Credit Termination and the Technology Bubbles

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November 2010

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This Draft: November 2010

Preliminary: Comments Welcome

Abstract

We study the role of firms' credit histories in a business cycle model. Loans are dynamic contracts between banks and firms, and credit terminations are used as an incentive device. Banks deny future loans to an entrepreneur according to his credit histories in order to affect his choice of project *ex ante*. This will generate fluctuations from technology shocks to the riskiness of different types of projects as occurred during the technology bubbles. The model is used to explain the boom-and-bust of the dot-com bubble, one leading example of technology bubbles in the economy, in the late 1990s.

*The author would like to thank David Frankel, Bhattacharya Joydeep, and Cheng Wang for helpful comments.

1 Introduction

In this paper, we study the dynamic interaction between financial intermediaries (banks henceforth) and firms, in particular the role of firms' credit histories, in a business cycle model. In our model, banks deny future loans to an entrepreneur (credit termination) in some states according to his credit history in order to affect his choice of project *en ante*. This will generate fluctuations in an economy not only from shocks to the mean output (productivity), but also from technology shocks to the variance of the output (riskiness).

We argue that the model can explain several of the stylized facts surrounding the investment mania in internet technologies, namely the dot-com bubble, in the late 1990s. The dot-com bubble should be considered as one leading example of technology bubbles in the economy. Economists have not paid enough attention to technology bubbles. Based on the efficient markets hypothesis, even psychological biases lead to trade irrationally, the prices of the stocks need not be irrational since the rational traders can arbitrage by short selling (Fama, 1965). However, the doctrine is violated from time to time in practice. The stock market performance during the dot-com bubble era, covering roughly from 1998 to 2001, is one of the most recent and biggest in terms of scope examples.

Figure I compares the NASDAQ Composite index and the S&P 500 index from 1995 to 2005. Normalizing the initial data to 100, we can see the significant deviation, peaked in the early 2000, during the bubble era. During that period, the whole stock market itself was in an uptrend as the S&P 500 index shows. However, the stocks of dot-com companies in the NASDAQ were growing even faster. The dot-com booming lasted more than two years and made people believe that it was a "new economy paradigm". But, compared to the non-internet sectors, there was nothing unusual in the internet sector that could explain the dot-com booming. It turned out to be a technology bubble.[1]

[Figure I here]

Why didn't the market correct the illusion of the investors? Existing literature focused on the limits of arbitrage in the market (see Shleifer and Vishny, 1997, among others). Ofek and Richardson (2003) find that substantial short sales restrictions affected dot-com stocks, e.g., the higher short interest, the higher borrowing costs. They also suggest there was heterogeneity across investors based on low level of institutional holdings in dot-com stocks. Prices could move substantially because optimistic and pessimistic investors might have very different beliefs on the stock prices. Moreover, rational arbitrageurs might ride the bubbles as the stock prices continue to grow and generate high returns (Abreu and Brunnermeier, 2003). In Abreu and Brunnermeier's model, the prices are bid up above their fundamental values by "irrationally exuberant" behavioral traders. As rational arbitrageurs are informed sequentially, bubbles can persist for a period of time. Selling pressure bursts the bubble when a sufficient mass of arbitrageurs has sold out of stocks. Following this logic, Brunnermeier and Nagel (2004) study the behaviors

[1] An interesting firm level example further supports the irrationality of the stock market is the misprice of Palm-3Com discussed in Lamont and Thaler (2003). Share price ratios are self-sustainable in a short period in their case.

of institutions (hedge funds) in the dot-com bubble. They find: first, the hedge funds were heavily invested in dot-com stocks instead of correcting the stock prices during the bubble. Second, hedge funds captured the upturn, and avoided much of the downturn by reducing their positions in stocks which were about to decline. Therefore, they support the argument that sophisticated investors were riding the technology bubble.

Previous literature limits to model the behaviors of investors in the stock market. And it is hard to explain why suddenly so many investors were enthusiastic about the internet sector. During that period, entrepreneurs entered the dot-com industry eagerly because they believed the information technologies contribute to organizational complements such as new business processes, new skills, and new organizational and industry structures Investors were convinced that technological innovations would improve productivity not just alter the preference. For example, David (1990) suggests that the spread of electricity provide an analogy to the internet technology.

So we offer a different story of the dot-com bubble. Tying the investors with the entrepreneurs, we put the story in a more general financial intermediation model. Banks are special in the sense that bank loans review private information about the borrowers (James, 1987). The stock market reacts to the signals (bank loans) about where to allocate the real resources in the economy. However, in our model, banks misunderstand the new technology due to information asymmetry. The misunderstanding of the investment opportunity leads to the bubble because the stock market believes banks have some good news about the new technology. The crash follows when banks observe a high default rate and tight the credit to the entrepreneurs.

Our model has two notable features. Firstly, in traditional business cycle models, shocks affect mean output of project. But we, in order to mimic the technological innovations, introduce a specific technology shock which brings a new type of project. Entrepreneurs prefer to invest in the new one due to the cutting-edge nature of the project. However, the project may not be profitable. Secondly, a bank could affect the entrepreneur's investment choice by cutting off the credit and restricting the flow of funds when the company has a bad performance. Credit termination could turn the entrepreneur's attention back to the profitability of the projects, but it also has some costs, e.g., the economic activities are reduced sharply.

More precisely, we assume the set of feasible investment projects changes before and after a technological innovation. Initially, each entrepreneur can invest in one of two projects: a good project with a high expected output and a bad project with a low expected output. As a standard assumption in a moral hazard model, the entrepreneur needs to pay an additional cost if he chooses the good project. Then technological innovation gives rise to a third type of project, which has the same mean output as the bad project but a higher variance. For example, before an innovation, suppose that each entrepreneur has two investment opportunities, either to produce food or to produce a movie. Food production, the "good" project, has a high expected output, while movie-production, the "bad" project, has a low expected output. Food production is a boring investment to an entrepreneur, so an incentive is needed in order to entice him to invest in this project instead of movie-production. After a technology shock, each entrepreneur has a new, even more glamorous option: to invest in a dot-com. This project has the same mean output as movie-production (the bad project), but is even riskier. Therefore, it is even more difficult to motivate an entrepreneur to invest in food production.

And in dynamic borrowing/lending relationships, banks, which cannot directly observe an entrepreneur's project choice, have two methods, each associated with a different cost, to motivate the project choice: (i) by giving a (limited liability) rent to the entrepreneur; or (ii) by cutting off the credit with some probability when the entrepreneur defaults. Stiglitz and Weiss (1983) pointed out "banks often deny future loans to defaulters rather than raising the interest rate that a defaulter would have to pay". We study contingency contracts in which bad outcomes may lead to an end of the borrowing/lending relationships. Credit is terminated with some probability or entirely when, due to low output in the past, the entrepreneur's continuation payoff is close to a threshold in which the bank can no longer motivate him to choose a good project in the future. The credit termination probability rises continuously from zero to one with the optimal rate determined by minimizing the costs to induce the entrepreneur's choice of project.

In the context of this model, we study the effect of the technology shock. The shock could worsen the entrepreneur's incentive problem. Since the shock is mean-preserving, if there are no financial frictions, there should be no fluctuations, that is, the entrepreneur will only choose the good project. But we assume that there are financial frictions. Initially, receiving the funds, the entrepreneur will choose the good project, but he is indifferent between the good and bad project because the good project entails an additional cost for him, that is, his incentive compatibility constraint binds. In response to a technological innovation, which creates a project which is even riskier and even more appealing to the entrepreneur, the residual claimant, the bank must strengthen the entrepreneur's incentive to choose the good project. Aggregate loans decrease due to two reasons: first, the bank will cut off the credit. When, due to search frictions, some of these banks fail to find alternative borrowers after they cut off the entrepreneur's credit, there will be more inefficient unemployment of resources, which is essentially what happened at the end of the bubbles. Second, banks need to transfer rents which, due to the zero-profit condition for the bank, entail a lower interest rate for depositors. This causes a decline in the supply of deposits, so there are even fewer loans after the credit termination.

The paper is structured as follows. We discuss related literature in the next section. In Section 3, we setup the basic model. We study the dynamic loan contract and an explicit solution for a special case with two projects and two output levels in Section 4. We solve the equilibrium and find the comparative static properties in Section 5.

2 Related Literature

The incentive effect of termination was first studied in a credit (or labor) market model by Stiglitz and Weiss (1983). Spear and Wang (2005) solved for the optimal termination conditions in a labor contract model (the executive contracts). They show that if the worker is risk-neutral, termination occurs when the worker is too poor to punish. On the other hand, if the worker is risk-averse, termination may occur when the worker is too rich to motivate. Our model results from embedding their risk-neutral case in a business cycle setting. In addition, we reinterpret the moral hazard problem as resulting from a choice of investment projects rather than a choice of effort levels. We focus on the effects of a technological innovation which provides entrepreneurs with a risky but glamorous new project.

In a dynamic setting, borrowing constraints have been found important in generating persistent fluctuations and amplifying business cycles (Scheinkman and Weiss, 1986; Kiyotaki and Moore, 1997). There have been efforts at explicitly modeling borrowing constraints and financial intermediation in equilibrium business cycle models. For example, Williamson (1987), and Bernanke and Gertler (1989) use a model with costly state verification to study the effects of asymmetric information between borrowers and lenders in business cycles. In Williamson, each firm has a different *en ante* auditing cost while in Bernanke and Gertler, the investment cost varies from one project to another. During a recession, inefficient firms are driven out of the market. The relationship between the firms and the intermediaries is static in those models.

However, the distribution of credit histories (or "financial capacity" in Gertler [1992]) across firms is an important determinant of aggregate economic activity (Smith and Wang, 2006). We introduce a dynamic loan contract model in which firms are *en ante* identical, but firms face different credit restrictions based on their prior performances. Compared to the one-period loan contract models, the dynamic loan contract model does not have to assume heterogeneous firms *en ante*. Thus, we endogenize firm's credit constraints in the equilibrium path by modeling that banks will keep records of firms' historic performances.

3 The Model Setup

Time is discrete and the horizon is infinite: $t = 1, 2, \ldots$. There is one perishable good which can be used as a consumption or investment good in the economy. Investment good can be used in the production of output.

The economy consists of a sequence of generations, each lives two periods. We assume there is one old agent alive for each young agent born. With an exogenous probability η, a newborn agent becomes an "entrepreneur". The rest becomes a "lender". There is no intragenerational heterogeneity within a class of agents. The number of births and the number of deaths are equal in each period, so the total measures of entrepreneurs and lenders in this economy are invariant.

3.1 Lenders and Entrepreneurs

A lender lives two periods, and she is endowed with h units of labor time supplied inelastically in the first period of her life, and each unit of labor time produce one unit of good.

Lenders, who live overlapping generations, maximize their expected utility $U(c_{1t}, c_{2t+1})$, where, for a lender born at time t, c_{1t} is the consumption at time t when she is young, and c_{2t+1} is the consumption at $t+1$ when she is old. Each unit of labor time produces one unit of consumption good when the lenders are young. Lenders cannot produce when they are old and do not access to any storage technology. However, they can deposit their goods in a financial intermediary.[2]

An entrepreneur lives two periods. Entrepreneurs are risk-neutral and born with zero initial wealth. But each entrepreneur accesses to a set of projects $\mathbb{M}$, and each project produces a stochastic output θ, which takes value from the finite set $\Theta \equiv \{\theta_1, \theta_2\}$ with $\theta_1 < \theta_2$, in each period of time. Given a project $j \in \mathbb{M}$, the output θ is distributed with a density $\pi_{ij} = \Pr\{\theta = \theta_i | \, j\}$, and $\pi_{1j} + \pi_{2j} = 1$. Each project is carried out with two inputs: one unit of capital (the investment good) and an entrepreneurial cost. In order to finance his project, the entrepreneur has to borrow from a bank in the financial market since he has no initial wealth.

For simplicity, suppose there are two types of projects, i.e., $\mathbb{M} \equiv \{1, 2\}$.[3] Assume $0 < \pi_{21} < \pi_{22} < 1$, that is project 1 has a small probability to produce a high output than project 2. We call project 1 a "bad" project and project 2 a "good" project. It is easy to check that our model satisfies the monotone likelihood ratio property (MLRP).

Definition 1 *The functions* $\Pr\{\theta = \theta_i | j\}$, *for* $j \in \mathbb{M}$, *are said to satisfy the MLRP: if* $j < j'$, *then* $\frac{\Pr\{\theta=\theta_i|j\}}{\Pr\{\theta=\theta_i|j'\}}$ *is non-increasing in* θ_i.

Normalize the entrepreneurial cost for the bad project to zero, i.e., $v_1 = 0$; and the cost for the good project is $v_2 = \psi > 0$.

Assume the entrepreneur's period utility function $H(c|j)$ is additively separable between the consumption and the entrepreneurial cost for any project j. Due to risk neutrality, the utility function takes the form $H(c|j) = c - v_j$, where $c \in \mathbb{R}^+$ denotes the entrepreneur's consumption and v_j measures the entrepreneurial cost for project j. We also assume that an entrepreneur has a reservation utility $w_0 = 0$ in each period.

3.2 Financial Intermediation

Financial intermediaries (banks) arise as institutions of delegated monitoring (Diamond, 1984). There are a large number of risk-neutral banks which gather deposits from the lenders and lend to the entrepreneurs. While banks cannot observe an entrepreneur's choice of project, they observe the project's *ex post* outcomes.[4] Since the outcome distri-

[2] Market is incomplete in the sense that there is no time zero "clearing house" organizes the aggregate demand and supply for goods in different periods.

[3] Restrict to two types of projects and two levels of outputs will not change the results and make the solution easy to follow.

[4] If an entrepreneur can repay her loan, she must repay it. The bank can observe the loan repayment status: success or failure.

bution depends on the project, the bank can infer the entrepreneur's behavior from the realized outcome. Therefore, the bank specifies a payoff arrangement to the entrepreneur conditional on the realized outcome (namely the terms of the financial contract) in order to motivate his choice of project. Terms of the contract will be specified in the next section.

Our model takes as given that there are ongoing relationships between entrepreneurs and banks. Banks lend to entrepreneurs and promises them a certain level of expected utility. Banks can offer long-term or/and short-term contracts. If it uses a long-term contract, then at the end of the first period, the bank has a choice to continue the loan contract or to cut off the credit line and replace the entrepreneur with a new one. If it is a short-term contract, it only lasts one period. The short-term contract is standard. Innes (1990) proved that with the MLRP and a constraint that the payoff function is non-decreasing in the outcome, the debt contract is an optimal contract in a static model. In general, the optimal contract may not be a standard debt contract in a dynamic relationship. However, we restrict our attention to those contracts which have a debt contract form in each period because debt contracts are commonly observed in practice.

4 The Loan Contracts

4.1 The Short-Term Loan Contract

Denote B_i the bank's payoff when the output is θ_i.[5] Let the bank's payoff be non-decreasing in the output. In each period, the payoff takes the standard debt contract form: the payoff is $B_i = \theta_i$ if $\theta_i < R$, and $B_i = R$ if $\theta_i \geq R$, where $R > 0$ is the interest rate the entrepreneur is charged. Limited liability constrains the loan contracts in two ways: the entrepreneur cannot repay more than his output, i.e., $B_i \leq \theta_i$; and the bank's liability is limited to its investment in the firm, i.e., $0 \leq B_i$. The latter one simply makes the entrepreneur's expected utility be bounded above so that the optimization problem is well defined. Let $c_i = \theta_i - B_i$ be the entrepreneur's payoff when the output is θ_i.

Definition 2 *A short-term loan contract is:* $\sigma_S = \{B_i\}_{i \in \{1,2\}}$.

Let $j \in \mathbb{M}$ be the project suggested by the bank. If the bank promises an entrepreneur a utility level w, its expected profit per loan from the short-term loan contract is:

$$V_l(w) = \max_{\sigma_S} \sum_{i=1,2} \pi_{ij} B_i - r, \tag{1}$$

subject to:

$$\sum_{i=1,2} \pi_{ij} c_i - v_j = w, \tag{2}$$

[5] Omit the time subscript without confusing in this section.

$$j \in \arg\max_{j' \in \mathbb{M}} \sum_{i=1,2} \pi_{ij'} c_i - v_{j'}, \tag{3}$$

where r is the bank's cost of collecting money from the lenders (or the interest rate paid to the lenders). The loan contract satisfies the promise-keeping constraint (2) and the incentive compatibility constraint (3).

Let $\overline{\theta}_j$ denote the expected output of project j, i.e., $\overline{\theta}_j = \sum_{i=1,2} \pi_{ij} \theta_i$. Given the cost of collecting money from the lenders, we assume it is never optimal to implement the bad project and the good project is socially efficient. That is, throughout the paper, we shall assume:

A1. $\overline{\theta}_1 \leq r < \overline{\theta}_2 - \psi$.

Assume the bank promises the firm $w \in \Phi \equiv [0, \overline{w}]$. Here Φ is the set of feasible utilities. The promise utility w is great or equal to 0, otherwise the entrepreneur can walk away. The upper bound $\overline{w}$ is from the limited liability of the bank. The constraints of the incentive problem (1) lead to a threshold expected utility $\underline{w}$ such that for any promised utility greater (less) than the threshold, the good project is (not) implementable.

Lemma 3 *There is a threshold expected utility, $\underline{w} = \pi_{21}\psi / (\pi_{22} - \pi_{21})$, such that for any promised utility greater than this threshold, the good project is implementable.*

The optimal contract is standard. The bank wants to punish the defaulters as severe as possible. Due to the limited liability, the entrepreneur's payoff c_i is nonnegative for $i \in \{1, 2\}$. Thus, the payoff is $c_1^* = 0$ when the project fails. And from the promise-keeping constraint (2), We have the following payoff functions when the project succeeds: (a) if $w \geq \underline{w}$, the good project is implemented and the entrepreneur's optimal payoff is: $c_2^*(w) = (w + \psi)/\pi_{22}$; (b) if $w < \underline{w}$, the good project cannot be implemented and the optimal payoff is: $c_2^*(w) = w/\pi_{21}$. Substitute the optimal payoff plan into (1). The value function of the bank conditional on lending to the entrepreneur is:

$$V_l(w) = \begin{cases} \overline{\theta}_2 - \psi - r - w, & \text{if } w \geq \underline{w} \\ \overline{\theta}_1 - r - w, & \text{if } w < \underline{w} \end{cases}. \tag{4}$$

4.2 The Long-Term Loan Contract

Following Spear and Wang (2005), we characterize the long-term relationship between the bank and the entrepreneur as a dynamic loan contract with termination conditions. The bank can choose the entrepreneur's credit status k from the finite set $\mathbb{K} \equiv \{l, f\}$ in the second period where l is for lending and f is for cutting-off. The credit termination condition is a probability that the bank cuts off the credit given the realized output in the first period.

Definition 4 *A dynamic loan contract with credit termination condition is offered at the beginning of the first period of life time, and the terms of the contract take the following form:* $\sigma_L = \left\{p_i, (B_{ik}, w_{ik})_{k \in \mathbb{K}}\right\}_{i \in \{1,2\}}$.

In this definition, $p_i \in [0,1]$ is the probability of credit termination if the output in the first period was θ_i. In addition, at the end of the first period, according to the contract, the firm pays B_{ik} to the bank conditional on the credit status k when the output in the first period was θ_i. The payoffs subject to the limited liability constraints: $0 \leq B_{ik} \leq \theta_i$. Let $c_{ik} = \theta_i - B_{ik}$ be the entrepreneur's payoff. Following Spear and Srivastava (1987) and others, we use the promised utility to the entrepreneur as the state variable. At the end of the second period, the bank will deliver a promised utility equal to $w_{ik} \in \Phi$ to the firm conditional on the credit status k when the output was θ_i in the first period.

The following problem (5) determines the terms of the optimal contract in which the bank promises an expected utility exactly equal to x to the entrepreneur at the beginning of the first period of his life time.[6] If the suggested project is j, then,

$$\max_{\sigma_L} \sum_{i=1,2} \pi_{ij} \sum_{k=l,f} p_{ik} \left[B_{ik} + V\left(w_{ik}\right)\right] - r, \tag{5}$$

subject to:

$$\sum_{i=1,2} \pi_{ij} \sum_{k=l,f} p_{ik} \left(c_{ik} + w_{ik}\right) - v_j = x, \tag{6}$$

$$j \in \arg\max_{j' \in \mathbb{M}} \sum_{i=1,2} \pi_{ij'} \sum_{k=l,f} p_{ik} \left(c_{ik} + w_{ik}\right) - v_{j'}. \tag{7}$$

Here we denote $p_{if} = p_i$ the probability of cutting-off and $p_{il} = 1 - p_i$ the probability of lending. The contract satisfies the promise-keeping constraint (6) and the incentive constraint (7). Following Stigliz and Weiss (1983), we assume that the first period loans have seniority over the later loans. That is, if the entrepreneur has outstanding obligations, he must repay them before new loans from elsewhere are repaid. So when the credit is terminated, the entrepreneur cannot refinance the project due to the credit history he had. So the expected utility to the entrepreneur is w_{if} when the bank cuts off his credit.

It is easy to see that once the promised utility w is given, the terms of contract in the second period will not affect the first-period choice. So we can solve the contract in the second period as a static loan contract. Following Spear and Wang (2005), let the bank's value function in the second-period be:

$$V\left(w\right) = \max\left\{V_l\left(w\right), V_f\left(w\right)\right\}, \tag{8}$$

where $V_l\left(w\right)$ and $V_f\left(w\right)$ are the bank's value function conditional on lending and cutting-off respectively.

Explicitly, the bank's value function is:

$$V\left(w\right) = \begin{cases} \overline{\theta}_2 - \psi - r - w, & \text{if } w > \underline{w} \\ \left(\overline{\theta}_2 - \psi - r - w\right) - \underline{w}, & \text{if } w \leq \underline{w} \end{cases}. \tag{9}$$

[6] In this simple model, an entrepreneur lives two periods. So banks and entrepreneurs take x as exogeneously given. However, x should be interpreted as the entrepreneur's credit history in a model where the entrepreneur could potentially live infinite periods.

If the bank lends to the entrepreneur, the second-period contract is equivalent to the static loan contract problem (1). If the bank denies the future loan to the entrepreneur, it will pay the promised utility w to the entrepreneur to end the relationship and look for a replacement in the market. The expected value is:

$$V_f(w) = \max_{w'} \{V_l(w') \mid w' \geq \underline{w}\} - w. \tag{10}$$

We assume there are enough entrepreneurs who have no investment histories and are looking for funds in the market. So the bank will find a replacement among them after it terminates an entrepreneur's credit. The new entrepreneur is paid $w' = \underline{w}$ which maximizes the bank's one-period profit by (1). And thus, if the bank pays w to terminate the credit, from (10) and the value function (4), the value function conditional on credit termination is:

$$V_f(w) = \left(\overline{\theta}_2 - \psi - r - w\right) - \underline{w}. \tag{11}$$

It is never optimal to implement the bad project by assumption (A1),[7] so we have $V_l(w|w < \underline{w}) < V_f(w)$ and $V_l(w|w \geq \underline{w}) > V_f(w)$. And thus we have the bank's value function in the second period (9) by comparing (4) and (11).

Given the bank's value function in the second period, we can solve the optimal long-term contract which implements the good project in both periods. Spear and Wang (2005) proved that when the agent's promised utility is too low to support the desired effort, termination occurs as an incentive device in an executive compensation model. The same result holds here that credit termination is a necessary punishing device if the contract must make the entrepreneur sufficiently poor in the second period. The bank's optimal termination policy $p_i^*(x)$ in the terms of financial contract is summarized in the following Proposition (5).

Proposition 5 *The bank's optimal termination policy associated with a promise to deliver expected utility equal to $x \in [0, \overline{w}]$ is:* [8]

$$p_1^*(x) = \min\left\{\left(2 - \frac{x}{\underline{w}}\right)^+, 1\right\}, \text{ and } p_2^*(x) = 0.$$

So, (a) The bank will never terminate the entrepreneur's credit if he has a high output. (b) When the entrepreneur's output is low, the bank will terminate the credit if promised expected utility the cost of termination is not too high, i.e., $x \in [0, \underline{w}]$; the bank will cut off the credit with some positive probability if the termination cost is higher, i.e., $x \in [\underline{w}, 2\underline{w}]$; and if it is too expensive to terminate, i.e., $x \in [2\underline{w}, \overline{w}]$, the bank will endure the relationship. In other words, credit termination is a decreasing function of the entrepreneur's initial promised utility x.

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[7] This comes from the assumption that the good project is efficient but the bad project is not, $\overline{\theta}_2 - \psi - r - \underline{w} > 0$, and $\overline{\theta}_1 - r < 0$.

[8] The function $X^+ \equiv \max\{X, 0\}$.

5 Shocks and Technology Bubbles

So far we have shown that the bank's long-term loan contract is characterized by that firms with bad outcome will potentially face credit cutting-off. In this section, we will define the market equilibrium when the banks are competing for both borrowers and depositors (lenders). And then we introduce a technology shock and show that the mania stage of a technological bubble is on the off-equilibrium path where banks have not adjusted loan contracts due to information asymmetry. After more and more firms default the loan repayment, banks will restrict the credit. That is, firms with low output are terminated with a higher probability which is related to the crash of a technology bubble.

First, we calculate the supply of the loanable funds. In each and every period, a young lender solves the following intertemporal utility maximization problem (12), taking the market interest rate r as given:

$$U\left(c,c'\right)=\max_{s} u\left(c\right)+E\left[c'\right] \tag{12}$$

subject to: $c+s=h$ and $c'=rs$, where $0\leq s\leq h$ denotes the representative lender's savings in the first period; $c,c'\geq 0$ are consumption in each period. Let $u\left(\cdot\right)$ take the usual concave form. Let $u'\left(\cdot\right)$ and $u''\left(\cdot\right)$ denotes the first and second order derivatives with respect to the consumption. Then $u'\left(\cdot\right)>0$ and $u''\left(\cdot\right)<0$. Lenders are risk-neutral with respect to the consumption when they are old. Here $E\left[\cdot\right]$ denotes the expectation and the discount factor is one for simplicity. So the young lenders save and they consume the savings when they are old. The following first-order conditions determine a solution under the assumption that an interior solution to the problem exists with $0<s<h$:

$$u'(h-s)=r. \tag{13}$$

Thus we can solve the savings, $s\left(r\right)$, as a function of interest rate from the first order condition.

Now, assume that banks promise $y\geq \underline{w}$ to a young entrepreneur who signs a short-term contract and x to whom signs a long-term contract in his first period of life time. Banks choose the promised utility taking the interest rate r as given. In the second period, only entrepreneurs who signed the short-term contract in the first period can sign a new contract with some other banks (include those banks looking for a replacement). Entrepreneurs who signed the long-term contract commit to the contract. And even if they were cut off the credit, they cannot sign a new contract due to the debt seniority assumption. The promised utility to an old entrepreneur is $\underline{w}$, the threshold expected utility. Assume the old entrepreneur has a cost, $\left(1-\rho\right)\underline{w}$ with $\rho\in\left[0,1\right]$, to sign the second period contract. In equilibrium, the young entrepreneur is indifferent with the long-term and the short-term contracts, or he has the same expected utility, i.e., $x=y+\rho\underline{w}$. Assume entrepreneurs take the long-term contract with probability α. In the credit market, we simply assume banks can find a replacement after they cut off the credit of an entrepreneur without any cost. This assumption is possible if α is not too big (e.g., only half of the banks will issue long-term contract $\alpha<1/2$). The value of a short-term contract given a promised utility y is $V(y)$. And the competition among the banks for both borrowers and depositors will make the value equal to zero,

$$V(x - \rho \underline{w}) = 0. \tag{14}$$

From the above zero profit condition, in the first period, the promised utilities for the long-term and short-term contracts are $x(r) = \left(\overline{\theta}_2 - \psi + \rho \underline{w}\right) - r$ and $y(r) = \left(\overline{\theta}_2 - \psi\right) - r$ respectively.

Then, we calculate the demand of investment funds. In our model, in each period, banks write a large number of loan contracts with the entrepreneurs. We can measure the existing firms in each period by the law of large numbers. Assume that there is a stationary distribution of the promised utility, so the measure of the firms terminated in the second period is:

$$\begin{aligned} \Pi(x) &\equiv \frac{1}{2}\eta\alpha\pi_{12}p_1^*(x) \qquad (15) \\ &= \frac{1}{2}\eta\alpha\pi_{12}\min\left\{\left(2 - \rho - \frac{\overline{\theta}_2 - \psi - r}{\underline{w}}\right)^+, 1\right\}, \end{aligned}$$

which is a weak increasing in the threshold utility $\underline{w}$. The result comes from the definition of $p_1^*(x)$.

As we assume that once the credit line is cut off, no banks will finance this entrepreneur's project again. Every entrepreneur requires one unit of capital except those defaulted the first period contract and were terminated in the second period. That is, the demand for investment fund is: $\eta - \Pi(x)$. To close the model, the credit market clear condition requires that the quantity of loans is equal to the quantity of deposits,

$$\frac{1}{2}(1-\eta)s(r) = \eta - \Pi(x). \tag{16}$$

Definition 6 *Given $\{p_i^*\}_{i=\{1,2\}}$ from the banks' optimal loan contract σ_L^*, the credit market equilibrium is $\{s^*, r^*\}$ solved from equations (13), (15) and (16).*

5.1 Technology Shocks

Technology shocks are introduced into the economy. A similar type of shocks with continual support is discussed in Williamson (1987). The special feature of this type of shocks is it will not change the productivity but the riskiness of the economy. Let S_t take value from the finite set $\mathbb{S} \equiv \{a, b\}$ and denote the state of the economy at time t. In a normal period ($S_t = a$), the set of feasible investment projects is $\mathbb{M}_a \equiv \{1, 2\}$. While, in a bubble period ($S_t = b$), due to a technological innovation, there is a new type of project (project 1^b) and the set of feasible investment projects changes, i.e., $\mathbb{M}_b \equiv \left\{1, 1^b, 2\right\}$. Here we use superscript to denote the new project. Assume the new project has the same salvage value as the bad project (project 1), $\theta_1^b = \theta_1$. The expected return on the new project is the same as that on the bad project, but the new project is riskier than the bad project in the sense that if the entrepreneur chooses the former, he has a lower chance $\pi_{21}^{b} < \pi_{21}$ to get a higher outcome $\theta_2^b > \theta_2$, with the following condition holds,

$$(1-\pi_{21}^{b})\theta_1^b + \pi_{21}^{b}\theta_2^b = (1-\pi_{21})\theta_1 + \pi_{21}\theta_2.$$

Other features of the economy are identical to those specified in previous sections in both states. The new project is mean preserving to the bad project and will not produce fluctuations in the absence of financial frictions.[9] However, with financial frictions (moral hazard and limited liability), it is even more difficult to induce the entrepreneur to choose the good project with the mean preserving technology shock.

Lemma 7 *Entrepreneurs prefer the glamorous, new project (project* 1^b*) than the bad project (project* 1*) under the loan contract.*

Mirrlees (1999) has shown if the support of distribution varies with different projects, the first-best can be achieved when the support is observable. Here we assume when the output is high, the bank cannot distinguish θ_2^b from θ_2. So the bank cannot infer the two states directly. This assumption consists with our model setup because when the output is high, debt is repaid fully and banks get the same interest rate in both states. When the firm defaults, banks will get $\theta_1^b = \theta_1$, the same salvage value before the technology shock. However banks might infer the states by the default rate since when the firms choose the glamorous project, the probability of low output is higher than those of the bad project ($\pi_{11}^{b} > \pi_{11}$) and the good project ($\pi_{11}^{b} > \pi_{12}$).

5.2 Technology Bubbles

To show how aggregate variables depend on state $S_t \in \mathbb{S}$, we can carry out a comparative static analysis when the economy is in a stationary equilibrium. Assume that the model economy is in state a initially. By equations (13), (15) and (16), we can solve the equilibrium $\{s^a, r^a\}$. After a technology shock, the model economy changes to state b. However, we assume that the banks cannot response to the shock immediately.

Proposition 8 *If the banks cannot response immediately to a technology shock, the entrepreneurs will switch to the glamorous, new project (project* 1^b*).*

The result holds due to the information asymmetry. After the technology shock, the entrepreneurs observe it and choose the glamorous, new project since it is intrinsically appealing to them. We interpret that entrepreneurs switch to the glamorous project as a technology bubble which is on the off-equilibrium path.

When the banks infer the bubble by a high proportion of defaults, they will restrict the credit and the new equilibrium $\left\{s^b, r^b\right\}$ is restored. By Proposition (8), we have

[9] In the model, the preference, average productivity, and population are identical in each period t.

$\underline{w}^b > \underline{w}^a$ since the bank need to give more incentive rents to the entrepreneur to choose the good project in the new state. And thus we have:

$$\Pi\left(x|\underline{w}^b\right) = \frac{1}{2}\eta\alpha\pi_{12}p_1^*\left(x|\underline{w}^b\right) > \Pi\left(x|\underline{w}^a\right) = \frac{1}{2}\eta\alpha\pi_{12}p_1^*\left(x|\underline{w}^a\right),$$

where the superscript denotes the state. There is an inefficient unemployment of resources after the shock. The following Proposition (9) gives several predictions of the model economy with the technology shock.

Proposition 9 *With a technology shock, we predict decreases in interest rate (r) and savings (s) after the shock is disclosed to the banks.*

Intuitively, the interest rate falls because, in order to promise a higher utility to an entrepreneur, banks must lower the cost of the funds to keep a zero profit given entrepreneurs are *ex ante* identical. This is different with the prediction of traditional credit cycle model such as Williamson (1987) where the market rate increases with a shock and firms with high auditing costs will be driven out of the credit market. In our model, firms are driven out of the credit market by the increase of the rate of termination. The treasury bill rate dropped from 4.82% per year in 1998 to 3.45% per year in 2001, and 1.61% per year in 2002. The model also predicts that savings will drop which is observed at the end of the dot-com bubble (Figure II).

[Figure II here]

5.3 Testable Hypotheses

The model connects the real and financial sectors. We propose two pairs of hypotheses:

Hypothesis 1a. Financial intermediaries, which do not have full controls on the entrepreneurs' investment behavior, lend a large amount of money to firms before they know the information of the technology shocks.

Hypothesis 1b. Investors, even rational arbitrageurs, have no better knowledge than the financial institutions, and thus most of the investors are probably convinced in a "new economy paradigm" observing the credit flowing into the hi-tech sector.

With the mature of internet technology, entrepreneurs were attracted by some interesting business ideas such as online stores and delivery services, etc., and they looked for funds to invest in these projects. We do not have firm level data to trace the credit flowing into those dot-com projects, but the aggregated credit flow gives us some clues of what was going on in the economy during that period of time. Figure III records the funds flowing into the nonfinancial corporate businesses (excluding farms) by the net increase in liabilities. From 1998 to 2000, there was a large increase of the firms' net liabilities.

[Figure III here]

Hypothesis 2a. Observing the inforamtion on default rate, the financial intermediaries re-optimize their loan contracts. Hi-tech companies are in a disadvantaged condition because the funds may dry up under disadvantage shocks, and so the value of the firms fall.

Hypothesis 2b. The outside investors realized that the hi-tech companies are difficult to make higher profits on average, they reduce their positions in stocks, which further lower the value of these firms.

Those projects in the dot-com bubble had razor-thin margins on average to begin with, and few of them could attract enough customers to justify their costs. From Figure III, there wasn't any significant sign of a profit increasing during that period. Brynjolfsson and Hitt (1995) find positive relationship between the information technology investment and productivity, but also a great deal of individual variation in firms' success with information technology. And much of the research on the relationship between technology and productivity used economy-level or sector-level data and found little supporting evidence (see Gordon, 2000). But the entrepreneurs still invested in the dot-com industry because they hoped that if other companies could not sustain expending, they would take all the shares of the market and gain large profits (Noe and Parker, 2005). Unfortunately, defaulting increased due to a high proportion of low returns (see Table I).

[Table I here]

6 Conclusion

In this paper, we construct a business cycle model in which financial intermediation plays an important role. Loan contracts with termination conditions are long-term relationships between financial intermediaries and entrepreneurs. Due to information asymmetry, intermediaries cannot observe entrepreneurs' investment behaviors. So credit termination is used as an incentive device to affect an entrepreneur's choice of project *ex ante*. This is connected to the withdrawal of credit after the bust of the technology bubbles.

The model can be used to explain the dot-com bubble in the late 1990s which is one leading example of the technology bubbles in the economy. From time to time, there are beliefs that some technological innovations change the productivity, e.g., internal combustion engine, electric motor, internet, or green energy, etc. Some of them did make fundamental transformations in the economy, while others were just incremental technological changes. In the latter case, investment manias might cause inefficiency because investors could not know in advance and they were eager to catch up the technological wave. With the development of financial intermediation, the technology shocks will be amplified which leads to severe economic fluctuations since complicated loan contacts are used. Proper designs of financial contracts or regulations are required to reduce the inefficiency.

A Appendix

Lemma 3. Proof. Consider the second period contract $\{B_i\}$ for an entrepreneur which implements a good project, $j = 2$, so the promise-keeping (2) and incentive (3) constraints become:

$$(1 - \pi_{22}) c_1 + \pi_{22} c_2 - \psi = w,$$

$$(1 - \pi_{22}) c_1 + \pi_{22} c_2 - \psi \geq (1 - \pi_{21}) c_1 + \pi_{21} c_2.$$

The incentive constraint requires that $c_2 - c_1 \geq \psi / (\pi_{22} - \pi_{21})$. From the promise-keeping constraint, we have

$$\begin{aligned} w &= (1 - \pi_{22}) c_1 + \pi_{22} c_2 - \psi \\ &= c_1 + \pi_{22} (c_2 - c_1) - \psi \\ &\geq c_1 + \frac{\pi_{22}\psi}{\pi_{22} - \pi_{21}} - \psi \\ &= c_1 + \frac{\pi_{21}\psi}{\pi_{22} - \pi_{21}}. \end{aligned}$$

Given the limited liability of the entrepreneur, we have $c_1 \geq 0$. So the threshold expected utility $\underline{w}$ to implement the good project is: $\underline{w} = \pi_{21}\psi / (\pi_{22} - \pi_{21})$. ■

The following Lemma (10) and Proposition (5) are from Spear and Wang (2005). To solve the optimal long-term loan contract which implements the good project, the promise-keeping and incentive constraints must hold:

$$\sum_{i=1,2} \pi_{i2} \sum_{k=l,f} p_{ik} (c_{ik} + w_{ik}) - \psi = x, \tag{A.1}$$

$$\sum_{i=1,2} \pi_{i2} \sum_{k=l,f} p_{ik} (c_{ik} + w_{ik}) - \psi \geq \sum_{i=1,2} \pi_{i1} \sum_{k=l,f} p_{ik} (c_{ik} + w_{ik}), \tag{A.2}$$

where $p_{if} = p_i$, and $p_{il} = 1 - p_i$. It is straightforward to establish two preliminary results: (i) $B^*_{1k} = \theta_1$, and $c^*_{1k} = 0$, for $k \in \{l, f\}$; (ii) $w^*_{if} = 0$, for $i \in \{1, 2\}$. The first result is due to debt contract form with limited liability. The bank maximizes the surplus from the contract and provides the entrepreneur with incentives. Also, it is optimal to set the promised utility to zero if the credit is cut off. We need to prove the following Lemma for the Proposition.

Lemma 10 *For $i \in \{1, 2\}$, if $p^*_i > 0$, then it must hold that $w^*_{il} = \underline{w}$; if $w^*_{il} > \underline{w}$, then it must hold that $p^*_i = 0$.*

Proof. Notice that the optimization problem (5) implies

$$\begin{aligned}
& \max_{\sigma_L} \sum_{i=1,2} \pi_{ij} \sum_{k=l,f} p_{ik} \left[B_{ik} + V\left(w_{ik}\right)\right] - r \\
\Longleftrightarrow \quad & \max_{\sigma_L} \sum_{i=1,2} \pi_{ij} \left\{\left(1-p_i\right)\left[B_{il} + V\left(w_{il}\right)\right] + p_i \left[B_{if} + V\left(\underline{w}\right)\right]\right\} - r \\
\Longleftrightarrow \quad & \max_{\sigma_L} \sum_{i=1,2} \pi_{ij} \left\{B_i + \left[\left(1-p_i\right) V\left(w_{il}\right) + p_i V\left(\underline{w}\right)\right]\right\} - r \\
\Longleftrightarrow \quad & \max_{\sigma_L} \sum_{i=1,2} \pi_{ij} \left\{B_i + \left(1-p_i\right)\left[V\left(w_{il}\right) - V\left(\underline{w}\right)\right] + V\left(\underline{w}\right)\right\} - r.
\end{aligned}$$

But this is equivalent to the following problem (A.3):

$$\max_{\{p_i, w_{il}\}} \left(1-p_i\right)\left[V\left(w_{il}\right) - V\left(\underline{w}\right)\right] \tag{A.3}$$

subject to:

$$p_i \in [0,1] \text{ and } w_{il} \geq \underline{w}, \text{ for } i \in \{1,2\}.$$

Therefore, if $p_i^* > 0$, it must be the case that $V\left(w_{il}^*\right) = V\left(\underline{w}\right)$, or $w_{il}^* = \underline{w}$. If $w_{il}^* > \underline{w}$, then $V\left(w_{il}\right) - V\left(\underline{w}\right) > 0$, so $p_{il}^* = 1$. ■

Proposition 5. Proof. We first prove the second part of the Proposition. Suppose $p_2^*(x) > 0$, then $w_{2l}^* = \underline{w}$ by the previous lemma. Then the entrepreneur is indifferent with the two projects. However, for any $\varepsilon > 0$, if the bank sets $w_{2l}^* = \underline{w} + \varepsilon$, then the entrepreneur will prefer the good project and the bank can make more surplus. It is a contradiction that $p_2^*(x) > 0$ solve the optimization problem.

Then we prove the first part of the Proposition. Similar to the previous argument, if $p_1^*(x) > 0$, then we have $w_{1l}^* = \underline{w}$ by the previous lemma. Notice given the expected utility x, the promise-keeping constraint (A.1) could be written as:

$$\pi_{12}\left(1-p_1^*\right)\underline{w} + \pi_{22}\left(c_{2l}^* + w_{2l}^*\right) = x + \psi. \tag{A.4}$$

Define $\widetilde{w} \equiv \psi / \left(\pi_{22} - \pi_{21}\right)$, the incentive constraint (A.2) must be binding to solve this problem, which could be written as:

$$\left(c_{2l}^* + w_{2l}^*\right) - \left(1-p_1^*\right)\underline{w} = \widetilde{w}. \tag{A.5}$$

Solve these two equations (A.4) and (A.5) jointly, we get:

$$p_1^* = 1 - \frac{x + \psi - \pi_{22}\widetilde{w}}{\underline{w}} = 2 - \frac{x}{\underline{w}}.$$

And $p_1^* \in [0,1]$, so the bank's optimal termination policy comes directly. ■

Lemma 7. Proof. Let us only consider the old entrepreneurs. Assume the interest rate for a loan is R, so the expected return is $\pi_{21}^b(\theta_2^b - R)$. Given the contract, so we can only compare project 1 and project 1^b. Notice the bank's expected return decreases if the entrepreneur chooses project 1^b,

$$(1-\pi_{21}^b)\theta_1+\pi_{21}^b R-r<(1-\pi_{21})\theta_1+\pi_{21}R-r,$$

since $\pi_{21}^b<\pi_{21}$. Therefore the entrepreneur's expected return increases

$$\pi_{21}^b(\theta_2^b-R)>\pi_{21}(\theta_2-R),$$

since project 1^b and project 1 have the same expected return. The entrepreneur is indifferent between project 1 and project 2, and thus he will choose project 1^b over project 2. ■

Proposition 9. Proof. First, if $\underline{w}\leq\left(\overline{\theta}_2-\psi-r\right)/(2-\rho)$ or $\underline{w}\geq\left(\overline{\theta}_2-\psi-r\right)/(1-\rho)$, then $\Pi(x)$ equals 0 or $\eta\alpha\pi_{12}/2$ respectively. In these two scenarios, there is no change in the rate of credit termination. We rule out these two scenarios and only consider the the more interesting case where $\left(\overline{\theta}_2-\psi-r\right)/(2-\rho)<\underline{w}<\left(\overline{\theta}_2-\psi-r\right)/(1-\rho)$.

Then, total differentiating equilibrium condition (13) and (16), we get

$$\begin{aligned} u''(h-s)\,ds+dr &= 0, \\ (1-\eta)\,\underline{w}^2ds+\eta\alpha\pi_{12}\underline{w}dr &= -\eta\alpha\pi_{12}\left(\overline{\theta}_2-\psi-r\right)d\underline{w}. \end{aligned}$$

That is

$$\begin{pmatrix} u''(h-s) & 1 \\ (1-\eta)\,\underline{w}^2 & \eta\alpha\pi_{12}\underline{w} \end{pmatrix}\begin{pmatrix} \frac{ds}{d\underline{w}} \\ \frac{dr}{d\underline{w}} \end{pmatrix}=\begin{pmatrix} 0 \\ -\eta\alpha\pi_{12}\left(\overline{\theta}_2-\psi-r\right) \end{pmatrix}.$$

And use the Cramer's rule, we have

$$\begin{aligned} \frac{ds}{d\underline{w}} &= \frac{\eta\alpha\pi_{12}\left(\overline{\theta}_2-\psi-r\right)}{\det(A)}<0, \\ \frac{dr}{d\underline{w}} &= \frac{-u''(h-s)\,\eta\alpha\pi_{12}\left(\overline{\theta}_2-\psi-r\right)}{\det(A)}<0, \end{aligned}$$

since $u''(\cdot)<0$ and also

$$\begin{aligned} \det(A) &= \det\begin{pmatrix} u''(h-s) & 1 \\ (1-\eta)\,\underline{w}^2 & \eta\alpha\pi_{12}\underline{w} \end{pmatrix} \\ &= u''(h-s)\,\eta\alpha\pi_{12}\underline{w}-(1-\eta)\,\underline{w}^2<0. \end{aligned}$$

■

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Table I Moody's Default Counts

Issuer counts and dollar calue in North American. Data Source: Moody's Global Credit Policy.

Year	Issuer Counts	Dollar Value (Millions)
1995	26	4,816
1996	16	5,270
1997	21	5,129
1998	45	11,597
1999	78	31,887
2000	116	52,929
2001	146	114,284
2002	99	152,930
2003	62	38,286
2004	34	13,587
2005	30	40,015

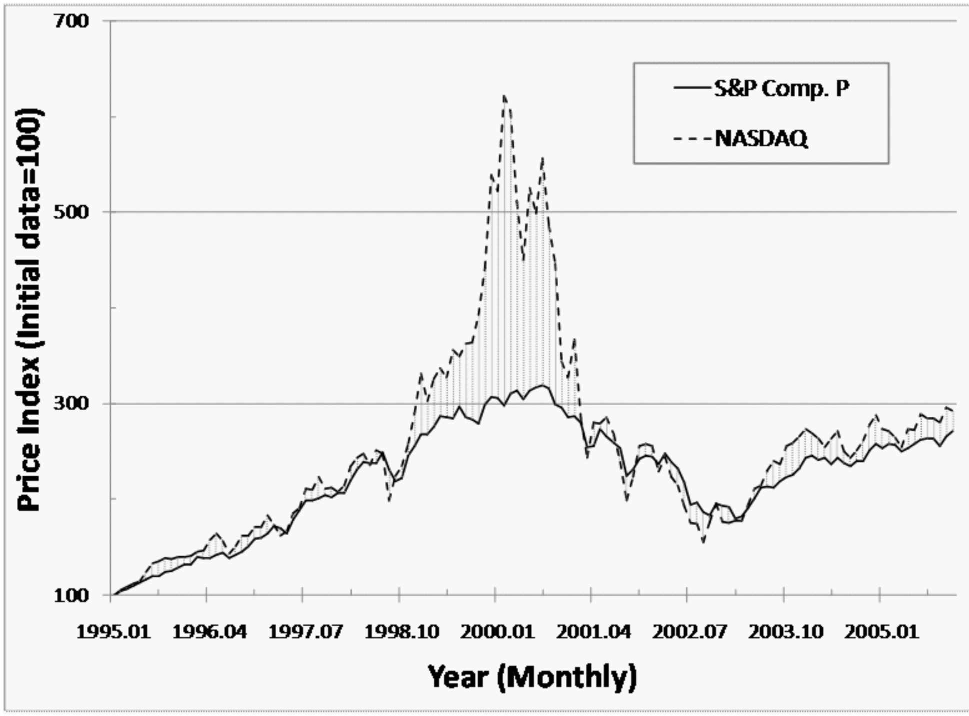

Figure I Peaks and Valleys of Stock Price Indexes, S&P and Nasdaq composite.

Comparison of the S&P index and the Nasdaq composite index for the period from 1/1995 to 12/2005. Both indexes are scaled to be 100 on Jan. 1995. Data Source: Yahoo! Finance.

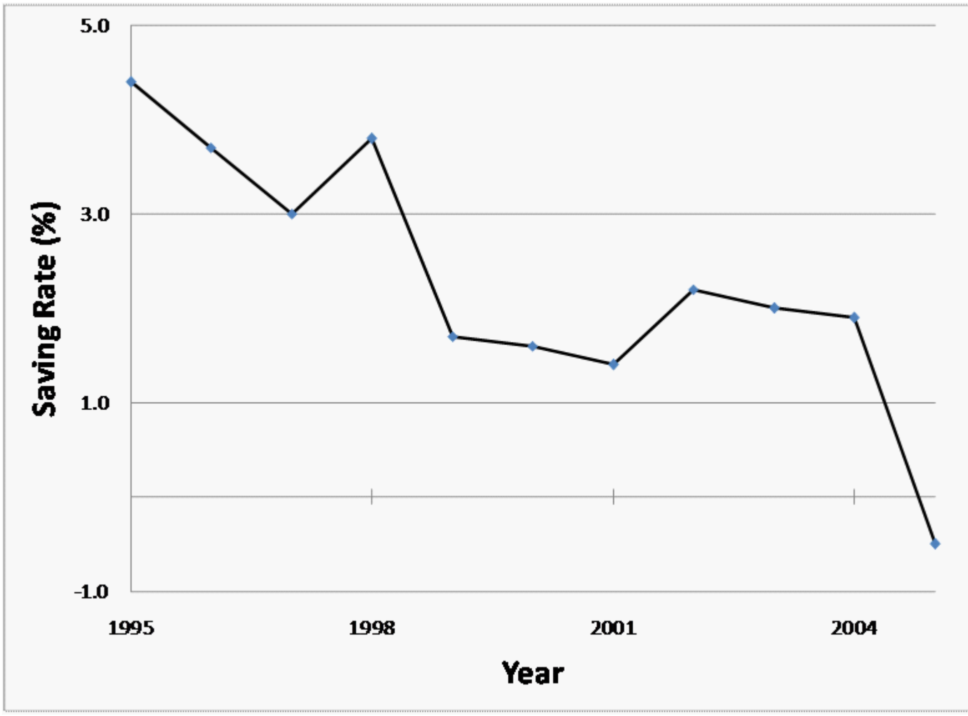

Figure II Saving Rate.

The households' saving rate from 1995 to 2005.Data Source: DEA.

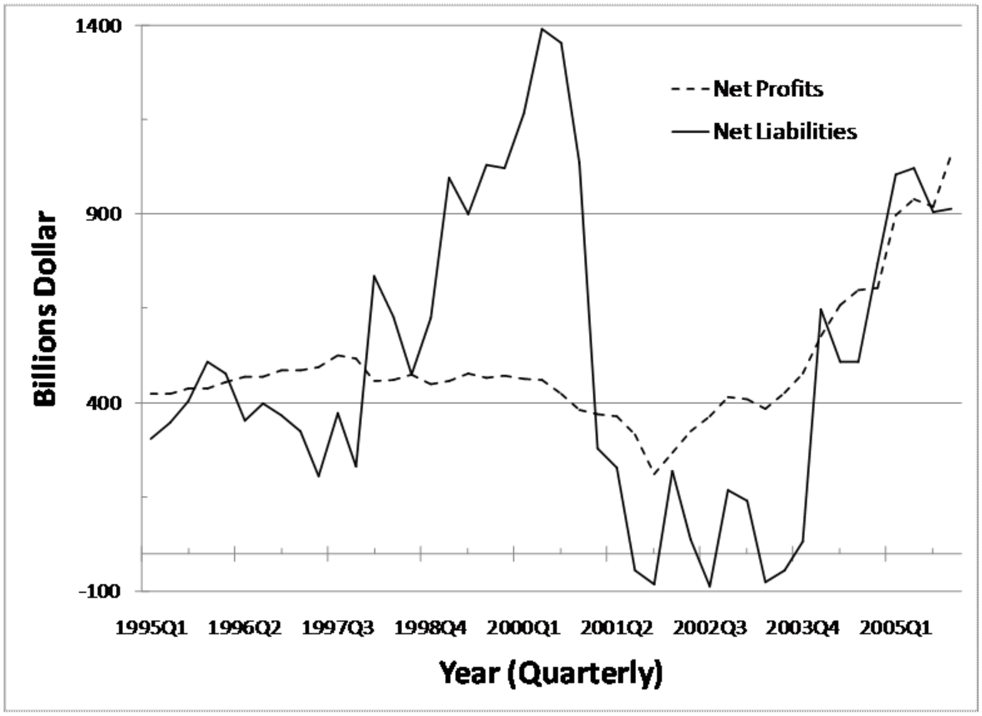

Figure III Credit Flow and Profit

The Net Liabilities and the Net Profits for the period from Q1-1995 to Q4-2005. Data Source: Flow of Funds.