time after the first period.

The right panels illustrate the dynamics for scenario 2. The difference from the left panels is that when the economy experiences low endowment, it also experiences loss of access to new borrowing. The economy deleverages between $t = 1$

Figure 2.3: Time-series paths (left panels= endowment shock only, right panels= both shocks)



and $t = 4$ as in the left panels. Then in $t = 5$, one period before the economy experiences the sudden stop, it accumulates reserves financed by new debt issuance. Notice there is simultaneous holding of reserves and debt in this period. In $t = 6$, the economy is not allowed any new borrowing, and decreases debt. It decumulates reserves at the same time, helping smooth consumption. In $t = 7$, the second period of no new borrowing, the economy decumulates the reserves completely while partially decumulating debt. The complete decumulation of reserves is consistent with Proposition 8, which states that there cannot be coexistence when the constraint on new borrowing is not binding next period. Debt is gradually decumulated between $t = 8$ and $t = 16$. The same pattern of coexistence and its dissapearance is repeated between $t = 17$ and $t = 19$.

The simultaneous holding of reserves and debt helps smooth consumption, as can be observed by the small consumption fluctuation compared to the endowment fluctuation during sudden stops. Consumption smoothing is not perfect, however. This is due to the positive interest rate spread. If I assume $r = r^s$, perfect consumption smoothing will be achieved.[9]

2.2.3 Stochastic Version

Most of the model properties in the perfect foresight version carry over to the stochastic version. For example, one can show that propositions 7, 8, and 3 hold in the stochastic case. I repeat the (stochastic and recursive) Euler equations and

[9]While there is perfect consumption smoothing in the left panels of figure 2.3, this is not a robust result that holds for the endowment shock only economy in general. When the intertemporal resource transfer dictate the economy to hold positive reserve holding, it chooses to disrupt allow for fluctuation in consumption because of the opportunity cost due to $\beta(1 + r^s) < 1$.

propositions below for the sake of completeness of presentation.

$$\frac{u'(c)}{\beta E u'(c')} = 1 + r^s + \frac{\eta^a}{\beta E u'(c')} \tag{2.20}$$

$$\frac{u'(c)}{\beta E u'(c')} = 1 + r - \frac{\beta E \psi' I' - \psi + \eta^b}{\beta E u'(c')} \tag{2.21}$$

Proposition 4. *If the endowment shock is the only exogenous shock, the economy never chooses to hold reserves and debt simulataneously.*

Proof. Set $\eta^a = \eta^b = 0$ in (2.20) and (3.20). In the absence of the sudden stop shock, $\psi = 0$ and $E\psi' I' = 0$. Then the system of equations (2.20) and (3.20) does not have a solution. □

Proposition 5. *If $\lambda < 1$ and the economy faces both the endowment shock and the sudden stop shock, the economy may choose to hold reserves and debt simultaneously only if the borrowing constraint from the sudden stop shock next period binds in expectation.*

Proof. Suppose otherwise. Then $E\psi' I' = 0$. The system of equations (2.20) and (3.20) would not have a solution if $\eta^a = \eta^b = 0$. □

Proposition 6. *If $\lambda = 1$, there will be no simultaneous holding even if the economy faces both the endowment shock and the sudden stop shock.*

Proof. Set $\lambda = 1$, $\eta^a = \eta^b = 0$. Then the system of equations (2.20) and (3.20) does not have a solution. □

A main difference from the perfect foresight case is that the probability of a sudden stop next period is $0 < \pi < 1$ whereas in the perfect foresight case it is either

0 or 1. The implication is that simultaneous holding is likely to be persistent in the stochastic case because the economy needs to take into account the possibility of a sudden stop every period, whereas in the perfect foresight case the simultaneous holding appears only one period before the sudden stop, and disappears immediately after the sudden stop ends. I will show numerically that that the simultaneous holding is indeed persistent.

2.3 Calibration

2.3.1 Parameters

Table 2.1: Calibration Parameters

Parameters	Values	Description
r^s	0.032	10-year U.S. Treasury bond, deflated
r	0.052	Spread of 200 bp
σ	2	Standard value for risk aversion
λ	0.2	Set for duration=4 years
A	0.308	Domestic demand other than consumption
ρ_y	0.725	Persistence of log endowment shock
ϵ_y	0.0377	Standard deviation of log endowment shock
π	0.1	Probability of sudden stop

I calibrate the model to a sample of emerging market economies. I do this instead of calibrating to a particular country because later we perform an experiment that compares average behavior of sudden stop events and low output events for a sample of emerging markets. In order to obtain a sufficient number of sudden stop events and low output events, I need multiple emerging market economies. One period is assumed to be a year. Table 3.7 lists the calibrated parameters.

The parameters are set so that the exogenous shock processes are set to match the data. Given these targets, I am interested in the adjustments of reserves and debt.

I set $r^s = 0.032$. I obtained this by subtracting the average annual U.S. inflation rate from the average annual yield of 10-year Treasury bond in 2009.

There is uncertainty around the appropriate r. Many papers, including Neumeyer and Perri (2005) and Fernandez-Villaverde et al. (2010), define the borrowing interest rate of the emerging market economies as the sum of the risk-free interest rate plus JP Morgan's EMBI index that reflects default risk of sovereign debt. Figure 2.4 reports the two aggregate indices of EMBI in 1998-2010. These indices have had very large fluctuations over time. The extremely high numbers are irrelevant in the context of my model, because those numbers are analogous to losing access to borrowing, and r in the model is the borrowing interest rate when the economy *has* access. I set r so that the spread is close to its historical low in the benchmark model because these data values correspond to periods with minimum default risk. I experiment with other values of r in the sensitivity analysis.

I set $\lambda = 0.2$. This corresponds to debt duration of approximately 4 years.[10] Klingen et al. (2004) report that for countries included in the EMBI global index, average debt duration was within 3 to 4.2 years during the 1990's. b^h needs to ensure that the economy repays the debt while maintaining positive consumption in every state. I set $b^h = 2$, taking into account the numerical errors caused by grid

[10]Macaulay's definition of duration is $D = \sum_{t=1}^{\infty} t \frac{c_t(1+r)^{-t}}{q}$, where c_t is payment to creditor in period t, q is the price of asset in period 0. In our model, $c_t = (r+\lambda)(1-\lambda)^{t-1}$ and $q = 1$, resulting in $D = \frac{1}{r+\lambda}$ in our model.

discretization.

$A = 0.308$ is obtained from the national accounts of the countries in the sample and the budget constraint in the model. The budget constraint at the steady state is $A = y + r^s a - rb - c$. Substituting r^s and r as above, and long-term average $\frac{a}{y}$, $\frac{b}{y}$ and $\frac{c}{y}$ country-by-country from national accounts into the budget constraint obtains A for each country. Taking the average results in $A = 0.308$.

Exogenous shock parameters are set as follows:

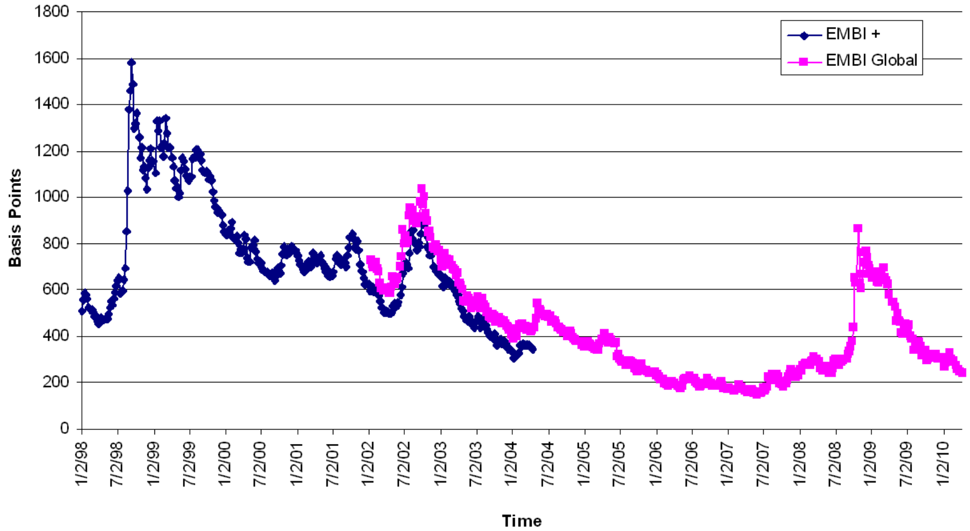
- For endowment shock parameters, I fit an AR(1) process to logged and linearly detrended real GDP for 16 emerging market economies country-by-country. I obtain ρ_y^i, $i = 1 \ldots 16$ this way. The standard deviation of the innovation is obtained as $\epsilon^i = \sqrt{{\epsilon_y^i}^2(1-{\rho_y}^2)}$, where ϵ_y^i is the standard deviation of the endowment. I take the simple average of ρ_y^i and ϵ^i to obtain $\rho_y = 0.725$, $\epsilon = 0.0377$.[11]

- The probability of a sudden stop is 0.1, as in Jeanne and Ranciere (2009). I set $\mathrm{corr}(y_t, \overline{b_t}) = 0.5$ in order to account for the fact that the sudden stop tends to coincide with low output in practice.

$$\begin{bmatrix} 0.1 & 0.9 \\ 0.1 & 0.9 \end{bmatrix} \tag{2.22}$$

[11] I also fitted AR(1) for logged and HP-filtered cyclical components for countries in the sample separately and took an average. I used smoothing parameter=6.25,following Ravn and Uhlig (2002)'s recommendation for annual data. I obtained very low persistence ($\rho_y = 0.176$).

Figure 2.4: EMBI Time Series



2.3.2 Numerical Method

We approximate the value function along the reserves and debt dimensions using a bivariate Chebyshev polynomial. We take a 12-th order approximation for both saving and debt, and use a complete polynomial specification in order to economize on the number of coefficients. We take 21 Chebyshev nodes in $[0, b^h]$ for both saving and debt. An initial guess is obtained by modified value function iteration as described in Judd (1998), linearly interpolated at the Chebyshev nodes. The choice of the method is based on the consideration that, on the one hand, we need global approximation of the model because there are occasionally binding constraints, but on the other hand, we need to be mindful of the curse of dimensionality because the distinction of saving and debt increases the number of state variables.

We construct the exogenous shocks as follows. First we correspond endowment shock and sudden stop shock separately to $N(0, 1)$ so that both shocks can be expressed as a discretization of $N(0,1)$. On the endowment dimension, for any current period value y_i, the next period value $y_j|y_i$ is distributed in $N(\rho_y y_i, \sqrt{\sigma_\epsilon^2(1-\rho_y^2)})$. This implies that $\frac{y_j - \rho_y y_i}{\sqrt{\sigma_\epsilon^2(1-\rho_y^2)}}$ is distributed as N(0,1). We follow Tauchen (1986) and approximate this distribution into 4 regions that correspond to the probability of being in one of the discretized values of y_j. For the shock to $\overline{b}$, we approximate it by dividing the cumulative distribution function of $N(0,1)$ into two regions $\overline{b} \leq \tilde{x}$ and $\overline{b} > \tilde{x}$ where $\tilde{x}$ satisfies $\int_{-\infty}^{\tilde{x}} F(x)dx = \pi_{i1}$, $i = 1,2$ and $F(x)$ is the cumulative distribution function for the standard normal distribution. $\overline{b} \leq \tilde{x}$ corresponds to being in a sudden stop next period and $\overline{b} > \tilde{x}$ represents not being in a sudden stop next period.

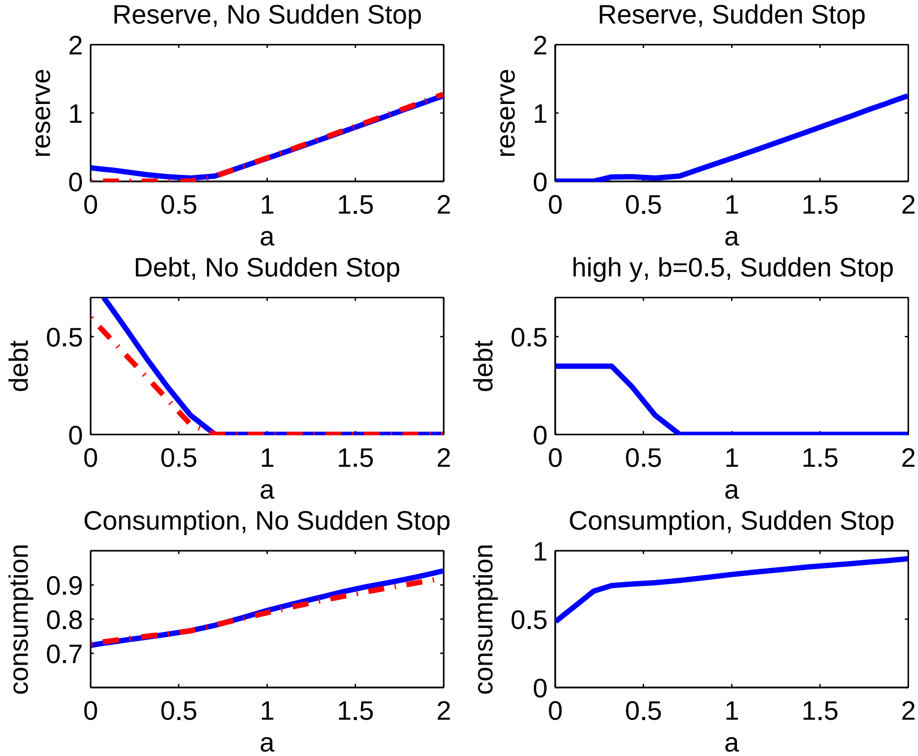
Second, we divide the bivariate normal distribution with shock correlation γ into 8 regions according to the approximation in the first step. The probability density function in each region constitutes the transition probability from $(y_i, \overline{b_i})$ to $(y_j, \overline{b_j})$. We repeat this for all the combinations of initial values $(y_i, \overline{b_i})$. We obtain an 8-by-8 Markov chain as a result.

2.4 Results

2.4.1 Benchmark decision rule

Figure 2.5 describes the benchmark decision rule as a function of initial states. Solid lines plot the decision rule for a_t as given along the x-axis, $b_t = 0.5$, and $y_t = \underline{y}$. In the left panels, the economy has access to foreign borrowing in the current period. In the right panels, the economy experiences a sudden stop in the current period.

Figure 2.5: Decision Rule



As a preliminary step, we confirm that there is no simultaneous holding when there is no possibility of a sudden stop. In the left panels, we also plot in dash-dot lines the decision rule for the case of no possibility of sudden stop for comparison purposes. The dash-dot lines show that the economy chooses either positive reserves and no debt or no reserves and positive debt depending on the initial net asset position, but never holds reserves and debt simultaneously.

Now let us introduce the possibility of the sudden stop. The left panels show that the decision rule changes little from the case with no probability of sudden stop when the initial asset position is strong, which translates to a strong net foreign asset position next period. In this case, the existing level of reserves is sufficient to smooth consumption if there is a sudden stop next period.

Simultaneous holding emerges when the optimal decision rule results in a weak net foreign asset position next period. In this case, $E\psi' I' > 0$ in (3.20) and maintaining higher gross debt and investing in reserves will be beneficial if there is a sudden stop next period. Compared with the case of zero sudden stop probability, the economy maintains higher debt and simultaneously holds reserves. A higher debt next period is accompanied by higher reserves because the higher debt amplifies the effect of the negative shock when the sudden stop occurs next period. This necessitates having higher reserves.

Consumption is higher for higher a. This is a standard result from any consumption smoothing model. Also note from the right panel that consumption sharply decreases when the sudden stop constraint is currently binding.

Moving to the right panels, the decision rule is identical to that in the left panels where the sudden stop shock is not binding. This happens when the initial net asset position is relatively strong, roughly corresponding to $a \geq 0.7$. When the debt limit is binding, $b' = (1 - \lambda)b$, a' is smaller than in the left panels and becomes 0 for weaker asset position, while c is smaller than in the left panels, especially for weak asset positions that make $a' \geq 0$ binding.

2.4.2 Ergodic distribution

Table 2.2 reports long-run moments of the model, namely, the mean and standard deviation of saving, debt, and consumption. The mean refers to the long-run average level of each variable. The standard deviation is taken for the logged and

Table 2.2: Ergodic Distribution

	mean	**std**	**corr. with endowment**	**corr. with reserves**
reserve	0.23	0.12	-0.26	1.00
debt	1.34	0.47	-0.24	0.83
consumption	0.63	0.05	0.39	-0.47
endowment	1.00	0.06	1.00	-0.26

linearly detrended version of each variable in order to ensure comparability with data series. I obtain positive average reserves and debt in the long run, while volatilities of reserves and debt are much larger than those of endowments or consumption, suggesting that the economy actively adjusts both reserves and debt. The reserves and debt are both positive in close to 100 percent of the simulation periods.

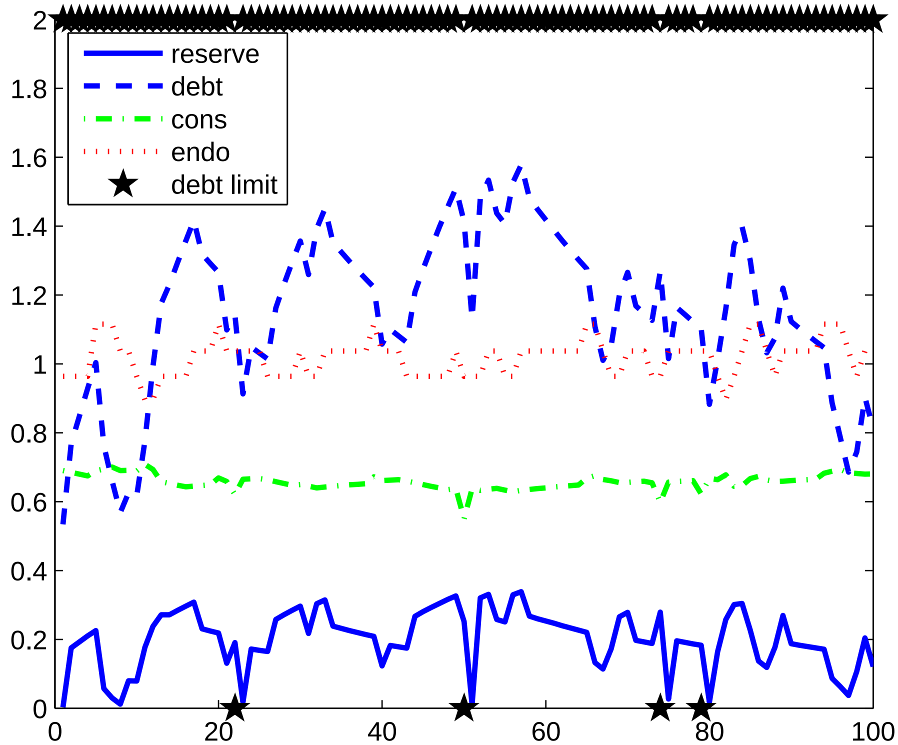
2.4.3 Sample Time Series

Figure 2.6 shows simulated time series of 100 periods. Most importantly, it is confirmed that positive debt and reserves happen simultaneously, rather than reserves being observed only in some periods and debt only in others. I also find some regularities in the time series. First, when there are sudden stops, reserves decrease sharply. Second, low endowments without sudden stops are accompanied by an increase in both debt and reserves. I explore these properties further below.

2.5 Sensitivity Analysis

In this section, I explore the sensitivity of numerical results to changes in interest rate spreads and in the probability of sudden stops, and allow for endogenization of the sudden stop probability.

Figure 2.6: Sample Time Series



2.5.1 Changes in Interest Rate Spread

I change the spread between the lending interest rate and borrowing interest rate by changing r^s. This amounts to changing the opportunity cost of insurance. The smaller the spread, the smaller the insurance cost. Figure 2.7 shows that the simultaneous holding of reserves and debt increases as r^s increases, with both reserves and debt higher as r^s increases, as observed in the top and middle panels. Higher coexistence results in smoother consumption, as observed in the bottom panel of figure 2.7.

Table 2.3 and table 2.4 show that long-run average reserve accumulation increases as the interest rate spread shrinks, as the lower interest rate spread means that the opportunity cost of self-insurance is lower. This sensitivity of reserve accumulation to the interest rate spread is consistent with the fact that reserve accumulation accelerated during 2003-2007, a period of low interest rates. While explanations based on financial globalization and asymmetric financial development between the developed economies and emerging markets are certainly plausible as an explanation of reserve accumulation by the emerging markets, a simple explanation based on narrowing of the interest rate spread may have also contributed. A serious pursuit of this line of explanation requires microfoundations on the process of sudden stops and interest rate determination, of course.

2.5.2 Changes in Sudden Stop Probability

Figure 2.8 compares the benchmark decision rules with the decision rules for different probabilities of sudden stops. The figure shows that a higher probability of sudden stops leads to more simultaneous holding and a higher level of reserves.

Table 2.5 and table 2.6 compute the long run moments with different probabilities of sudden stops. I find that the level of reserves becomes higher as the probability of sudden stops increases. However, the level of debt does not necessarily increase with the probability of sudden stops. This can be explained as the following. On the one hand, an increase in the probability of the sudden stop induces the economy to hold a higher level of reserves per unit of debt. On the other hand, the higher probability of sudden stops imply that the economy has to deleverage more often. This contributes to lower average debt.

Figure 2.7: Decision Rule (Different Values of r^s)

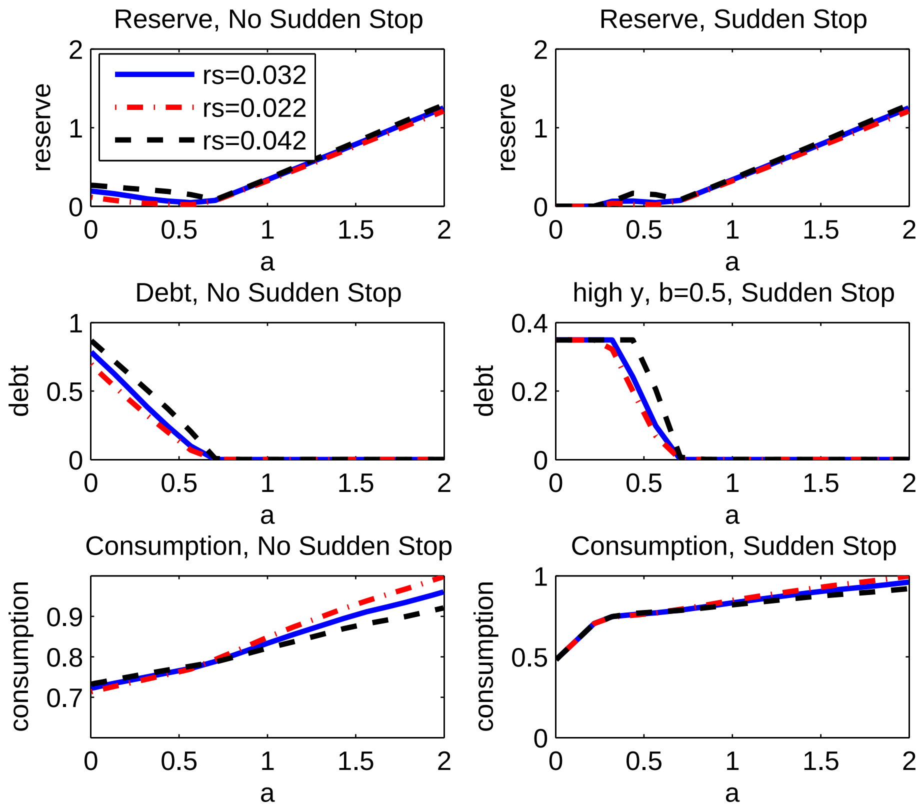


Table 2.3: Ergodic Distribution ($r^s = 0.042$)

	mean	**std**	**corr. with endowment**	**corr. with reserve**
reserve	0.33	0.13	-0.13	1.00
debt	1.59	0.38	-0.24	0.76
consumption	0.63	0.05	0.48	-0.28
endowment	1.00	0.06	1.00	-0.13

Table 2.4: Ergodic Distribution ($r^s = 0.022$)

	mean	**std**	**corr. with endowment**	**corr. with reserve**
reserve	0.14	0.11	-0.30	1.00
debt	1.02	0.52	-0.23	0.88
consumption	0.65	0.05	0.35	-0.53
endowment	1.00	0.06	1.00	-0.30

Figure 2.8: Decision Rule (Different Values of π)

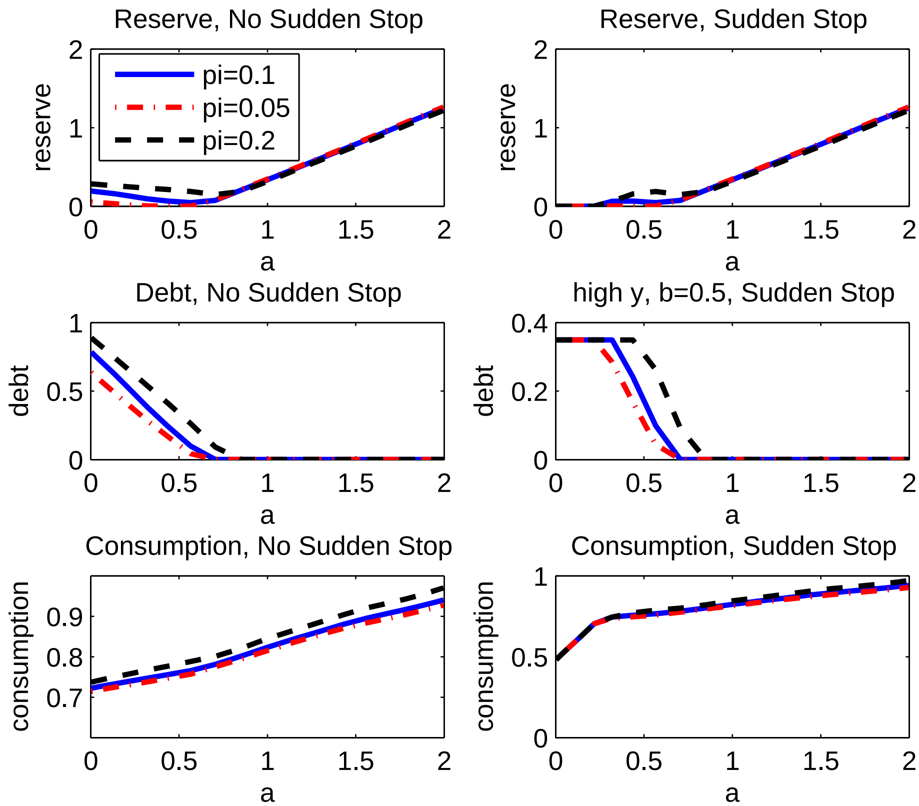


Table 2.5: Ergodic Distribution ($\pi = 0.05$)

	mean	**std**	**corr. with endowment**	**corr. with reserve**
reserve	0.18	0.11	-0.29	1.00
debt	1.33	0.54	-0.24	0.89
consumption	0.63	0.05	0.40	-0.61
endowment	1.00	0.06	1.00	-0.29

Table 2.6: Ergodic Distribution ($\pi = 0.2$)

	mean	**std**	**corr. with endowment**	**corr. with reserve**
reserve	0.25	0.16	-0.19	1.00
debt	1.19	0.47	-0.22	0.85
consumption	0.64	0.06	0.39	-0.36
endowment	1.00	0.06	1.00	-0.19

2.5.3 Endogenization of Sudden Stop Probability

The probability of sudden stop is an exogenously given constant in the baseline scenario. In practice, however, the probability of sudden stops may be a function of state variables.

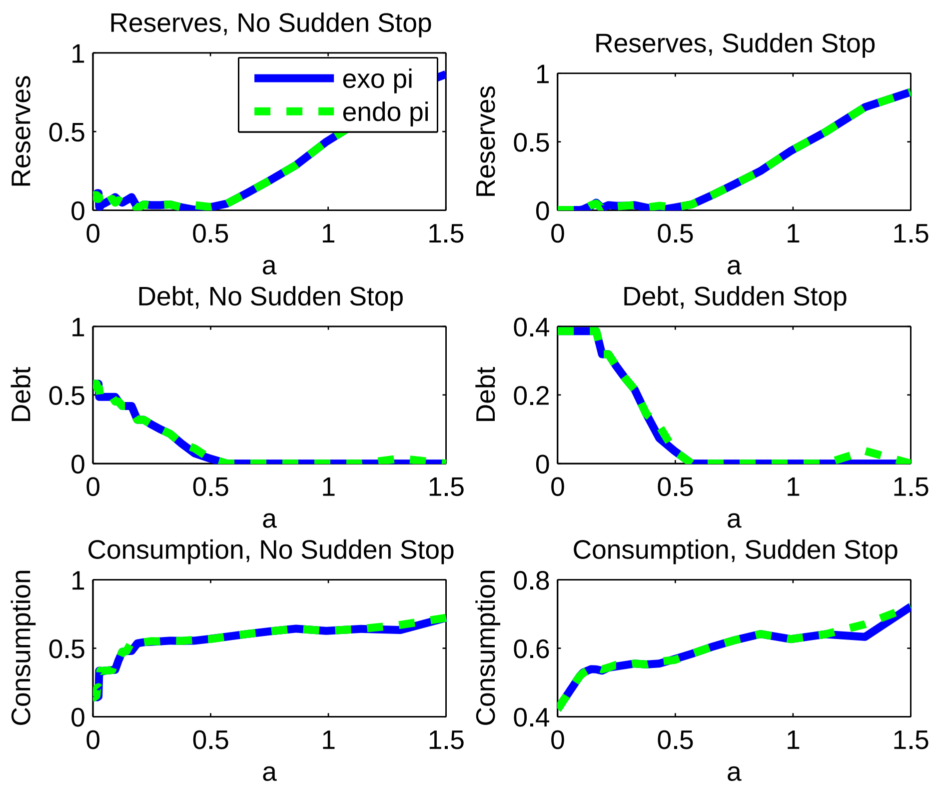
I endogenize the probability of sudden stop as the following

$$\pi(a,b) = F\Big(\kappa_1 - \kappa_2 \frac{(1+r^s)a}{(r+\lambda)b}\Big) \tag{2.23}$$

where F denotes the cumulative distribution function for the standard normal distribution and κ_1 and κ_2 are parameters with $\kappa_2 > 0$. Thus we assume that the probability of sudden stop follows a Probit specification and is a decreasing function of the reserves to short term debt ratio. This specification can be found in Jeanne (2007) and Jeanne and Ranciere (2009) and implies a crisis prevention benefit to reserve accumulation.

In this subsection, I switch to a modified value function iteration with 55 grid points for both reserves and debt in $[0, b^h]$. I also reduced the number of grid points for the endowment to just two. These changes were made to ensure convergence of the iteration within a reasonable time. κ_1 is set at $F(\kappa_1) = 0.1$ in order to facilitate comparison with the benchmark case, and I set $\kappa_2 = 0.3$, the upper limit of the estimation results from Jeanne (2007). Figure 2.9 indicates that the decision rule changes very little when the probability of sudden stop is endogenized. This result is contrasting to that in Jeanne and Ranciere (2009), who conclude that optimal reserve holding increases when the probability of a sudden stop is a decreasing function of the reserves to short-term debt ratio, and the effect generally strengthens as κ_2 increases. The difference can be explained by the different model assumptions during non-sudden stop periods. In their model, the borrowing constraint is always binding, which implies a constant debt to output ratio. Thus an increase in reserves comes at the expense of consumption. When the probability of a sudden stop is decreasing in reserves, it is worthwhile for the economy to sacrifice some consumption and increase reserves. In contrast, the economy does not face a binding constraint when there are no sudden stops in my model. Thus the economy could increase reserves by debt issuance and without sacrificing consumption. If the reserve increase is financed by debt issuance, however, the reserves' net contribution to consumption-smoothing during sudden stops is smaller than when the reserves are financed by sacrificing consumption because of the increased debt repayment obligations. Taking also into account the costs from interest rate differences, it is not optimal for the economy to increases reserves. Thus the endogenization of the probability of sudden stops that follows Jeanne and Ranciere (2009) does not lead to an increase in optimal reserves. Note that the empirical results are inconclusive. While Garcia and Soto (2004) find that reserve accumulation decreases the probability of the sudden stops, Calvo, Izquierdo, and Mejia (2004), Jeanne and Ranciere (2009), and Cavallo and Frankel (2004) do not find an effect of reserve adequacy on the probability of sudden stops.

Figure 2.9: Decision Rule when probabability of sudden stop is endogenously determined



2.6 Comparison with data

In this section I compare average model responses to different types of shocks and constrast the behavior of reserves and debt in response to different shocks. Moreover, I compare the model properties with those of detrended data in 1981-2007 from a sample of emerging markets.

For this purpose, I generate a 10000-period simulated time series from the model. After discarding the first 500 periods, I construct 5-year windows of sudden stop events and low endowment events. The windows are constructed so that the event takes place in $t = 2$. Low endowment events are identified by $y = y^{\text{lowest}}$ conditional on the 5-year windows not including the sudden stops. I take the simple average of each set of 5-year periods to generate the average responses to shocks. The results are illustrated in figure 2.10.

The left panels describe the response to endowment shocks. The debt stock increases because the economy responds by borrowing in order to smooth consumption. Reserves also increase because the higher debt stock increases the demand for self-insurance against a possible future sudden stop. The right panels describe the response to sudden stop shocks. The debt stock decreases by the definition of sudden stops. Reserves decrease for consumption-smoothing purposes.

Separately, I construct 5-year periods of sudden stop shocks and low output shocks from the data in a way that is parallel to the model. The choice of countries and identification of sudden stop events follows Durdu, Mendoza, and Terrones (2009). Table 2.7 lists the sudden stop events. A low output shock is defined as a

Figure 2.10: Average behavior (Model)

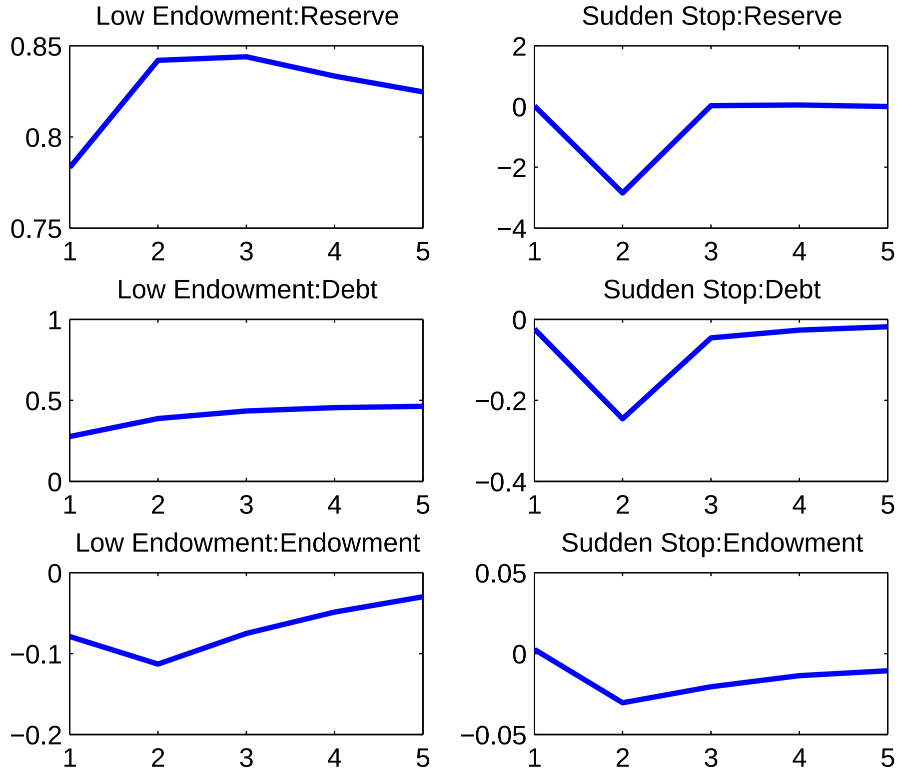
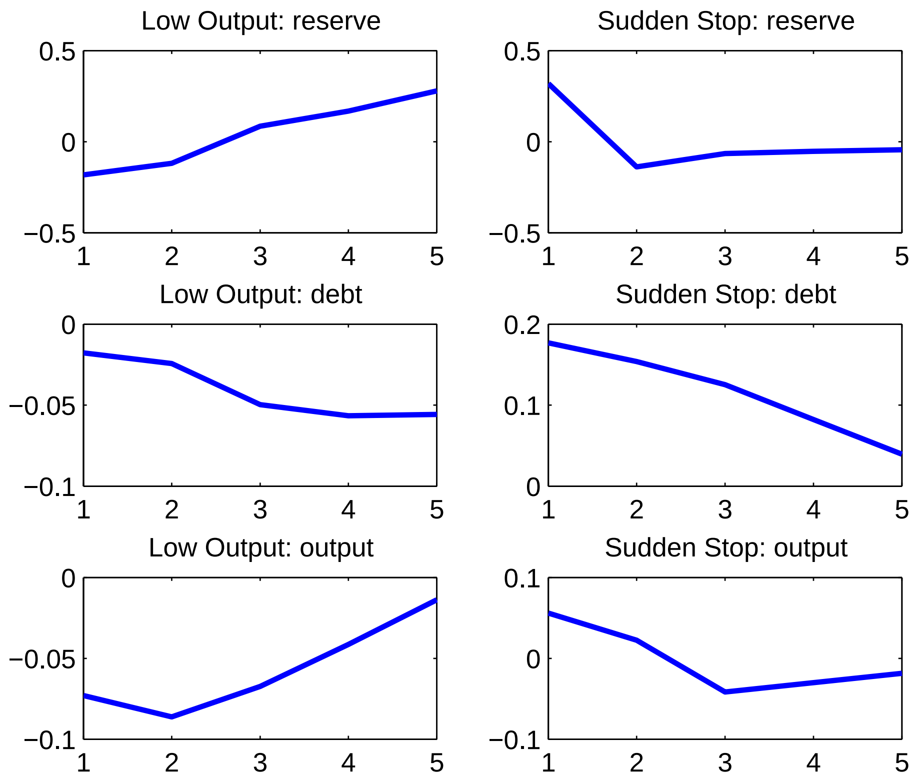


Figure 2.11: Average behavior (Data)



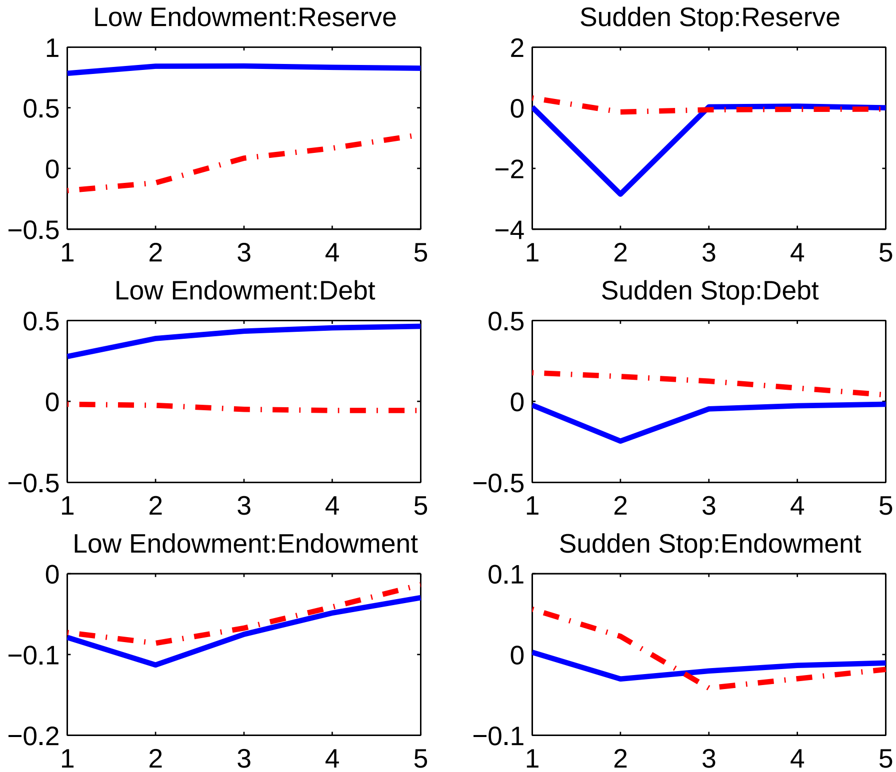
period in which output is more than one country-specific standard deviation output below the mean. I exclude events that include the sudden stop within the 5-year window. When there is more than one period of low output within a 5-year window, we take the first period as the event date. Table 2.8 lists the low output events. For both types of events, the shock cis defined as coming in $t = 2$. Figure 2.11 plots the aggregate time series for both shocks.

The left panels report the time series around the low output shock. Economies start the period with low reserves, and increase reserves while they experience low output. Debt decreases over time, but by much less than the change in reserves.

The right panels report the time series around the sudden stop shock. Reserves decrease sharply at the time of the sudden stop and stay at that level throughout the period. Debt decreases more mildly throughout the sample period. I also find that output declines sharply around the time of the sudden stop. This is not surprising given that sudden stop shocks typically coincide with financial crises that are costly in terms of output. Output decreases sharply one period after the sudden stop, not in the period of the sudden stop. This is because for some countries in the list, most notably Argentina, Indonesia, Korea, and Mexico, the dollar denominated GDP declined sharply one year after the sudden stop due to the collapse of a fixed exchange rate regime.

While both model and data show contrasting behavior of reserves in response to the sudden stop shock and the endowment shock, the magnitude differs substantially. Figure 2.12 reports aggregate time series from the model using a solid line and the data time series using a solid-dot line. Both model and data have constrasting reserve movements depending on the source of the shock, with a low output shock leading to an increase in reserves, while the sudden stop leads to a decrease in reserves. The model adjusts reserves and debt much more sharply than data, however.

Figure 2.12: Simulated Time Series



2.7 Conclusion

This paper proposes a small open economy model that explains why emerging markets simultaneously hold external debt and external reserves. Reserves may be held simultaneously with debt even when their return is lower than the interest rate on debt, because reserves are valuable as a vehicle of self-insurance. Two key assumptions that differentiate the liquidity of reserves and debt, namely the sudden stop in the debt market and the maturity difference between reserves and debt, are critical to generating this simultaneous holding.

The model generates simultaneous holding and frequent adjustments of reserves and debt, as observed in emerging markets' data. The model also generates responses to exogenous shocks that are qualitatively consistent with data. Reserves decrease sharply when the external shock is a loss of access to foreign borrowing, but do not necessarily decrease following a low endowment shock per se, provided that the country retains access to foreign borrowing.

Although my model has desirable properties mentioned above, there is much to be desired in terms of its quantitative fit. More importantly, the distinction between reserves and debt is highly stylized. Important parameters related to reserves and debt are also exogenously given. Microfounded characterization of the two markets would enable us to explain the mechanism behind the differences between reserves and debt, enriching the model. This is a topic for future research.

Table 2.7: List of Sudden Stop Sample Periods

Country	Period	Sudden Stop Year
Argentina	1993-1997	1994
Argentina	2000-2004	2001
Brazil	1997-2001	1998
Chile	1997-2001	1998
Colombia	1997-2001	1998
Ecuador	1998-2001	1999
Hong Kong	1997-2001	1998
Indonesia	1996-2000	1997
Korea	1996-2000	1997
Mexico	1993-1997	1994
Malaysia	1996-2000	1997
Pakistan	1997-2001	1998
Peru	1997-2001	1998
Philippines	1996-2000	1997
Thailand	1996-2000	1997
Turkey	2000-2004	2001
Uruguay	2001-2005	2002

Table 2.8: List of Output Decline Sample Periods

Country	Period	Output Decline Year
Argentina	1988-1992	1989
Brazil	1991-1995	1992
Brazil	2001-2005	2002
Chile	1992-1996	1993
Colombia	1990-1994	1991
Pakistan	1988-1992	1989
Pakistan	2000-2004	2001
Peru	1989-1993	1990
Philippines	1990-1994	1991
Turkey	1993-1997	1994

Chapter 3

Credit Shocks, Patterns of Firm Financing, and Creditless Recoveries

3.1 Introduction

Firms' responses to negative credit supply shocks have gained renewed interest in the wake of the latest global financial crises. While there is a substantial literature that studies the implications of predetermined, structural financial frictions in the existence of productivity shocks, shocks to financial frictions are only recently beginning to be incorporated into theoretical modeling of the firm. This paper proposes a dynamic model of the firm that explicitly incorporates credit shocks. After documenting that banking crises are followed by stagnation in credit and that investment is financed less by debt and more by internal funds or equity at the time of banking crises, I develop a dynamic model of the firm consistent with this finding. In the model, the firm increases its reliance on retained earnings or equity issuance in investment financing in response to a negative credit shock. Thus there is a substitution in the sources of financing. Comparing long-run distributions of the model with and without credit shocks, this paper finds that first and second moments in debt, equity payout, and capital are sensitive to inclusion of the credit shock. The development of the model with credit shocks is the first contribution of the paper.

The literature on creditless recoveries mostly uses aggregate data and documents that both industrial and emerging market economies often recover from financial crises without an accompanying recovery in credit. While there is a broad agreement on the existence of creditless recoveries, the reason for this phenomenon is not settled yet. The modeling and empirical results in this paper emphasize the role of credit shocks in generating creditless recoveries. Adding to the debate on creditless recoveries is another contribution of this paper.

Empirically, I interpret banking crises as negative credit shocks to firms and establish the following facts. First, using aggregate data I confirm that banking crisis incidence leads to stagnant credit developments in subsequent years. Then at the firm level, I show that firms located in countries that are experiencing banking crises tend to rely less on bank financing and more on other sources, such as retained earnings or equity issuance. Using a firm-level survey for a broad range of emerging market and developing economies in 2006-2009, I show that firms in countries experiencing banking crises have a lower proportion of bank financing and higher proportions of equity financing and owner's self financing of fixed asset investment. This remains true after controling for credit-to-GDP ratio of countries prior to banking crises.

Theoretically, I develop a dynamic firm model that features an exogenous shock to credit supply and the firms' substitution of sources of financing. The key assumptions are: (i) there is a shock to the borrowing limit as well as a standard productivity shock, (ii) equity financing is allowed but with a friction in the form of a quadratic issuance cost. The model generates a substitution of financing sources in response to a negative credit shock. The mechanism is the following. The shock leads to a decline in current period debt capacity. The firm then attempts to maintain investment by resorting to internal funds. If the shock is sufficiently large that the firm needs to issue equity, however, it reduces investment because of the equity issuance cost.

Calculating the long-run distribution, I find that the firm is much more leveraged on average when it faces the productivity shock only. Volatilities of both debt and equity payout is much higher when the firm faces both shocks. Equity payout, debt issuance, and investment are all procyclical whether the firm incurs both shocks or the productivity shock only. With both shocks, output is correlated more positively with equity issuance and less with debt issuance, and is less positively correlated with investment. These results can be interpreted as the following. When the credit shock exists, credit may not be available as needed. Knowing that, the firm retains more earnings when the credit constraint is more relaxed, and draws retained earnings down when the constraint is tighter. In contrast, the firm quickly leverages itself and provides large equity payouts in the absence of credit shocks.

The model also generates creditless recoveries from financial crises in response to an extended period of negative credit shocks. When new borrowing is curtailed in the presence of relatively large current period debt and relatively large expected productivity of next period capital, the firm determines it is worth incurring the equity issuance cost to increase investment. While bank credit continues to be curtailed because of the tight borrowing constraint, output can increase, supported by the use of retained earnings or equity issuance. Because equity issuance is expensive, however, when the firm needs to resort to equity financing, the level of investment is lower than frictionless investment.

I perform a set of sensitivity analyses in order to assess model properties. A higher initial level of debt leads to a deeper recession initially. This is because the higher debt repayment obligation in response to the negative credit shock is not fully offset by the equity issuance, reflecting quadratic issuance cost. A smaller fluctuation in the credit limit leads to a more gradual business cycle in general and deemphasizes the creditless recovery pattern. Given that the loss of access to foreign borrowing during crises is more severe for emerging market economies, this last result is consistent with the stylized fact documented in Abiad et al. (2011) that emerging markets and developing economies experience creditless recoveries more frequently. Finally, the introduction of long-term bonds also results in more gradual adjustments in the overall business cycle.

While the firm capital structure has been central to corporate finance research at least since Modigliani and Miller (1958)'s seminal paper, only a limited number of papers have explored the link between macroeconomic conditions and capital structure, such as Korajczyk and Levy (2003), Hackbarth, Miao, and Morellec (2006), Chen (2010), and Covas and Den Haan (2010a). Most of these papers use U.S. data and existing evidence is inconclusive on the nature of the relationship between the capital structure and the business cycle. Even fewer papers consider the effect of credit shocks on the capital structure. Jermann and Quadrini (2010) document using aggregate data that equity payouts are procyclical while debt payouts are countercyclical for U.S. firms at the aggregate level. They also develop a closed economy model where credit shocks play an important role in capturing business cycle dynamics. While their model assumes an always binding constraint, I show that the introduction of the credit shock results in the firm often conserving debt capacity even in the periods of a relaxed credit limit. Covas and Den Haan (2010a) document using firm level data that debt issuance is procyclical and that equity issuance is also procyclical except for the largest firms. Regarding firms' responses to credit shocks, there is a string of recent empirical literature, with notable contributions including Kalemli-Ozcan, Kamil, and Villeagas-Sanchez (2009), Desai, Foley, and Forbes (2008), Duchin, Ozbas, and Sensoy (2010), Chava and Purnanandam (2011), and Campello, Graham, and Harvey (2010). This literature typically concludes that an exogenous shock to the supply of credit has a negative effect on the firms' valuation, investment and profit. In the theoretical corporate finance literature, there is a growing set of papers that model firms' dynamic financing and investment decisions under uncertainty in productivity and in the presence of financial frictions. The list includes Gomes (2001), Cooley and Quadrini (2001), Hennessy and Whited (2005), Gamba and Triantis (2008), Korinek and Stiglitz (2009), Bolton, Chen, and Wang (2009), DeAngelo, DeAngelo, and Whited (2011), Rampini and Viswanathan (2011), and Boileau and Moyen (2009). Papers in this strand of literature do not model shocks to credit supply, however.

Creditless recoveries were first documented by Calvo, Izquierdo and Talvi (2006) for emerging market economies. Claessens, Kose, and Terrones (2008, 2009) show that advanced economies also experience creditless recoveries. Abiad, Dell'Ariccia, and Li (2011)'s work further studies the link between creditless recoveries and other economic events, using both aggregate and sectoral data. At the aggregate level, they find that a creditless recovery is more likely when a recession is associated with credit booms and banking crises. At the sectoral level, they show that industrial sectors that inherently depend more on external financing tend to recover more slowly from recession, suggesting the existence of impairment in financial intermediation. This paper's focus on a binding external borrowing constraint is consistent with their results. Its distinction is that it highlights the different composition of financing sources at the firm level.

Theoretical models to replicate creditless recoveries have been limited. Biggs, Mayer, and Pick (2010) show that the introduction of long-term debt can replicate a creditless recovery around the time that credit growth suddenly decreases. They make the point that growth in the flow of credit is closely correlated with growth in output even if growth in the stock of credit is not. A key difference between their model and mine is that while substitution between debt and internal financing/equity generates a creditless recovery in my model, such substitution is not allowed in their model. Thus my model can generate a creditless recovery under the standard assumption of one-period debt. In Dagher (2010), a negative shock to trend productivity growth following Aguiar and Gopinath (2007), interacting with an endogenous credit constraint, generates creditless recovery. The negative shock decreases the value of the firm, tightening the credit constraint. As a result, the firm deleverages toward the new steady state with less debt relative to output. Output drops initially as the firm makes costly dividend reductions to finance investment. However, the relevance of negative trend productivity shocks in the aftermath of financial crises is debatable. In emerging markets, financial crises are often accompanied by real depreciations, providing improved profit opportunities for the tradables sector. See Kalemli-Ozcan, Kamil, and Villegas-Sanchez (2009) and Desai, Foley, and Forbes (2008), for empirical evidence. At the aggregate level, Garcia-Cicco, Pancrazi, and Uribe (2010), and Chang and Fernandez (2010) question the importance of trend shocks in explaining emerging economies' business cycle fluctuations. My paper does not rely on shocks to productivity, however; in my model, a credit shock alone generates a creditless recovery.

The rest of the paper is organized as follows. Section 2 shows stylized facts. Section 3 describes the model and characterizes the firm's policy analytically. Section 4 solves the model numerically and describes the decisoin rule. Section 5 describes shows various simulation results, including ergodic distribution and creditless recovery results. Section 6 concludes.

3.2 Stylized Facts

3.2.1 Macro Data

Abiad, Dell'Ariccia, and Li (2011) document that among different potential explanations, banking crises are closely related to creditless recovery. I interpret banking crises to be negative credit supply shocks and confirm that they are associated with stagnant credit developments in subsequent years.

For this purpose, I summarize the relationship between the transition of output and credit around the recession and recovery periods and measure how the existence of banking crises affect it. I use output and credit for 1970-2007 for 124 countries that encompass industrial, emerging market, and other developing economies. GDP deflator is used to convert nominal variables into real variables. The choice of countries is dictated by data availability. All data are obtained from the IMF's International Financial Statistics.

The bottom of the recession is defined as local minimum in detrended output that is also lower than minus one standard deviation from trend. The method of detrending is Hodrick-Prescott filter with smoothing parameter 6.25 as recommended for annual data by Ravn and Uhlig (2002). I define recovery periods to be 3 years after the bottom of the recession. This practice follows Abiad Dell'Ariccia, and Li (2011) and Braun and Larrain (2005). Credit is measured by bank credit to the private sector (IFS line 22d). Identification of banking crisis follows Laeven and Valencia (2010). They define a systemic banking crisis to start when the two conditions are satisfied: 1) significant signs of financial distress in the banking system, 2) significant banking policy intervention measures in response to significant losses in the banking system. They define the banking crisis to end in the year before two conditions to hold: real GDP growth and real credit growth are positive for at least two consecutive years. This procedure identifies 323 recessions and recoveries episodes, 51 of which are associated with banking crises.

First, I simply compare the transition of credit to GDP ratio when recessions are associated with banking crises and when they are not. A recession is considered to be associated with banking crisis if there is a banking crisis within two years prior to the bottom or at the time of the bottom of the recession. I take arithmetic mean of credit to GDP ratio at the bottom of the recession and three years after the bottom for both banking crisis subsample and non-banking crisis subsample.

Table 3.1 show the results. Credit to output ratio is clearly more stagnant when recessions are associated with banking crises than without them. While credit to GDP ratios are not very different between banking crisis subsample and non-banking crisis subsample at the bottom of the recessions, subsequent developments differ significantly. Whereas credit to output ratio exceeds that at the bottom of the crisis three years later, it stays below that at the bottom of the crisis when the recessions are associated with banking crises. The credit deceleration during

Table 3.1: Credit to GDP ratio

	Bottom	**3 years later**
With Banking Crisis	0.329	0.227
Without Banking Crisis	0.351	0.425

the banking crises can also be observed by tracking credit and output separately. Figure 3.1 averages the detrended output and credit separately for downturns with and without banking crises. While credit recovers in parallel with output after the initial downturn in non-banking crises average, credit decelerates more rapidly than output and stays stagnant in the aftermath with banking crises average. Note also the boom in credit prior to downturn for with banking crises average. Looking at country-specific series for selected emerging markets and industrial countries, figure 3.2 and figure 3.3 confirm that credit decelerates during the banking crises and much more so than output, whether in emerging markets' financial crises, industrial countries' financial crises of the late 2000's, or the banking crisis in Japan in the late 1990's.

Next, I run a regression in order to measure how the banking crises are associated with subsequent credit developments. The regression specification is the

Figure 3.1: Credit, Output and Banking Crisis (Aggregate)

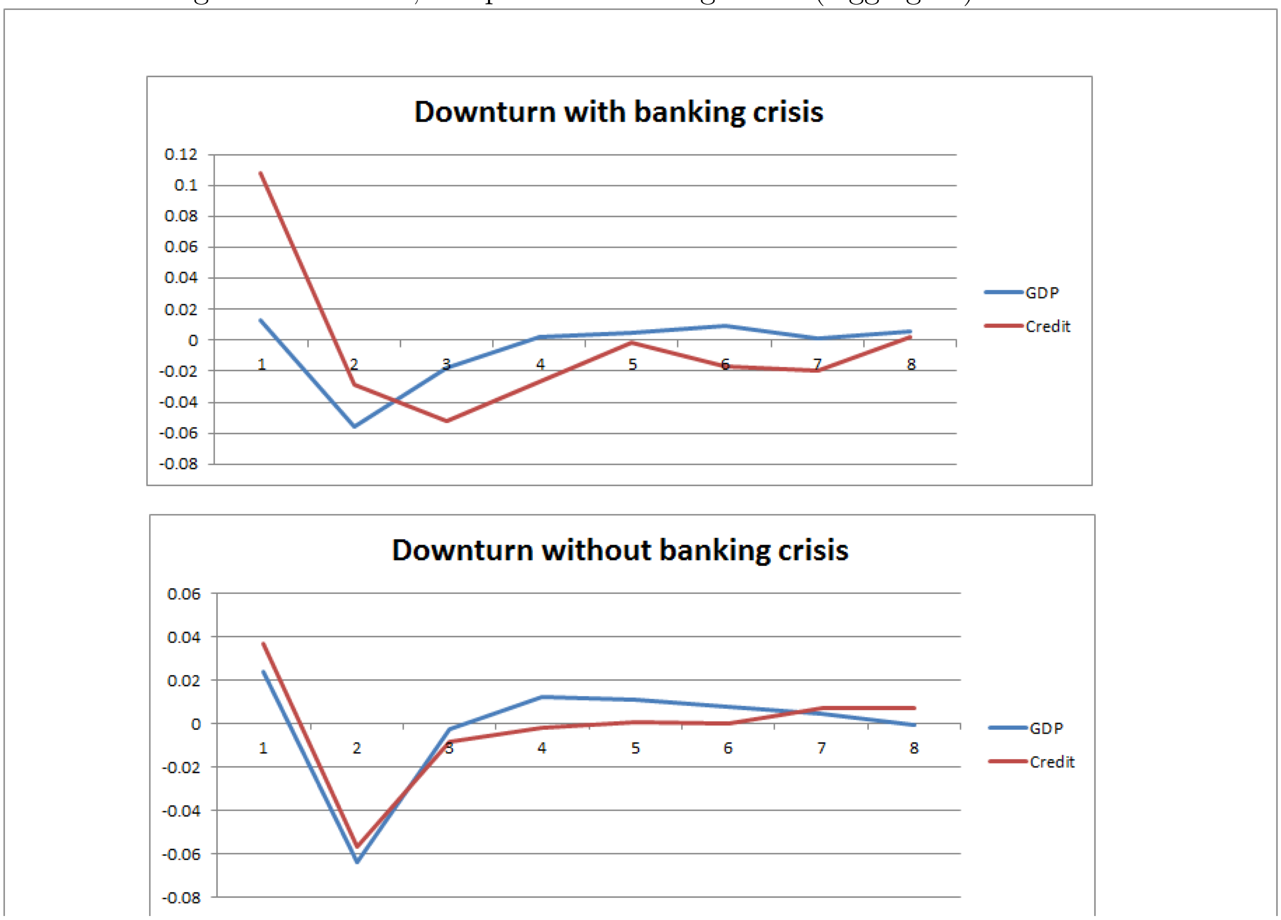


Figure 3.2: Credit, Output and Banking Crisis (Emerging Markets)

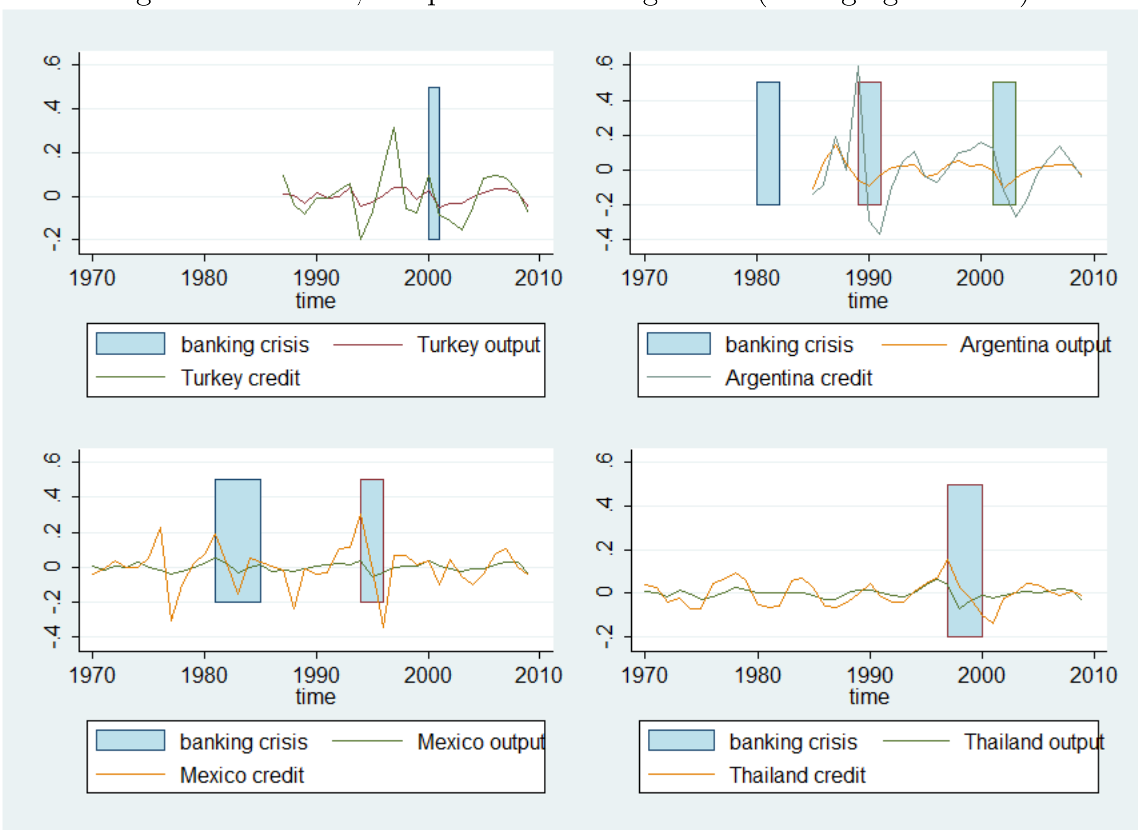
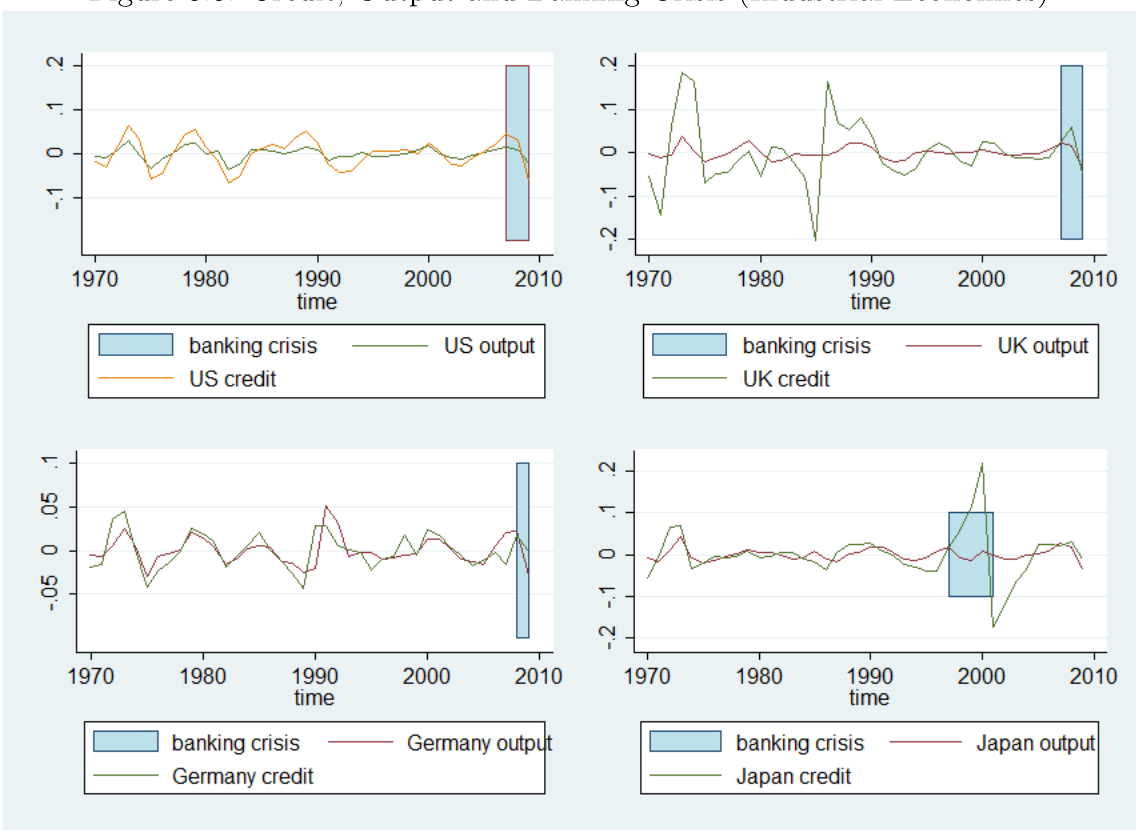


Figure 3.3: Credit, Output and Banking Crisis (Industrial Economies)



following.

$$cr_{j,t} = \beta_0 + \beta_1 * \text{bankingcrisis}_{j,t-i} + \beta_2 * cr_{j,t-i} + \alpha_j + \epsilon_{j,t} \tag{3.1}$$

where $i = 1, 2, 3$. Credit is measured alternatively by credit to output ratio and HP-filtered deviation from trend. Current period credit is added to RHS given the persistence in the credit time-series. I also add country-fixed effect α_j for country j.

Table 3.2: Macro Regression (cr=credit to GDP ratio, All countries)

	(1)	(2)	(3)
	F.creditoutput	F2.creditoutput	F3.creditoutput
bankingcrisis	-0.0750	-0.0694	-0.0551*
	(-1.63)	(-1.23)	(-2.15)
creditoutput	0.702***	0.467***	0.135***
	(124.45)	(69.26)	(44.01)
trough	-0.107**	-0.138**	-0.0592**
	(-2.62)	(-2.83)	(-2.70)
_cons	0.134***	0.230***	0.354***
	(11.31)	(16.05)	(53.87)
N	3995	3871	3747

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.2 and table 3.3 show that the incidence of banking crisis has a negative effect on credit developments in the next one to three years in general. When credit development is measured by credit to output ratio, the coeffcient for banking crisis dummy has a negative sign but significant only for the credit developments three years later. When credit development is measured by HP-filtered deviation from

Table 3.3: Macro Regression(cr=deviation from HP-filtered trend, All countries)

	(1)	(2)	(3)
	F.hp_lnrealcredit	F2.hp_lnrealcredit	F3.hp_lnrealcredit
bankingcrisis	-0.0649***	-0.0619***	-0.0318**
	(-5.40)	(-5.17)	(-2.62)
hp_lnrealcredit	-0.0447**	-0.256***	-0.230***
	(-2.76)	(-16.24)	(-14.51)
trough	-0.00333	-0.00965	-0.00800
	(-0.32)	(-0.95)	(-0.78)
_cons	0.00546	0.00536	0.00245
	(1.80)	(1.79)	(0.80)
N	3821	3697	3573

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

trend, the coefficient is negative and significant for all years. While current period credit to output ratio has a positive effect on its future values, HP-filtered deviation from trend has a negative effect on its future values. This is reasonable because credit to output ratio is a measure of financial development with high persistence while HP-filtered deviation from trend is business cycle movements.[1]

Table 3.4 and table 3.5 show the results when the sample is limited to emerging market economies. The results are consistent with the results when all countries are included but with the more pronounced effect of the banking crisis dummy, as the coefficient for banking crisis dummy is negative and significant for all cases.

[1]I also run the pooled OLS, that is, without the fixed effect. The results are in line with the results in the above baseline regression. Results are available from the author upon request.

Table 3.4: Macro Regression (cr=credit to GDP ratio, Emerging Markets)

	(1) F.creditoutput	(2) F2.creditoutput	(3) F3.creditoutput
bankingcrisis	-0.0377***	-0.0702***	-0.0872***
	(-3.73)	(-5.38)	(-5.98)
creditoutput	0.863***	0.738***	0.649***
	(51.05)	(33.45)	(25.93)
trough	-0.0277*	-0.0253	-0.0196
	(-2.02)	(-1.44)	(-1.00)
_cons	0.0677***	0.126***	0.168***
	(9.51)	(13.69)	(16.31)
N	834	808	782

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.5: Macro Regression(cr=deviation from HP-filtered trend, Emerging Markets)

	(1) F.hp_lnrealcredit	(2) F2.hp_lnrealcredit	(3) F3.hp_lnrealcredit
bankingcrisis	-0.0963**	-0.135***	-0.0780*
	(-3.08)	(-4.31)	(-2.41)
hp_lnrealcredit	-0.144***	-0.218***	-0.161***
	(-4.11)	(-6.32)	(-4.52)
trough	-0.0130	0.00999	0.00509
	(-0.31)	(0.24)	(0.12)
_cons	0.0153	0.0175	0.00911
	(1.39)	(1.59)	(0.79)
N	807	781	755

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.2.2 Micro Data

A recovery of output without an accompanying recovery suggests the possibility of changes in sources of financing at the firm level. Here I investigate firm level changes in financing sources around financial crises.

Data come from enterprise surveys of the World Bank. The World Bank conducts a survey of business and investment environment that covers a broad range of developing economies. For each country, the survey is designed to cover a sample of firms that matches the distribution in that country's private sector. While the survey asks questions in broad areas concerning investment environment, including corruption, infrastructure, I focus on the questions regarding the sources of investment financing.

I investigate the link between the incidence of banking crises and sources of investment financing. I use all the enterprise surveys conducted between 2006-2009. It includes 70 surveys, all for different countries. I run a pooled regression with the following specification:

$$y_i = \beta_0 + \beta_1 * \text{bankingcrisis}_i + \beta_2 * \text{vector of control}_i + \epsilon_i \tag{3.2}$$

y is proportion of financing of fixed asset investment for five possible sources, internal financing, bank financing, equity/owner's fund financing, trade credit financing, and other sources. Banking crisis dummy is the same as in the regression for aggregate data above. $\text{bankingcrisis}_i = 1$ if country in which firm i is located was experiencing a banking crisis when the survey took place. I am interested in

β_1, the coefficient for the banking crisis dummy. A vector of control variables is included in order to control for characteristics of the firm that can affect a firm's choice of financing. I include a categorical variable for firm size. A firm is defined large if the number of employees is over 100, and defined to be medium-sized if it is over 20 and smaller than 100, small if it is less than 20. Additionally, I include a dummy variable for exporter. A firm is defined to be an exporter if the proportion of export in total sales is larger than 10 percent. A dummy variable for banking crises three years later is included in order to check for reverse causation from financial structure to the incidence of banking crises. Because Laeven and Valencia's index is available only up to 2009, I constructed the index myself applying their definition of the banking crises for any country-year pair missing from their index. In one specification, I also include credit to output ratio in 2006, the starting year in the sample period in order to control for financial development. Notice that no country in the sample had banking crisis in 2006. Thus credit to output ratio in 2006 represents financial development in normal times, without being affected by banking crisis.

From table 3.6, I find that banking crisis dummy is associated with higher proportion of internal financing and equity/owners' own financing, and lower proportion of bank financing, in their financing of fixed asset purchase.[2] The coefficients are significant at the 1 percent level. This effect remains even after taking into account other factors that affect other factors that affect the sources of financing.

[2]Results for trade credit and other sources as regressand are omitted as β_1 was not significant in these regressions.

Table 3.6: Pooled Regression

	(1)	(2)	(3)	(4)	(5)	(6)
	internal	bank	equity_own	internal	bank	equity_own
bankingcrisis	10.09**	-7.951***	4.204**	13.92***	-9.805***	4.344**
	(3.24)	(-5.68)	(3.20)	(4.10)	(-6.49)	(3.04)
postbankingcrisis	-3.737	7.869***	-2.876	8.651*	-0.494	-4.199**
	(-1.12)	(3.48)	(-1.88)	(2.38)	(-0.19)	(-2.61)
exp	0.0209	2.611	0.509	1.227	1.724	0.583
	(0.01)	(1.53)	(0.65)	(0.33)	(0.91)	(0.69)
small	19.23***	-6.426***	1.759	19.40***	-6.938***	1.948
	(4.08)	(-3.30)	(1.40)	(4.06)	(-3.46)	(1.48)
medium	5.994	-2.962	0.306	6.327	-3.544	0.191
	(1.11)	(-1.61)	(0.26)	(1.15)	(-1.90)	(0.16)
credoutput				-46.82***	29.78***	3.574
				(-6.36)	(5.65)	(1.60)
_cons	46.48***	22.50***	2.603*	60.95***	13.67***	1.391
	(9.95)	(12.35)	(2.31)	(12.83)	(6.56)	(1.07)
N	18471	13789	18472	15790	12270	15791

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Coefficients for control variables also have correct signs and are typically significant. Smaller firms tend to rely less on bank financing and more internal financing, and firms in countries with higher credit to output ratio in 2006 tend to rely more on bank financing and less on internal financing. Bank financing is closely associated with future incidence of banking crisis in the version without credit to output ratio in 2006. However, notice that most of the banking crisis incidence three years later is a continuation from current year's banking crisis, not present year's high reliance on bank financing causing a new banking crisis. This effect disappears in the version that controls for credit to output ratio.

3.3 The Model

This section presents a dynamic model of the firm. It is characterized by (i) shock to the debt limit, (ii) equity financing being allowed but only with quadratic issuance cost.

3.3.1 Setup

The risk-neutral firm that lives indefinitely maximizes the presented discounted value of dividends. Its production function is decreasing returns to scale in capital (k), the only input. It finances capital investment either by current period cash flow, non-state contingent debt (b), or equity (d if $d < 0$). Debt issuance is subject to a stochastic collateral constraint and equity issuance is subject to a quadratic cost. The firm also faces a standard productivity shock (z). The problem can be described recursively as the following.

$$V(k, b; z, \phi) = \max_{k', b', d} \{\varphi(d) + \beta EV(k', b'; z', \phi')\} \tag{3.3}$$

s.t.

$$d = zk^{\alpha} - F - (1+r)b + b' + (1-\delta)k - k' \tag{3.4}$$

$$\varphi(d) = \begin{cases} d & \text{if } d \geq 0 \\ d - \kappa d^2 & \text{if } d < 0 \end{cases}$$

β is a fixed subjective discount factor of entrepreneurs. r is the interest rate on the non-contingent bond, taken exogenously and fixed. I assume $\beta(1+r) < 1$ in order to prevent the firm from accumulating sufficient saving and thus escaping from binding borrowing constraint altogether. This assumption can be motivated by tax advantages of debt issuance and used for example by Jeanne and Korinek (2011). F is fixed cost of production, following Gomes (2001) and Gamba and Triantis (2008). $'$ denotes next period values. The firm pays dividend when $d > 0$ and issues equity when $d < 0$. Thus specification of $\varphi(d)$ includes the quadratic equity issuance cost. Equity issuance cost can be rationalized by transaction cost or asymmetric information, and this specification is similar to Covas and Den Haan (2010b) and DeAngelo, DeAngelo, and Whited (2011). The two exogenous shocks are specified as follows:

- Exogenous productivity shock

$$z \in \{z^l, z^m, z^h\} \tag{3.5}$$

- Exogenous shock to debt limit

$$b' \leq \phi k' \tag{3.6}$$

$$\phi = \begin{cases} \phi^h & \text{high debt limit} \\ \phi^l & \text{low debt limit} \end{cases}$$

The productivity shock takes three values that follow Markov process. Unlike Dagher (2010), there is no trend shock to productivity. The borrowing limit shock takes two values that follow Markov process.

The collateral constraint is rationalized as the following. When the borrower attempts to default, the lender can confiscate fraction ϕ of the physical capital whose price is fixed at 1. The lender cannot confiscate current period cash flow, which is fungible. As a result, the repayment obligation must not exceed $'$. ϕ is known at the time of the lending.

The shock to debt limit is assumed to be a purely exogenous process that is orthogonal to the producivity shock. This assumption can be rationalized from the perspective of the firm, which has to take as given the shock that happens at the aggregate level. The model also abstracts from any tool to hedge against this credit shock.

3.3.2 Characterization of Solution

First order conditions and envelope conditions are as follows, where η and μ is the Lagrangian multiplier of budget constraint (3.4) and borrowing limit (3.6), respectively.

First order conditions

$$\varphi'(d) = \eta \tag{3.7}$$

$$\beta E V_k(k', b', z', \phi') - \eta + \mu\phi = 0 \tag{3.8}$$

$$\beta E V_b(k', b', z', \phi') + \eta - \mu = 0 \tag{3.9}$$

Envelope conditions

$$V_b(k, b, z, \phi) = -\eta(1 + r) \tag{3.10}$$

$$V_k(k, b, z, \phi) = \eta(\alpha z k^{\alpha-1} + 1 - \delta) \tag{3.11}$$

Combining them, optimal choice of k' and b' are summarized by (3.12), (3.13), and (3.14).

$$\varphi'(d) = \beta E\left[\varphi'(d')(\alpha z' k'^{\alpha-1} + 1 - \delta)\right] + \mu\phi \tag{3.12}$$

$$\varphi'(d) = \beta(1 + r)E\left[\varphi'(d')\right] + \mu \tag{3.13}$$

$$\mu\left(\phi k' - b'\right) = 0 \tag{3.14}$$

(3.12) and (3.13) are Euler equations for the choice of capital and debt, respectively. (3.12) trades off marginal value of one unit of resource in the current period and expected next period marginal value of additional capital both for production and collateral purposes. (3.13) trades off marginal value of one unit of resource in the current period and the sum of expected marginal cost of one unit of resources tomorrow and the shadow value of current period borrowing constraint. Intuitively, current period marginal value of one unit of resource is higher when the borrowing constraint is binding. (3.14) is the Kuhn-Tucker condition for the debt limit.

Rearranging (3.13) results in

$$\left[E\frac{\beta\varphi'(d')}{\varphi'(d)}\right]^{-1} = \frac{1+r}{1-\dfrac{\mu}{\varphi'(d)}} \tag{3.15}$$

Thus the cost of capital when financed by debt issuance is

$$\frac{1+r}{1-\dfrac{\mu}{\varphi'(d)}} - 1 \tag{3.16}$$

Similarly, rearranging (3.12) results in

$$\left[E\frac{\beta\varphi'(d')}{\varphi'(d)}\right]^{-1} = E\left(\alpha z' k'^{\alpha-1} + 1 - \delta\right) + \frac{\operatorname{cov}(\beta\varphi'(d'), \alpha z' k'^{\alpha-1} + 1 - \delta) + \mu\phi}{E\left[\beta\varphi'(d')\right]} \tag{3.17}$$

Thus the cost of capital when financed by equity issuance is

$$E\left(\alpha z' k'^{\alpha-1} + 1 - \delta\right) + \frac{\operatorname{cov}(\beta\varphi'(d'), \alpha z' k'^{\alpha-1} + 1 - \delta) + \mu\phi}{E\left[\beta\varphi'(d')\right]} - 1 \tag{3.18}$$

3.3.2.1 Costless Equity Issuance

Let us abstract from equity issuance cost for a moment. Now the optimality conditions and the budget constraint are the following.

$$1 = \beta E(\alpha z' k'^{\alpha-1} + 1 - \delta) + \mu\phi \tag{3.19}$$

$$1 = \beta(1 + r) + \mu \tag{3.20}$$

$$\mu\left(\phi k' - b'\right) = 0 \tag{3.21}$$

$$d = zk^{\alpha} - F - b + (1 + r)b' + (1 - \delta)k - k' \tag{3.22}$$

Simplifying the model this way allows us to derive analytical results for the composition of sources of investment financing. I establish a couple of lemmas.

Lemma 1 (**Always Binding Borrowing Constraint**). *When equity issuance is costless, borrowing constraint is always binding.*

Proof. Immediate from the assumption $\beta(1 + r) < 1$ and (3.20). □

Lemma 2 (**Optimal choice of capital**). *When equity issuance is costless, next period capital is an increasing function of expected next period productivity and debt limit parameter ϕ.*

Proof. From (3.19) and (3.20),

$$k' = \left(\frac{\beta\alpha E z'}{\beta(r + \delta) + \mu(1 - \phi)}\right)^{\dfrac{1}{1-\alpha}} \tag{3.23}$$

Clearly a function only of $E(z')$ and ϕ with $\frac{dk'}{dE(z')} > 0$ with $\frac{dk'}{d\phi} > 0$. $\square$

While the reason for the effect of expected productivity on the level of optimal choice of capital is intuitively clear, the effect of the parameter of debt limit on capital is related to the role of capital as collateral and the assumption $\beta(1+r) < 1$. Because capital has the role of collateral, an increase in ϕ implies that the marginal contribution of an additional unit of capital to the debt capacity is now larger. Given the assumption $\beta(1 + r) < 1$, optimal borrowing constraint is always binding as shown in Lemma 1. Thus the higher debt capacity necessarily beneficial to the firm. Investment can be financed by either issuing new debt or dividend reduction/equity issuance.

Using the lemmas above, I show the following proposition on the composition of investment financing.

Proposition 7 (**Credit shock and financing**). *When equity issuance is costless and if the effect of credit shock on optimal capital is small, a negative shock in credit with unchanged expected productivity leads to substitution of financing out of debt into equity financing.*

Proof. From (3.21) and Lemma 2,

$$b' = \phi k' \tag{3.24}$$

From (3.21), (3.22) and Lemma 2,

$$d = zk^{\alpha} - F - (1+r)b + (\phi - 1)k' + (1-\delta)k \tag{3.25}$$

Totally differentiating them, I obtain

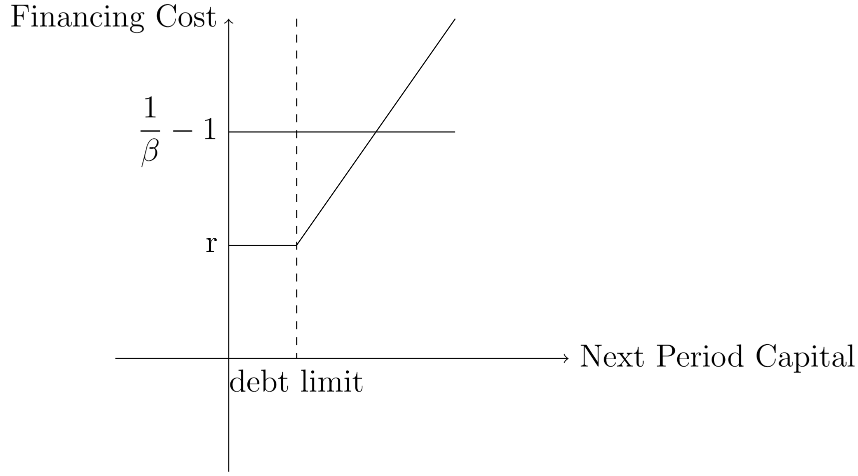
$$\frac{db'}{d\phi}|_{z=\bar{z}} = \frac{\partial b'}{\partial \phi} + \frac{\partial b'}{\partial k'}\frac{\partial k'}{\partial \phi} \tag{3.26}$$

$$\frac{dd}{d\phi}|_{z=\bar{z}} = \frac{\partial d}{\partial \phi} + \frac{\partial d}{\partial k'}\frac{\partial k'}{\partial \phi} \tag{3.27}$$

The first terms on RHS are $\frac{\partial b'}{\partial \phi} = k' \geq 0$ and $\frac{\partial d}{\partial \phi} = k' > 0$. If $\frac{\partial k'}{\partial \phi}$ is small that its effect is negligible, $\frac{db'}{d\phi} > 0$ $\frac{dd}{d\phi} > 0$ holds. □

Proposition 7 is key to understanding the substitution of financing sources and the creditless recovery result. It shows that similar levels of investment can be financed by different combinations of debt issuance and internal financing/equity issuance, and that the combination is dependent on the initial states. Assuming the effect of ϕ on k' is negligible, expected next period productivity $E(z')$ and initial capital k determines optimal investment. The firm finances the investment first by borrowing to the limit, reflecting the assumption $\beta(1+r) < 1$. The net debt capacity depends on the collateral constraint parameter ϕ and initial debt b. Dividend d is obtained as the residual. If the external borrowing is not sufficient to finance investment, the firm issues equity by setting $d < 0$. Suppose for example ϕ decreases for given $E(z')$, k, b. Now net debt capacity is lower for the same investment opportunity. Then the same level of investment is maintained by replacing the

Figure 3.4: Cost of Capital



lower net borrowing by decreasing retained earnings ($d > 0$) or costlessly issue equity ($d < 0$).

The firm borrows up to the debt limit because the cost of debt financing r is always lower than the firm's intertemporal rate of substitution, $\frac{1}{\beta} - 1$. After reaching the debt limit, the firm switches to equity financing. As equity financing increases to finance investment, the Lagrange multiplier continues to increase (an increase in effective interest rate) until it equals the intertemporal rate of substitution in equilibrium.

I also establish the relationship between the productivity shock and the capital structure. It turns out that the direction of debt issuance is clear but the direction of equity issuance is ambiguous, depending on the effect of the change in capital on debt capacity.

Proposition 8 (Productivity shock and financing). *When equity issuance is costless and if the productivity shock is persistent, an increase in productivity increases both capital and debt.*

Proof. $\frac{\partial k'}{\partial E(z')} > 0$ from Lemma 1. $\frac{\partial E(z')}{\partial z} > 0$ if we assume persistence in productivity shock. Thus $\frac{dk'}{dz}|_{\phi=\overline{\phi}} = \frac{\partial k'}{\partial E(z')}\frac{\partial E(z')}{\partial z} > 0$. This also implies $\frac{db'}{dz}|_{\phi=\overline{\phi}} > 0$ using Lemma 2 and (3.21). □

An increase in productivity increases optimal next period capital because of the persistence in productivity shock, which in turn increases debt capacity through the collateral constraint. Debt increases to the new, higher collateral constraint, financing the increase in capital.

3.3.2.2 Costly Equity Issuance

While abstraction from equity cost allows us to derive analytical results, this assumption and its implication in lemma 2 is not necessarily realistic. In practice, adjustment of capital is slow and capital is not adjusted to the level that reflects the expected productivity every period. Thus I reintroduce the equity issuance cost to the model to reflect this. [3] Nevertheless, the analytical results obtained in proposition 7 are useful in understanding the numerical results below.

When equity issuance cost is added, capital choice reflects equity issuance cost as well as expected productivity of capital. Next period capital is again determined by the Euler equation (3.12), tradeoff between the marginal value of current period additional unit of resource (the cost of dividend reduction or equity issuance) and expected marginal value of next period capital, taking into account expected next period equity issuance cost. In particular, costly equity issuance decrease the op-

[3] In practice, firms may face costs in other aspects of financial transactions. See Gamba and Triantis (2008), Hennesey and Whited (2005), Bolton, Chen, and Wang(2009) for models with multiple transaction costs.

timal investment. Thus the introduction of equity issuance cost leads to gradual adjustment of capital in response to exogenous shocks.

The introduction of equity issuance cost would also imply that the firm may not always exhaust its borrowing capacity. It is because accumulating excessive debt would lead to high debt repayment and runs the risk of having to resort to costly equity issuance next period. Next period debt is again determined by the Euler equation (3.13). The intertemporal rate of substitution is now $\left[E\frac{\beta\varphi'(d')}{\varphi'(d)}\right]^{-1} - 1$. When the risk of having to resort to costly equity issuance next period is large, $\left[E\frac{\beta\varphi'(d')}{\varphi'(d)}\right]^{-1} - 1 = r$ and equilibrium is reached before the debt limit is reached.

3.4 Numerical Solution

I describe a decision rule based on numerical simulation. I assume one period to be a year. Parameters are in table 3.7 and the transition matrices for the two shocks are the following.

- Transition matrix for productivity shock

$$\begin{bmatrix} P_{ll} & P_{lm} & P_{lh} \\ P_{ml} & P_{mm} & P_{mh} \\ P_{hl} & P_{hm} & P_{hh} \end{bmatrix} = \begin{bmatrix} 0.5 & 0.25 & 0.25 \\ 0.25 & 0.5 & 0.25 \\ 0.25 & 0.25 & 0.5 \end{bmatrix} \tag{3.28}$$

- Transition matrix for debt limit

$$\begin{bmatrix} P_{ll} & P_{lh} \\ P_{hl} & P_{hh} \end{bmatrix} = \begin{bmatrix} 0.1 & 0.9 \\ 0.1 & 0.9 \end{bmatrix} \tag{3.29}$$

Table 3.7: Calibration Parameters

Parameters	**Values**	**Description**
α	0.45	Degree of DRS, Gamba and Triantis (2008)
r	0.04	Standard for annual data
β	$\frac{1}{1+r}$-10^{-3}	$\beta(1+r) < 1$
κ	0.05	
ϕ^l, ϕ^h	0, 0.7	No new borrowing if $\phi = \phi^l$
z^l, z^m, z^h	0.9, 1, 1.1	

The details of the numerical method is the following.

- Given the non-linear, non-smooth nature of our model, we use modified policy function iteration with the use of McQueen-Porteus error bound, as described in Rust (1996).

- $k \times b = 51 \times 51$ grids

- Grid for b is equal-spaced, grid for k is constructed as $\overline{k} * (1-\delta)^i$, $i = 1, 2, ...51$. $\overline{k}$ satisfies $z^h \overline{k}^\alpha - (r+\delta)\overline{k} = 0$. As described in Gomes (2001), $k > \overline{k}$ is not economically profitable.

Figure 3.5 describes the decision rule when new borrowing is not allowed ($\phi = 0$) and productivity is median ($z = z^m$) in the current period.

First notice that debt limit is clearly binding throughout as shown in the upper-left panel. Decision rules for other variables differ whether $d \geq 0$ or $d < 0$.

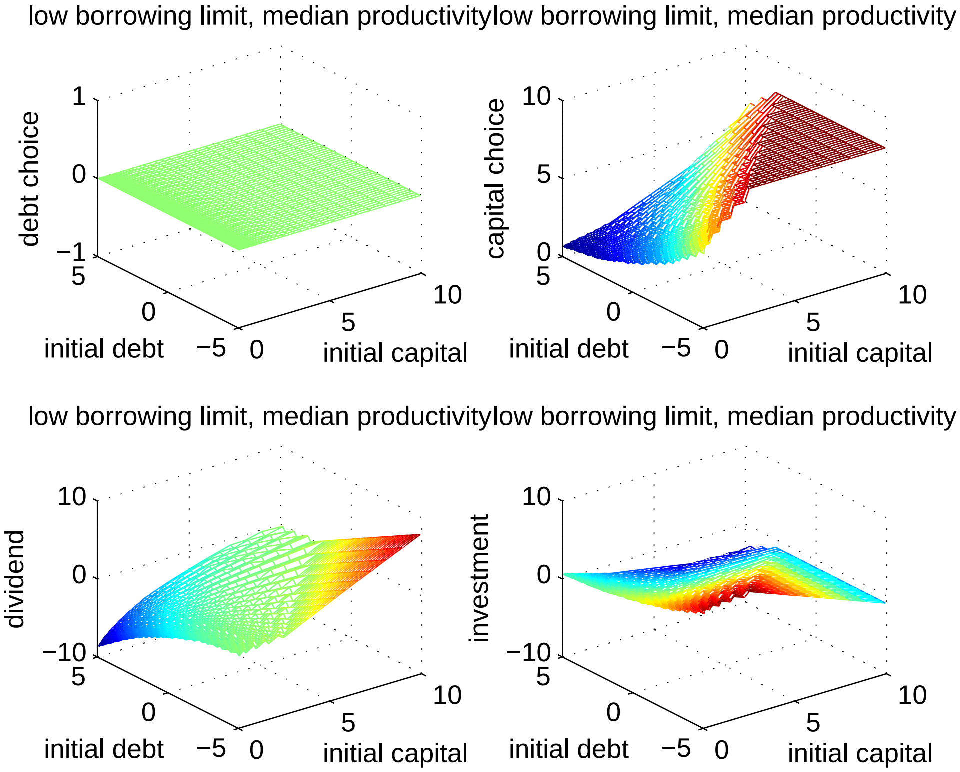
For high k and low b, the optimal decision leads to $d \geq 0$. The firm sets k' at a constant level that approximately reflects expected next period productivity $\mathrm{E}(z')$. As a result, investment is smaller for higher k and is invariant in b, as seen in lower-right panel. Dividend is higher for larger k because of the higher current period cash flow and lower need for investment and for smaller b because of the higher current period cash flow, as seen in lower-left panel.

For low k and high b, k' is smaller because now the optimal choice would entail equity issuance as seen by $d < 0$ in the lower-left panel. Given the quadratic cost, the higher the equity issuance, the marginal cost of financing is higher. Thus it is lower for larger b, because the larger debt repayment obligation decreases current period cash flow, requiring greater reliance on equity issuance. It is also lower for smaller k, because the lower initial k and binding borrowing constraint implies that more equity issuance is needed to get to the same k'.

Figure 3.6 describes the decision rule when new borrowing is allowed ($\phi = \phi^h$) and productivity is median ($z = z^m$) in the current period.

For high k and low b, the firm chooses not to exhaust its debt capacity. A constant level of k' is achieved by current period cash flow without resorting to equity issuance. As explained above, borrowing to the limit would run the risk of costly equity issuance next period. As a result, the firm chooses not to exhaust its debt capacity even though $\beta(1 + r) < 1$. For low k and high b, however, the firm chooses to exhaust its debt capacity and further issue equity. Given the equity issuance cost, an increase in financing by debt issuance contains current period financing cost, outweighing the expected cost of debt repayment next period. In this region,

Figure 3.5: Decision rule ($\phi = \phi^l$)

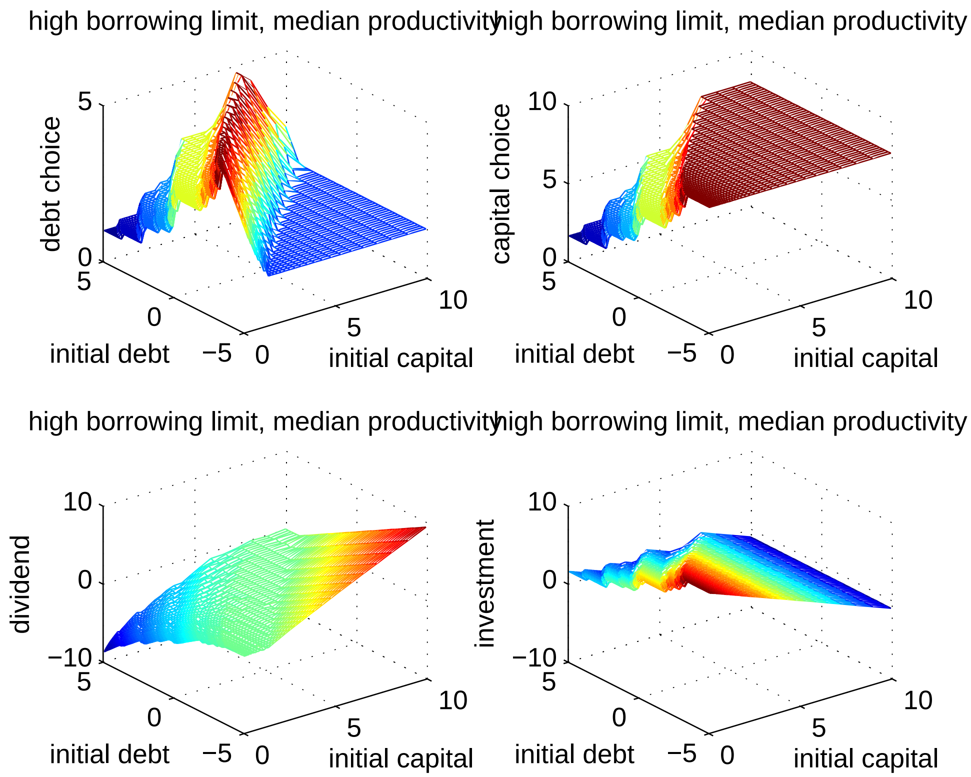


k' is smaller as the level of equity issuance is larger because the quadratic equity issuance cost implies that the financing cost is higher.

3.5 Simulation Results

In this section, I first generate ergodic distribution in order to explore the relationship between output and equity payout, debt issuance, and investment. Then I simulate the model to a particular series of shocks. I show that creditless recovery can result as an optimal response by the firm to a persistent negative credit shock. I also experiment with the symmetric shock of persistent, positive credit shock, akin to credit boom. Subsequently I perform a set of sensitivity analyses and illustrate how the model dynamics are affected when changing initial size of debt or when

Figure 3.6: Decision rule ($\phi = \phi^h$)



negative credit shock still allows for some debt in the balance sheet.

3.5.1 Ergodic Distribution

I document here the correlation between output and debt issuance, equity issuance, and investment. I run a Monte-Carlo simulation of 100000 periods. Simulations are run with both shocks and with productivity shock only, fixing $\phi = \phi^h$, in order to illustrate the effect of credit shock. Table 3.8 summarizes the results.

The firm is much more leveraged on average when it faces the productivity shock only. Volatility of both debt and equity payout is much higher when the firm faces both shocks. In terms of correlation with output, equity payout, debt issuance, and investment are all procyclical whether the firm incurs both shocks or productivity shock only. With both shocks, output is correlated more with equity issuance and less with debt issuance. It is also less correlated with investment.

Table 3.8: Ergodic Distribution

	Both shocks	**Productivity shock only**
Mean equity payout	1.17	1.07
Std equity payout	0.65	0.35
Mean Debt	2.16	4.86
Std Debt	0.90	0.10
Mean Capital	8.24	8.35
Std Capital	0.53	0.42
corr. with equity payout	0.27	0.23
corr. with debt issuance	0.04	0.33
corr. with investment	0.15	0.39

The contrasting behavior can be highlighted by comparing sample time-series starting from the same state, as shown in figure 3.7. Red lines denote series with both shocks. The firm without the credit shock quickly leverages itself and pay out dividends. Also note that the firm chooses not to exhaust its borrowing capacity in the presence of credit shock.

These results can be interpreted as the following. When credit shock exists, credit may not be available as needed. Knowing that, the firm retains more earnings when credit constraint is more relaxed, and draw it down when the constraint is tighter. In contrast, the firm quickly leverages itself and provides large equity payout in initial periods in the absence of credit shocks.

Figure 3.8 shows frequency distribution for equity payout, debt, and capital. Red lines denote distribution with both shocks. It confirms that debt is lower on average and more disperse if there are credit shocks. Dividend is never negative if there is no sudden stop. Without credit shock, the firm can avoid costly equity

Figure 3.7: Both shocks v. productivity shock only: sample time-series from same state

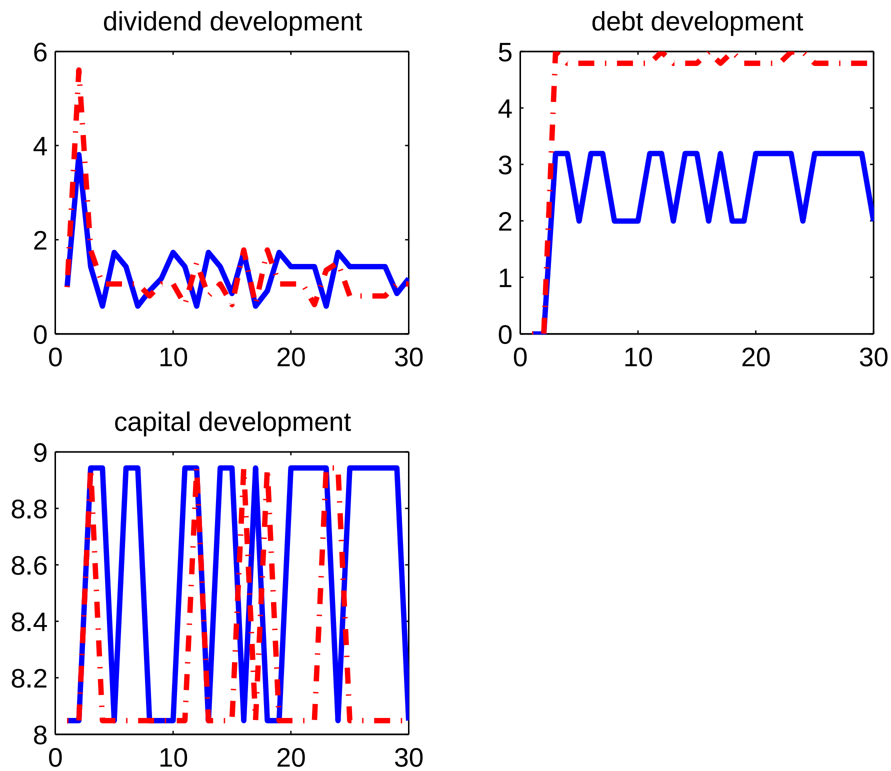
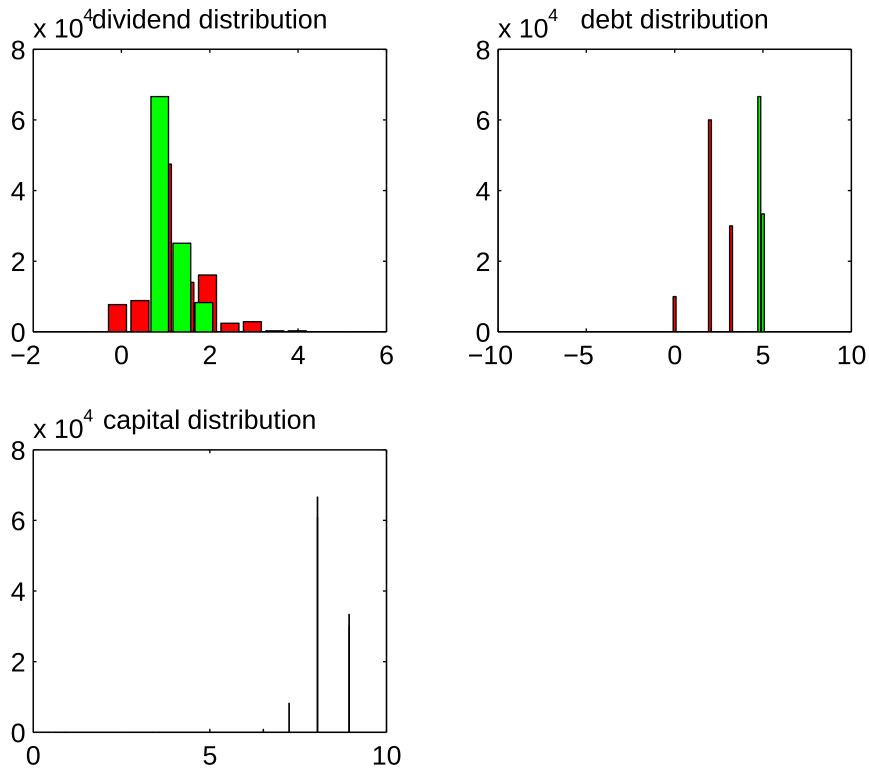


Figure 3.8: Frequency plot

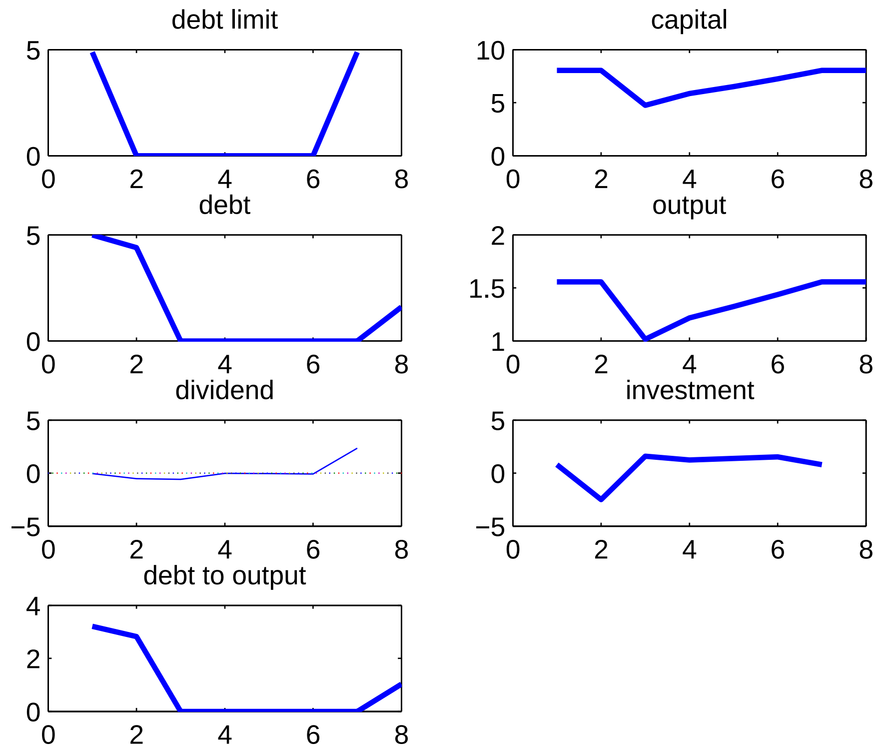


issuance. With credit shock, dividend is much more disperse and includes negative values occasionally. Capital takes only a few values, reflecting relatively low persistence of productivity shock.

3.5.2 Simulated time series path

I consider a particular series of credit shocks that intend to replicate the external financing environment that firms face in the aftermath of the financial crises. In the scenario that extend for 8 periods,the firm incurs loss of access to new borrowing in period 2, which continues for 5 periods. Productivity stays at $z = z^m$ throughout. Initial capital is set as $k_1 = (\frac{1-\beta(1-\delta)}{\beta\alpha})^{\frac{1}{\alpha-1}}$, optimal level of capital for frictionless world and $z = z^m$. Initial debt is set at the debt limit with $\phi = \phi^h$. The

Figure 3.9: Credit Shock Time Series

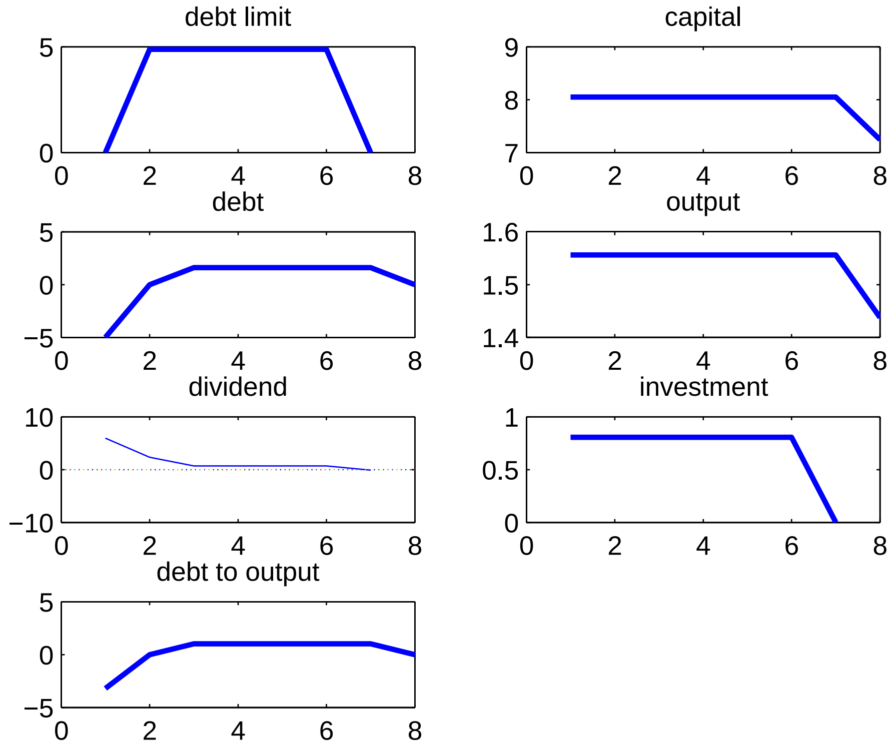


results are shown in figure 3.9.

On impact of the shock in $t = 2$, the firm is forced to repay a large amount of debt, financed by equity issuance and sale of capital. Subsequently from $t = 3$ to $t = 6$, the firm makes positive investment, financed by equity issuance or lowering dividend payment. In $t = 7$, the firm regains access to new borrowing and starts to accumulate debt again.

This experiment makes two points. First, ouput can recover without credit provision, by resorting to equity financing or retained earnings. Second, the recovery is gradual because the equity financing is costly. These results are consistent with empirical evidence in Claessens et al. (2008) and Abiad et al. (2011) that point to creditless recovery taking place but recovery being weaker.

Figure 3.10: Credit Boom Time Series



Now let us consider an experiment contrary to sudden stop, that of credit boom. The firm starts with no debt capacity, but will obtain debt capacity between $t = 2$ and $t = 5$. In $t = 6$ and $t = 7$, the firm again faces lower debt limit. The firm starts with positive saving. In figure 3.10, the firm quickly accumulates debt and allocates it as dividend. Because there is no change in productivity and therefore no change in expected productivity, investment does not change.

3.5.3 Sensitivity Analysis

In this subsection I compare time series for different parameters in order to assess model properties. In particular, I experiment with different initial level of debt and different volatility in borrowing limit, and change in maturity.

3.5.3.1 Changes in Initial Level of Debt

High leverage often precedes financial crisis, as documented in Tornell and Westermann (2005), Mendoza and Terrones (2008). Furthermore, creditless recovery is frequently associated with preceding credit booms, as documented in Abiad, Dell'Arricia, and Li (2011). At the firm level, high leverage is associated with lower investment (Bleakley and Cowan (2009))

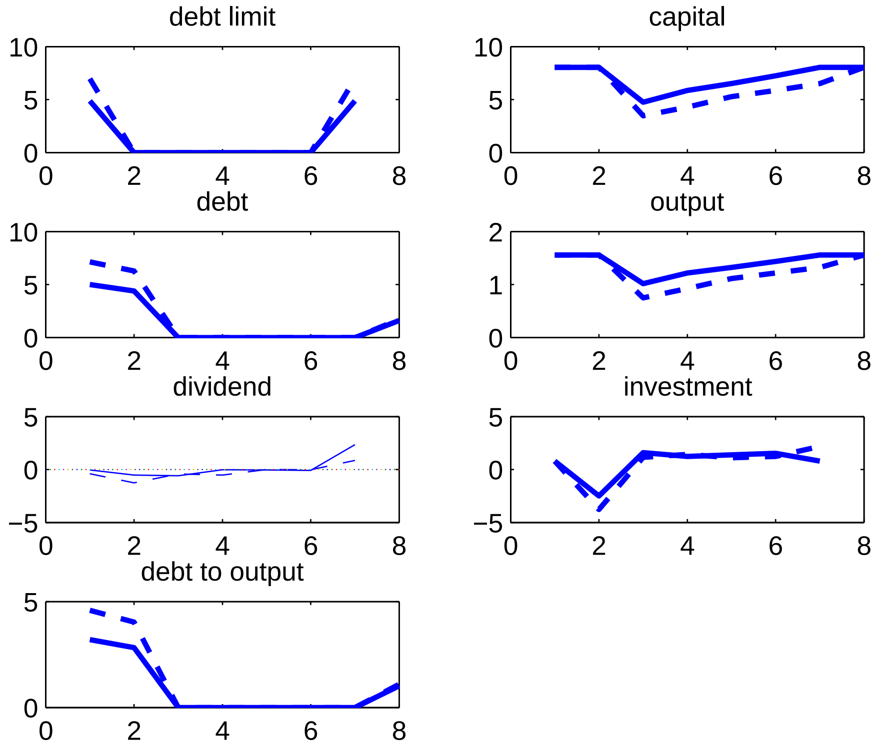
In order to explore the effect of high leverage on model dynamics, I set $\phi^h = 1$ instead of benchmark case $\phi^h = 0.7$, while maintaining everything else as in the benchmark case. Figure 3.11 shows the result. Overall dynamics are similar to the benchmark case. Initial deleveraging is more pronounced than the benchmark case. Because of increasing equity issuance cost in the level of issuance, the higher debt repayment is not fully offset by equity issuance, leading to lower investment than in the benchmark case. Subsequent investment broadly parallels the benchmark case. Output recovery is slower as a result.

3.5.3.2 Smaller Credit Shock

Abiad et al. (2011) document that creditless recovery is more frequent in emerging and developing economies than in industrial economies. It is also widely believd that the capital market imperfections are more extreme in the emerging markets and developing economies than in the industrial economies. Here I decrease the fluctuation of borrowing limit from $\phi^h = 0.7, \phi^l = 0$ to $\phi^h = 0.7, \phi^l = 0.3$.

Figure 3.12 shows the result. Smaller gap between ϕ^h and ϕ^l implies that

Figure 3.11: Credit Shock Time Series (larger initial debt)

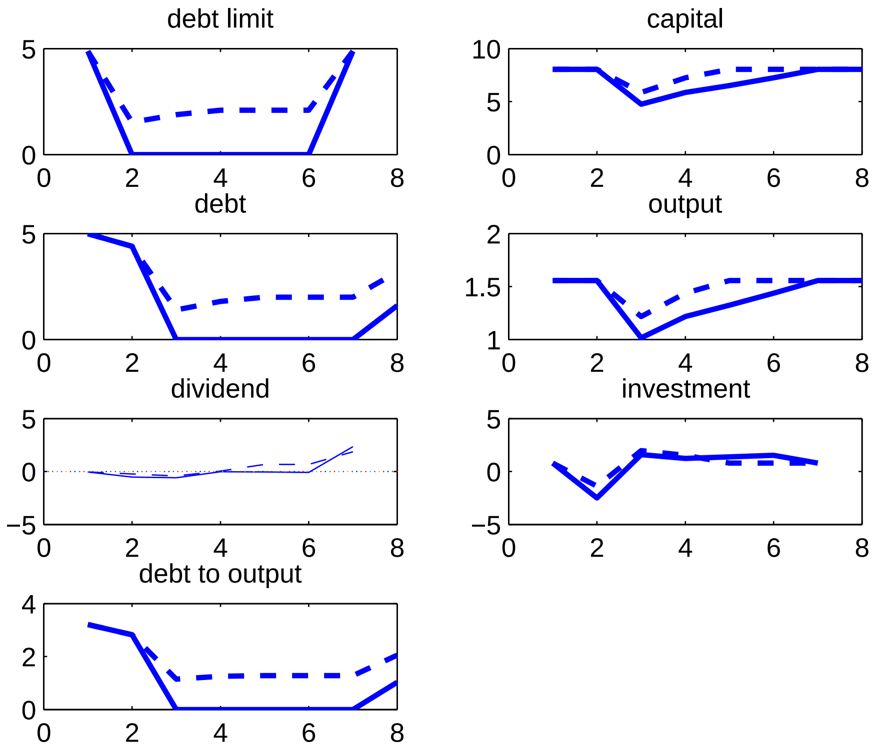


forced adjustment is smaller. Thus the response is more gradual compared with the benchmark case. Unlike the benchmark case, the economy never has to repay all its debt even after an extended period of negative credit shocks. As a result, the debt to output ratio decreases much less. There is no discernible pattern of creditless recovery. This result is consistent with Abiad et al. (2011)'s empirical evidence.

3.5.3.3 Introduction of long-term bonds

Benchmark case made a standard assumption of one-period debt. However, in practice a substantial fraction of debt has long-term maturity. Here I introduce

Figure 3.12: Credit Shock Time Series (Smaller Credit Shock)



long-term debt by modifying the borrowing constraint of the model (3.6) to:

$$b' \leq \max[\phi k', (1-\lambda)b] \tag{3.30}$$

λ is a proportion of the principal of the existing debt that needs to be repaid each period. Setting $\lambda = 1$ reduces the model to standard one-period debt. This is a simple way to introduce variation in maturity while maintaining tractability of the model. See Komatsuzaki (2011) and reference therein for other examples. A smaller λ implies a shock to the new borrowing is mitigated because a debter is not forced to repay all existing debt.

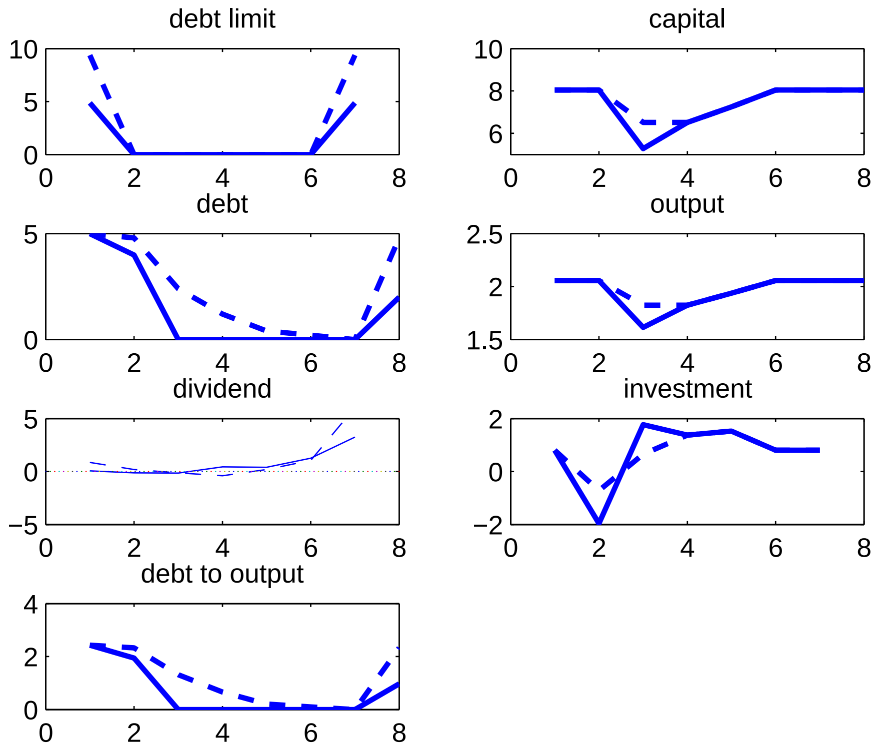
Figure 3.13 compares the transition with the benchmark case for $\lambda = 0.5$. Overall dynamics is smoother and more gradual than the benchmark case. The negative credit shock does not force the firm to repay debt all at once. Debt to output ratio slightly increases after the initial credit shock in fact, before the sequence of negative shocks decreases it. Because of the smaller repayment, the firm has more cash flow in $t = 2$ than in the benchmark case. Thus it does not have to decrease capital as sharply as the benchmark case. This, one the other hand, means that the turnaround investment and output is delayed compared with bencmark case because of the decreasing return to scale assumption. In $t = 4$, the decrease in capital increases expected next period marginal productivity of capital sufficiently. Simultaneously, the continuous develeraging decreases the burden of debt repayment and decreases financing cost of investment. The firm gradually increases its investment, supported by equity issuance. This again leads to creditless recovery. The creditless recovery happens only in the latter part of the simulation periods.

3.6 Conclusion

This paper investigates the relationship between credit shocks and firm financing patterns. It develops a parsimonious theoretical model in which the firm increases its reliance on retained earnings or equity issuance in response to a negative credit shock. The substitution mechanism in the model is supported by an empirical section that shows that investment is financed less by debt and more by internal fund/equity at the time of banking crises.

Empirically, this paper shows that the incidence of banking crises are associated with stagnant credit developments in the following years at the aggregate level.

Figure 3.13: Credit Shock Time Series(Long-term Debt)



It also shows using the firm data that the existence of banking crisis is associated with higher use of internal fund and equity financing and lower use of bank fund for financing investment.

Theoretically, this paper proposes a dynamic model of the firm that is consistent with the above empirical facts. Key assumptions are: (i) shock to the borrowing limit as well as standard productivity shock, (ii) equity financing is allowed but with a friction in the form of quadratic issuance cost.

This paper compares long-run distributions of the model with and without credit shocks. It finds that The firm is much more leveraged and has lower equity ayout on average when it faces the productivity shock only. In terms of correlation with output, equity payout, debt issuance, and investment are all procyclical whether the firm incurs both shocks or productivity shock only. With both shocks, output is correlated more with equity issuance and less with debt issuance. It is also less correlated with investment.

In response to an exogenous shock that curtails new bank borrowing, the firm chooses to use current period cash flow or issue equity in order to fund investment when it expects next period productivity to be high. This way the firm can expand its output without an accompanying increase in debt, generating creditless output recovery.

A.1 Data Sources

Data Series	Source
Reserves	Lane and Milesi-Ferretti (2007)
Gross Debt	Lane and Milesi-Ferretti (2007)
GDP	WEO
GDP deflator	WEO
Consumption	IFS
U.S. Treasury Bonds Interest Rates	GFSR, WEO
EMBI+, EMBI Global	WEO

A.2 Equilibrium conditions

For $\bar{b} = b^h$ the problem is the following.

$$V^h(a, b; y) = \max_{a', b', c} \left\{ u(c^h) + \beta \int_{y'} \left(P_{hl} V^l(a', b'; y') + (1 - P_{hl}) V^h(a', b'; y') \right) f(y', y) dy' \right\} \tag{31}$$

The first-order conditions are the following. μ^h, ψ^h, η^{ha}, η^{hb} are Lagrange multipliers for (2.2), (2.3), (2.4), (2.5), respectively.

$$\beta \int_{y'} \left\{ P_{hl} V_1^l(a', b', y') + (1 - P_{hl}) V_1^h(a', b', y') f(y', y) dy' \right\} - \mu^h + \eta^{ha} = 0 \tag{32}$$

$$\beta \int_{y'} \left\{ P_{hl} V_2^l(a', b', y') + (1 - P_{hl}) V_2^h(a', b', y') f(y', y) dy' \right\} - \mu^h + \eta^{hb} - \psi^h = 0 \tag{33}$$

The envelope conditions are the following:

$$V_1^h(a,b,y) = (1+r^s)\mu^h \tag{34}$$

$$V_2^h(a,b,y) = -(1+r)\mu^h \tag{35}$$

For $\bar{b} = 0$, the problem, first-order conditions, and envelope conditions are the following. μ^l, ψ^l, η^{la}, η^{lb} are Lagrange multipliers for (2.2), (2.3), (2.4), (2.5), respectively.

$$V^l(a,b;y) = \max\left\{u(c^l) + \beta\int_{y'}\big(P_{ll}V^l(a',b';y') + (1-P_{ll})V^h(a',b';y')\big)f(y',y)dy'\right\} \tag{36}$$

$$\beta\int_{y'}\left\{P_{ll}V_1^l(a',b',y') + (1-P_{ll})V_1^h(a',b',y')f(y',y)dy'\right\} - \mu^l + \eta^{la} = 0 \tag{37}$$

$$\beta\int_{y'}\left\{P_{ll}V_2^l(a',b',y') + (1-P_{ll})V_2^h(a',b',y')f(y',y)dy'\right\} - \mu^l + \eta^{lb} - \psi^l = 0 \tag{38}$$

$$V_1^l(a,b,y) = (1+r^s)\mu^l \tag{39}$$

$$V_2^l(a,b,y) = -(1+r)\mu^l + \psi^l(1-\lambda) \tag{40}$$

Combining the above optimality conditions, we obtain the following.

$$u'(c^i(a,b;y)) = \beta(1+r^s)\int_{y'}\big(P_{il}u'(c^{ll}(a',b';y'))+(1-P_{il})u'(c^h(a',b';y'))\big)f(y',y)dy'+\eta^{ia} \tag{41}$$

$$u'(c^i(a,b;y))+(\eta^{ib}-\psi^i) = \beta(1+r)\int_{y'}\big(P_{il}u'(c'^l(a',b';y'))+(1-P_{il})u'(c^h(a',b';y'))\big)f(y',y)dy' \\ - \beta(1-\lambda)P_{il}\int_{y'}\psi'^l f(y',y)dy' \quad (42)$$

$i = h, l$ is the current debt limit. (41) and (42) are the Euler equations for saving and debt, respectively. For these equations to be consistent with each other, we have the following observations.

(41) and (42) imply

$$\eta^{ha} = \beta(r-r^s)\int_{y'}\big(P_{il}u'(c'^l(a',b';y')) + (1-P_{il})u'(c^h(a',b';y'))\big)f(y',y)dy' \\ + (\psi^i - \eta^{ib}) - \beta P_{il}(1-\lambda)\int_{y'}\psi'^l f(y',y)dy' \quad (43)$$

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