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Bank net worth, asset prices and economic activity ☆

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Abstract

A dynamic general equilibrium model is proposed to study the interactions between the banking sector, asset prices and aggregate economic activity. A durable asset serves as a productive input and as a collateral for loans. The propagation mechanism of a negative productivity shock is enhanced and prolonged through the interaction of credit constraints and asset prices, where the bank loan and the investment are squeezed by a higher bank capital–asset ratio for lending and at the same time, a stricter collateral requirement for borrowing. The model explains why banking crises often coincide with depression in the asset markets. The results also bear policy implications for the debates over regulatory bank capital adequacy and credit control policies. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

This paper is a theoretical study of the dynamic interactions among banks, asset prices and economic activity. In particular, I investigate the propagation mechanism of a negative shock which results in falling bank loans, and generates persistent declines in aggregate investment and output. Furthermore, a durable asset is introduced and serves as an input for production as well as a collateral for loans, I examine how the propagation mechanism of an exogenous shock can be further amplified and prolonged through the interaction between credit constraints and asset prices.

For this purpose, a dynamic general equilibrium model is proposed to study the relationship between bank credit constraints and asset prices. There are two layers of relationship involved in financial contracts: entrepreneurs with banks, and banks with households. Banks intermediate funds between the households (ultimate lenders) and the borrowing entrepreneurs (ultimate borrowers) and act as delegates of depositors to monitor the entrepreneurs. Entrepreneurs have an incentive to choose the type of projects with lower expected returns, which allows them to consume private benefits. Banks can detect imperfectly the type of chosen projects with costly monitoring technology. To completely deter entrepreneurs from going after the private benefits, entrepreneurs are then required to invest their own funds in the projects. On the other hand, bankers may not dutifully monitor the entrepreneurs in order to save the costs of monitoring. Thus, households only lend to well-capitalized banks who have a lot to lose in case of loan default. Consequently, the bank's capital position and the entrepreneurial net worth jointly constitute the lending constraint of banks and the borrowing constraint of entrepreneurs, and thus determine the aggregate investment.

Since bank capital and entrepreneurial net worth serve as collateral, a change in the level of collateral has a direct impact on bank lending and investment. In the basic model without asset, when banks suffer capital erosion due to loan losses, take the "capital crunch" for example, banks with impaired capital positions find it difficult to seek alternative sources of finance and are forced to cut back lending. The initial effect persists: with less investment from the previous period, entrepreneurs and banks earn less revenue and end up with a lower level of net worth. This further weakens the lending capability of banks and borrowing capacity of entrepreneurs. Thus, the initial effect of a shock to bank capital propagates into subsequent periods through the interaction of the credit constraints on the banks as well as on the entrepreneurs, which together cause a spiral fall in bank lending and investment.[1]

[1] Bernanke and Lown (1991), Furlong (1992) and other authors found that capital positions of banks have positive and statistically significant effects on bank lending. This supports our emphasis of the "balance sheet effect" not only on the side of borrowers, but also on the side of the banks.

It is customary that entrepreneurs provide durable assets, such as their land, real estate, or machinery, as collateral for loans, and thus the fluctuations of these assets prices can change the value of collateral and thus affect the amount of bank lending and investment. The basic model is then extended to incorporate a durable asset. In this model, I consider a productivity shock that lowers investment returns. Entrepreneurs and banks earn lower revenues and are left with lower net worth positions. This constrains the levels of bank loans and investment. A lower level of investment depresses the prices of their collateralized assets and in turn erodes entrepreneurs' net worth and their debt capacity, resulting in even lower levels of bank loan and investment. Thus, the credit constraints and asset prices reinforce each other to enhance the propagation mechanism of an exogenous shock. The analysis explains why banking crises often coincide with depressions in asset markets as we have observed since the late 1980s in a large number of countries.[2]

In the basic model, I find that the loan interest rate rises and both the endogenous bank capital–asset ratio and entrepreneurial leverage fall if a negative shock hits bank capital, while they move toward the other direction if the shock hits entrepreneurs' net worth. In the full model with asset, the asset price becomes a dominant factor in determining the paths of the capital–asset ratio and entrepreneurial leverage. Following a negative productivity shock, even though the loan interest rate goes down, the credit constraints are further tightened because the bank capital–asset ratio increases and the entrepreneurial leverage decreases.[3] This bears policy implications for the debate on whether the regulator should impose rigid capital adequacy requirement for banks and credit control policies for borrowers.

The basic framework of this paper builds upon Holmstrom and Tirole's (1997) formulation of the moral hazard problems that occur on the side of borrowers as well as banks. Their model, however, is static and has only a single consumption good. Thus, there is no role for the prices of assets in the

[2] As many authors have observed, a common feature of the financial crises together with asset price boom-bust cycles from the 1980s to the early 1990s occurred in many countries is that, before the crash sets in, asset price inflation often follows a rapid increase in credit expansion. Nearly all OECD countries and most emerging countries in South America and East Asia experienced similar boom-bust cycles of asset prices and bank lending fluctuations. See Peek and Rosengren (1992, 1997), Ito and Iwaisako (1996), and Higgins and Osler (1997).

[3] There has been a heated debate about the significance of various monetary transmission channels: money channel, net worth channel and bank lending channel (see Gertler and Gilchrist, 1994; Bernanke and Gertler, 1995). Our model can be considered as a synthesis of the latter two views. The two channels are intertwined through the propagation mechanism described in the text.

dynamics of the propagation mechanism. Concerning the dual role of the durable asset as an input and collateral, Kiyotaki and Moore (1997) provided insights into the mechanism that the collateral-in-advance constraint amplifies and propagates a small shock to generate large, persistent fluctuations in outputs and asset prices. However, their model abstracts from banks which are "special" in that small and medium firms heavily rely upon bank financing due to severe agency problems. More importantly, incorporating banks explicitly allows inside capital of banks to play a role in the model's dynamics because under-capitalized banks may not have incentives to behave.[4]

The paper is organized as follows. Section 2 presents a basic model in which there is a single perishable good. The focus is the interaction between the evolution of the aggregate bank capital, entrepreneurial net worth and economic activity. I examine how the loan interest rate, bank capital–asset ratio, and entrepreneurial leverage may respond differently to a sector-specific shock. In Section 3, a durable asset is added to the basic model. When considering the effect of an aggregate productivity shock, the price of the asset plays an important role in the propagation mechanism. Section 4 discusses some policy issues implied in the model and some thoughts for further research.

2. The basic model

2.1. The environment

The economy consists of a continuum of risk-neutral agents. There are three types of agents: households, entrepreneurs and bankers, with a population of mass N, η, and $1-\eta$, respectively. There is a single final good each period which can either be consumed or used as an input for investment. The households are infinitely lived, each endowed with e^{H} units of good each period. Their preferences are given by $\mathrm{E}_t(\sum_s \beta^s c^{\mathrm{H}}_{t+s})$, where E_t is the expectations operator conditional on date t information, $\beta \in (0,1)$ is the discount factor, and c^{H}_t is the date t household consumption. The

[4] Along the line of Diamond (1984) and Williamson (1987), they emphasize the role of banks as a delegated monitor due to economies of scale in monitoring costs. In order to induce the bank to repay debts to depositors, they either impose some form of punishment on bankers who default, or have the lenders undertake costly auditing in the state of default. However, in their models, intermediaries are able to perfectly diversify credit risk, and therefore, there is no role for the own capital of the intermediaries. On the other hand, Bernanke and Gertler (1987) consider an arrangement between a bank and depositors whereby the inside capital of the bank perfectly collateralizes its debt. However, the amount of inside capital of intermediaries is exogenously given.

households are assumed to be neither capable of monitoring the activity of entrepreneurs nor of enforcing financial contracts with entrepreneurs, and therefore, they will not lend to entrepreneurs directly. The only alternative of savings is to make deposits at banks. The linearity of preferences implies that they are indifferent between consumption and making deposits along the equilibrium paths and thus the gross deposit interest rate equals their rate of time preference. As a result, the gross deposit interest rate is constant over time, denoted as r.

Each entrepreneur has access to an investment technology which utilizes the final good as an input. At date $t+1$ the investment yields a publicly observable return per unit of investment at date t, equaling either R if the project succeeds or 0 if it fails. Entrepreneurs can choose the scale of investment. Following the formulation of Holmstrom and Tirole (1997), the probability of success depends on the type of project the entrepreneur chooses. There are three types of projects: good, bad, and rotten. Each type of project involves different levels of private benefits which an entrepreneur can consume. The combinations of probability of success and private benefit are $(p_{\mathrm{H}}, 0)$, (p_{L}, bi_t), (p_{L}, Bi_t), respectively, where $0<b<B$, $0<\Delta p<p_{\mathrm{H}}<1$ and $\Delta p = p_{\mathrm{H}} - p_{\mathrm{L}}$. Note that the amount of private benefit is proportional to the size of investment and an entrepreneur consumes no private benefit if he chooses a good project. Also, we assume that the good projects are socially preferable:

$$p_{\mathrm{L}}R + B - r(1+c) < 0 < p_{\mathrm{H}}R - r(1+c), \tag{1}$$

where c is the unit monitoring cost of banks, which will be explained below. This says that the expected net surplus of a good project is positive, while that of a rotten project is negative even after the private benefit is accounted for.

Each period when the investment returns are realized, an entrepreneur may die with a constant probability $1-\pi^{\mathrm{E}}$. The probability that an entrepreneur dies is independent across entrepreneurs, and independent of an entrepreneur's age. At the same time a new generation of entrepreneurs is born. The birth rate is such that the population of entrepreneurs remains constant over time. The newborns start businesses with a small amount of endowment e^{E} which gives an entrepreneur a positive level of net worth so that he is able to borrow and invest. The expected lifetime utility function of an entrepreneur is given by $\mathrm{E}_t(\sum_s \beta^s c^{\mathrm{E}}_{t+s})$. The expectations are taken over the probability of success in investment and idiosyncratic lifetime. Due to linear preferences, entrepreneurs will repeatedly postpone consumption and accumulate net worth during their lifetimes as long as the rate of return is larger than the opportunity cost of investment. In that case, they consume only at the moment before they die.[5] Given net worth w_t at the beginning of date t, an entrepreneur borrows l_t from a bank and invests i_t. The flow of funds for an entrepreneur is given by

$$i_t = l_t + w_t. \tag{2}$$

There are many competitive banks, each endowed with monitoring technology which costs c units of good per unit of investment. They perform monitoring actions during the operation of the project.[6] The monitoring technology can detect whether the entrepreneur chooses a rotten project; however, it cannot tell whether the chosen project is good or bad. Therefore, an entrepreneur is left with two choices under a banker's monitoring: selecting the good or the bad one. I further assume that asset returns are perfectly correlated within a bank and are independently distributed across banks. This assumption can be considered as an extreme case of risky bank assets, as opposed to the tradition of perfectly diversified bank assets represented by Diamond (1984) and Williamson (1987) in which banks never fail and can be induced to monitor without own capital.

Since banks act as delegated monitors for depositors, they must be well-capitalized to convince depositors that they have enough stake in the risky projects. Given an investment project of size i_t, a banker pledges an amount a_t of own capital and lends l_t:

$$l_t + ci_t - d_t = a_t, \tag{3}$$

[5] The purpose of assigning a death rate to entrepreneurs (to bankers as well, see below) is that if they live infinitely and continue to postpone consumption, they might accumulate net worth over time until one day they do not need external finance and the agency problem no longer exists. An alternative way to deal with this problem is to follow Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997), in which they both assume the entrepreneurs have a higher rate of time preference. Given this assumption, Kiyotaki and Moore argue that in the neighbor of steady state, entrepreneurs do not want to postpone investment and thus they consume only non-tradeable output. Carlstrom and Fuerst, on the other hand, calibrate the discount rate such that the steady state internal rate of return equals one and thus entrepreneurs will consume to an extent that self-financing does not arise. Furthermore, in the appendix of Kiyotaki and Moore, they provide an overlapping generations version of their model where they also resort to the assumption that the agents die with a probability. In sum, the pattern of consumption by individual agents has no effect on the qualitative dynamics of the model to an exogenous shock in the aggregate, and therefore, other specifications that allow positive consumption during their lifetime do not affect the propagation mechanism of this model.

[6] Monitoring may involve inspecting the cash flows, balance sheet position, and management. This is different from ex-post monitoring in costly state verification (CSV) literature. In CSV models, lenders monitor when the project outcome is realized and only when the borrower defaults on repayments. Accordingly, the cost of monitoring in CSV literature is interpreted as bankruptcy cost.

where d_t is the amount of deposits contributed to the project.[7] The objective function of a banker resembles that of an entrepreneur. Each period a $1-\pi^{\mathrm{B}}$ number of bankers die, and the same number of newborns enters the economy with a small amount of endowment e^{B}.

2.2. Financial contracting and the equilibrium

Let the project unit return R be distributed among the entrepreneur (R_t^{E}), the banker (R_t^{B}), and households (R_t^{H}). All agents receive nothing when the project fails. The incentive compatibility condition for a banker requires that the expected return of a good project received by a banker, net of monitoring cost, must be greater than or equal to the expected return of a bad or rotten project if he does not monitor:

$$p_{\mathrm{H}} R_t^{\mathrm{B}} i_t - c i_t \geqslant p_{\mathrm{L}} R_t^{\mathrm{B}} i_t. \tag{4}$$

Given that the banker monitors, an entrepreneur will not choose the rotten project. The other incentive constraint is to induce the entrepreneur to choose the good one:

$$p_{\mathrm{H}} R_t^{\mathrm{E}} i_t \geqslant p_{\mathrm{L}} R_t^{\mathrm{E}} i_t + b i_t. \tag{5}$$

The household's expected rate of return from savings and the bank's expected rate of return from lending, respectively, require

$$r \leqslant p_{\mathrm{H}} R_t^{\mathrm{H}} i_t / d_t, \tag{6}$$

$$r_t^{\mathrm{L}} \leqslant p_{\mathrm{H}} R_t^{\mathrm{B}} i_t / a_t. \tag{7}$$

An entrepreneur maximizes his expected utility function, subject to incentive compatibility constraints (4) and (5), participation constraints (6) and (7), and non-negativity conditions $R_t^i \geqslant 0$ for $i = \mathrm{E}$, B and H and for all t. It is straightforward to see that under our environment, entrepreneurs are paid no more than the amount required to choose good projects and bankers are paid just enough so that they have incentives to monitor. The optimal contract is given by[8]

$$R_t^{\mathrm{E}} = b/\Delta p, \quad R_t^{\mathrm{B}} = c/\Delta p, \quad R_t^{\mathrm{H}} = R - (b+c)/\Delta p.$$

When Δp is small, the potential loss from choosing a bad project is small. Thus, given b and c, entrepreneurs and bankers must be compensated with a larger

[7] One might say that depositors are able to diversify their deposits (for example, using the service of brokered deposits) and therefore do not care about the soundness of their banks. Actually, even if depositors can diversify their deposits, they are still concerned whether banks make efforts to monitor, otherwise entrepreneurs might opt for rotten projects and the expected returns for depositors will fall.

[8] The financial contracting problem in the basic model here resembles that of Holmstrom and Tirole (1997).

return to induce them to behave.[9] On the other hand, when there is a greater incentive to divert funds (b is larger), or when the monitoring activity is more costly (c is higher), the payment share to an entrepreneur or a banker must be larger to be incentive compatible. Since the optimal contract is constant over time, the subscripts are dropped thereafter.

To close the model, we need to state the market-clearing conditions. The aggregate demand and supply for bank credit are given by

$$L_t^{\mathrm{D}} = I_t - W_t, \quad L_t^{\mathrm{S}} = D_t + A_t - cI_t, \tag{8}$$

where W_t, I_t, L_t, D_t, and A_t are, respectively, the aggregate variables of entrepreneurial net worth, investment, bank loans, deposits and bank capital. Recall that the households are indifferent between any path of consumption and savings, so they regulate the amount of deposits contingent upon the banks' capitalization. Thus, given the bank credit market equilibrium (8), the markets for deposits and final goods are cleared according to the Walras' Law. Market equilibrium is defined as a sequence of contract terms, loan interest rates, and allocations of bank loan, deposit, investment and consumption, $\{R_t^{\mathrm{B}}, R_t^{\mathrm{E}}, R_t^{\mathrm{H}}, r_t^{\mathrm{L}}, l_t, d_t, i_t, c_t^{\mathrm{B}}, c_t^{\mathrm{E}}, c_t^{\mathrm{H}}\}$, such that the entrepreneurs maximize their expected utility, subject to incentive compatibility constraints, (4) and (5), participation constraints, (6) and (7), and non-negativity conditions, $R^i \geqslant 0$ for $i = \mathrm{E, B, H}$; and finally the markets for final good, deposit and bank credit clear.

It can be easily verified that the loan demand schedule is downward-sloping and the loan supply schedule is upward-sloping in the loan interest rate. Thus, there exists a unique equilibrium loan interest rate for a given level of W_t and A_t:

$$r_t^{\mathrm{L}} = \frac{p_{\mathrm{H}} c (W_t/A_t + 1)}{\Delta p Z}, \tag{9}$$

where $Z = 1 + c - \beta p_{\mathrm{H}}[R - (b + c)/\Delta p]$. Existence of an equilibrium requires Z to be positive:

$$p_{\mathrm{H}} R - r(1 + c) < p_{\mathrm{H}}(b + c)/\Delta p. \tag{10}$$

The above inequality means that the expected per unit surplus of a good project is less than the expected sum of the shares paid to the entrepreneur and the banker. Thus Z can interpreted as the expected per unit return used for deterring moral hazard incentives net of the expected per unit surplus of the project. If Z is negative, the incentive to commit moral hazard is eliminated. Note also that the equilibrium loan interest rate depends on the ratio of aggregate entrepreneurial net worth to aggregate bank capital. An immediate

[9] When Δp is very small, meaning that bad projects are almost as good as the good ones, it seems counter-intuitive to give entrepreneurs and banks larger returns. However, according to the restriction (1), Δp is required to be large enough, that is: $\Delta p > B/R$.

implication is that when bank capital is relatively scarce, the loan interest rate tends to be higher.

Now we define two variables of interest: the capital–asset ratio CA_t, measuring the amount of own capital a bank must contribute for each unit of investment required to provide an incentive to perform monitoring, and the leverage LEV_t, defined as the amount of investment given a certain level of an entrepreneur's net worth:

$$CA_t \equiv a_t/(l_t + ci_t),$$

$$LEV_t \equiv i_t/w_t.$$

Using Eqs. (2), (3), (6), (7), and (9), the capital–asset ratio and the leverage can be solved in terms of parameters and state variables of the model:

$$CA_t = \frac{Z}{Z + \beta p_{\mathrm{H}} R^{\mathrm{H}}(1 + W_t/A_t)}, \tag{11}$$

$$LEV_t = \frac{1 + A_t/W_t}{Z}. \tag{12}$$

Note that both of the terms above decrease in the ratio of aggregate entrepreneurial net worth to aggregate bank capital. On the other hand, if the Z is bigger, a larger share of per unit return must be devoted to compensate for the agents who may commit moral hazard, and thus these agents are required to pledge more of their own capital to the project. For example, if the private benefit becomes larger, and thus raising Z, entrepreneurs are less willing to behave. Given that the moral hazard problem worsens, the market's response is to tighten bank lending and requires more collateral, through raising capital–asset ratio and lowering leverage.

When date t output is realized, the capital position of a bank is $R_t^{\mathrm{B}} I_t + e^{\mathrm{B}}$ if the project succeeds and e^{B} if it fails. On the other hand, the net worth of an entrepreneur becomes $R_t^{\mathrm{E}} I_t + e^{\mathrm{E}}$ if the project succeeds and e^{E} if it fails. The equations of motion of aggregate bank capital (A_{t+1}) and aggregate entrepreneurial net worth (W_{t+1}) are

$$\begin{aligned} A_{t+1} &= \pi^{\mathrm{B}}[p_{\mathrm{H}} R_t^{\mathrm{B}} I_t + (1-\eta)e^{\mathrm{B}}] + (1-\pi^{\mathrm{B}})(1-\eta)e^{\mathrm{B}} \\ &= \pi^{\mathrm{B}} p_{\mathrm{H}} c \frac{1 + W_t/A_t}{\Delta p Z} A_t + (1-\eta)e^{\mathrm{B}}, \end{aligned} \tag{13}$$

$$\begin{aligned} W_{t+1} &= \pi^{\mathrm{E}}[p_{\mathrm{H}} R_t^{\mathrm{E}} I_t + \eta e^{\mathrm{E}}] + (1-\pi^{\mathrm{E}})\eta e^{\mathrm{E}} \\ &= \pi^{\mathrm{E}} p_{\mathrm{H}} b \frac{1 + A_t/W_t}{\Delta p Z} W_t + \eta e^{\mathrm{E}}. \end{aligned} \tag{14}$$

Expressions (13) and (14) show the interdependence of these two sectors. For example, aggregate bank capital at date $t+1$ depends not only upon its own date t stock, but also upon the ratio of date t aggregate entrepreneurial net worth to aggregate bank capital. Thus, the effect of a (sector-specific) shock to bank capital will immediately spill over to the investment sector. Furthermore, the initial impact of a shock propagates into subsequent periods.

Market equilibrium starting date t can be characterized by the path of aggregate bank capital and aggregate entrepreneurial net worth, $\{A_{t+s}, W_{t+s} \mid s \geqslant 0\}$ satisfying (13) and (14), given A_{t-1} and W_{t-1}. The condition for the existence of a steady state and the conditions under which bankers and entrepreneurs continue to postpone consumption are characterized in Appendix A.

Given date t aggregate bank capital and entrepreneurial net worth, the aggregate investment and output are given by

$$I_t = LEV_t W_t = \frac{W_t + A_t}{Z},$$

$$Y_{t+1} = p_{\mathrm{H}} R I_t = p_{\mathrm{H}} R \frac{W_t + A_t}{Z}.$$

A drop in either W_t or A_t has a direct impact on the current investment and the next period output. Therefore, the banking sector and real economic activity are connected in such a way that the capital position of banks and entrepreneurial net worth jointly determine the debt capacity of entrepreneurs, bank lending and investment.

2.3. A benchmark case with perfect information

It would be useful to compare the above results with the benchmark case where there is no agency problem. In this case, there is no role for financial intermediation and monitoring. Since good projects are socially preferable, the bankers and households will contribute all of their wealth to investment in good projects. The aggregate investment is $I_t = A_t + W_t + H_t$, where H_t is the total wealth of the households. The investment returns will be distributed according to

$$R_t^{\mathrm{B}} = \frac{A_t}{\beta p_{\mathrm{H}} I_t}, \qquad R_t^{\mathrm{E}} = \frac{W_t}{\beta p_{\mathrm{H}} I_t}, \qquad R^{\mathrm{H}} = R - \frac{W_t + A_t}{\beta p_{\mathrm{H}} I_t},$$

and the aggregate variables accumulate according to

$$A_{t+1} = \pi^{\mathrm{B}}[p_{\mathrm{H}} R^{\mathrm{B}} I_t + (1-\eta)e^{\mathrm{B}}] + (1-\pi)(1-\eta)e^{\mathrm{B}} = \pi^{\mathrm{B}} A_t/\beta + (1-\eta)e^{\mathrm{B}},$$

$$W_{t+1} = \pi^{\mathrm{E}}[p_{\mathrm{H}} R^{\mathrm{E}} I_t + \eta e^{\mathrm{E}}] + (1-\pi)\eta e^{\mathrm{E}} = \pi^{\mathrm{E}} W_t/\beta + \eta e^{\mathrm{E}},$$

$$Y_{t+1} = p_{\mathrm{H}} R(A_t + W_t + H_t).$$

Note that there is no linkage across sectors as we have seen in the asymmetric information case. For example, the accumulation of aggregate bank capital depends only upon its own history. If the banks are hit by a negative shock specific to the banking sector, the effects will not transmit to other sectors. Due to the absence of interdependence across sectors that reinforces the initial effect, the impact of a shock is much smaller than the case under asymmetric information.

2.4. Wealth shocks

We consider a once-and-for-all wealth redistribution from bankers to households that mimics an unexpected sector-specific shock hitting the banking sector. This resembles the so-called "capital crunch" where bank lending is constrained by their impaired capital position. The same period impacts of a redistribution ε are given by

$$\frac{\mathrm{d}r_t^{\mathrm{L}}}{\mathrm{d}\varepsilon} > 0, \quad \frac{\mathrm{d}CA_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}LEV_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}L_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}I_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}Y_t}{\mathrm{d}\varepsilon} < 0.$$

The results are different from any of the comparative statics by changing a given model parameter. When there is a capital crunch, the decrease in the credit supply due to a drop in bank capital outweighs the decline in credit demand, and thus raising the loan interest rate. Note that the banking sector tightens credit even though the market is more lenient by allowing the capital–asset ratio to fall.[10] On the other hand, leverage is lowered, reducing the amount an entrepreneur can borrow per unit of net worth. This says that the market imposes a more stringent collateral requirement upon the entrepreneurs. In contrast, a wealth redistribution from entrepreneurs to households, which is reminiscent of Fisher's (1933) "debt-deflation" argument, yields a different behavior in loan interest rate, capital–asset ratio and entrepreneurial leverage:

$$\frac{\mathrm{d}r_t^{\mathrm{L}}}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}CA_t}{\mathrm{d}\varepsilon} > 0, \quad \frac{\mathrm{d}LEV_t}{\mathrm{d}\varepsilon} > 0, \quad \frac{\mathrm{d}L_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}I_t}{\mathrm{d}\varepsilon} < 0, \quad \frac{\mathrm{d}Y_t}{\mathrm{d}\varepsilon} < 0.$$

As suggested by Holmstrom and Tirole (1997), the fact that $\mathrm{d}CA_t/\mathrm{d}\varepsilon$ being negative in response to a bank capital shock seems to imply procyclical bank capital adequacy ratios, while a shock to the investment sector implies countercyclical capital–asset ratios. I will come back to this policy issue in Section 4.

A numerical simulation, which is not shown here, can be conducted accordingly: immediately upon the hit of a shock, either to the bank sector or the investment sector, all aggregate variables reach their peaks (or troughs) immediately and then gradually return to the steady state. Finally, a wealth shock under perfect information does not affect investment and output at all. It is simply a redistribution of wealth among agents.

[10] A lower capital–asset ratio will not impair banks' incentive to monitor as long as they are paid enough. In fact, their rates of return on loans have increased.

3. Asset prices and the credit constraint

3.1. The environment

In this section I introduce a durable asset to the basic model where the fluctuations of the asset prices play an important role in the propagation mechanism and enrich the dynamics of the model. Furthermore, in the basic model there is no intrinsic disturbance, thus the source of shocks mentioned above are rather artificial. Here I will consider a productivity shock as the source of disturbance.

In addition to households, entrepreneurs, and bankers, there are many competitive final-goods-producing firms. There are three types of commodities at each period of time: a final good, an intermediate good and a durable asset. The durable asset does not depreciate and its total supply is fixed at $\bar{K}$. At each date t a spot market for the asset opens in which the asset is traded for final goods at a price of q_t. Entrepreneurs own a fraction of the stock of asset, through their own net worth and by borrowing from banks, for investment to produce intermediate goods. The remaining stock of the asset is held by households for home production to produce final goods. The final-goods-producing firms employ intermediate goods and labor to produce final goods.

The households are each endowed with one unit of labor which is inelastically supplied to the final-goods-producing firms. Moreover, they have access to a simple home production technology exhibiting decreasing returns to scale, $y^{\mathrm{H}}_{t+1} = H(k^{\mathrm{H}}_t)$, where k^{H}_t is the asset held by the households and $H' < 0$, $H'' < 0$. An entrepreneur is endowed with stochastic investment technology which utilizes the durable asset k^{E}_t as an input and produces intermediate goods m_{t+1}. The investment yields intermediate goods equaling Rk^{E}_t if the project succeeds and 0 if it fails. The types of projects associated with the private benefits and probabilities of success remain the same as in the previous section. Note that private benefits are now in terms of intermediate goods. An entrepreneur who fails the investment project will forfeit his asset to his bank. Thus, an additional role for banks is to seize the asset of entrepreneurs who default. Finally, the assumption of random death for entrepreneurs and bankers carries over.

The technology of final-goods-producing firms employs intermediate goods and labor as inputs:

$$Y_t = \theta_t F(M_t, N_t),$$

where M_t is the aggregate intermediate goods available at the beginning of date t, N_t is the aggregate employment of labor, and θ_t is an aggregate productivity shock with constant mean $\theta > 0$, $\theta_t \in [\underline{\theta}, \bar{\theta}]$. The production function satisfies the standard neoclassical conditions. Factor markets are assumed to be competitive, while date t equilibrium wage and the price of intermediate goods are $w_t = \theta_t F_2(M_t, N_t)$ and $v_t = \theta_t F_1(M_t, N_t)$, respectively.

Entrepreneurs turn to banks for financing the difference between the market value of asset $q_t k_t^{\mathrm{E}}$ and their own net worth w_t. For an investment project k_t^{E}, the resource constraint for a bank and flow of funds for an entrepreneur are

$$l_t + ck_t^{\mathrm{E}} - d_t = a_t, \tag{15}$$

$$i_t = l_t + w_t, \tag{16}$$

where i_t is the amount of investment which equals the market value of the asset $q_t k_t^{\mathrm{E}}$. Note that the cost of monitoring is proportional to the size of asset employed for investment, because what is relevant for the cost of monitoring is the scale of the project, rather than the value of asset.

The sequence of events during date t is summarized as follows. At the beginning of date t, investment project outputs (intermediate goods) are realized. The entrepreneurs who default lose their collateral to banks. The seized collateral will be auctioned off in the asset market. An aggregate productivity shock is then observed. Final goods are produced by employing intermediate goods and labor and are split among agents according to the financial contract. Some entrepreneurs and bankers receive news that they are going to exit from the economy. The dying agents sell off assets and consume, and a new generation of bankers and entrepreneurs are born. In the middle of the period, agents engage in financial contracts. Entrepreneurs take loans from banks, choose projects and implement investments, and banks finally decide whether or not to monitor.

3.2. Financial contracting

Since there is no aggregate shock over the duration of the financial contract, the contract terms are contingent only upon the expected values of the functions of aggregate shock which will be realized in the next period. Let R_t^{E}, R_t^{B}, and R_t^{H} be the unit project returns in terms of intermediate goods when the project succeeds, distributed among the entrepreneurs, bankers and households. The incentive compatibility constraints for a banker and an entrepreneur, respectively, are

$$v_{t+1}^e p_{\mathrm{H}} R_t^{\mathrm{B}} k_t^{\mathrm{E}} - ck_t^{\mathrm{E}} \geqslant v_{t+1}^e p_{\mathrm{L}} R_t^{\mathrm{B}} k_t^{\mathrm{E}}, \tag{17}$$

$$v_{t+1}^e p_{\mathrm{H}} R_t^{\mathrm{E}} k_t^{\mathrm{E}} + p_{\mathrm{H}} q_{t+1}^e k_t^{\mathrm{E}} \geqslant v_{t+1}^e p_{\mathrm{L}} R_t^{\mathrm{E}} k_t^{\mathrm{E}} + p_{\mathrm{L}} q_{t+1}^e k_t^{\mathrm{E}} + v_{t+1}^e b k_t^{\mathrm{E}}, \tag{18}$$

where x_{t+1}^e denotes $\mathrm{E}_t(x_{t+1} \mid \Omega_t)$ for a random variable x_t; $\mathrm{E}(\bullet)$ is the mathematical expectations operator; and Ω_t is the information set at date t; $\Omega_{t-1} \subseteq \Omega_t$; Ω_t includes the past and current values of aggregate variables.

Given the date t net worth w_t, an entrepreneur needs to take an amount of loan $q_t k_t^{\mathrm{E}} - w_t$. Since the banks always monitor in equilibrium, the total outlay for a project is $(q_t + c)k_t^{\mathrm{E}}$. The households' expected rate of return from savings and a banker's expected rate of return from lending satisfy:

$$r = \frac{p_{\mathrm{H}} v_{t+1}^{e} R_t^{\mathrm{H}} k_t^{\mathrm{E}} + (1 - p_{\mathrm{H}}) q_{t+1}^{e} k_t^{\mathrm{E}}}{(q_t + c)k_t^{\mathrm{E}} - w_t - a_t}, \tag{19}$$

$$r_t^{\mathrm{L}} = \frac{v_{t+1}^{e} p_{\mathrm{H}} R_t^{\mathrm{B}} k_t^{\mathrm{E}}}{a_t}. \tag{20}$$

The optimal contract is derived in a similar manner as in the previous section:

$$R_t^{\mathrm{E}} = \frac{b}{\Delta p} - \frac{q_{t+1}^{e}}{v_{t+1}^{e}}, \quad R_t^{\mathrm{B}} = \frac{c}{\Delta p v_{t+1}^{e}}, \quad R_t^{\mathrm{H}} = R - R_t^{\mathrm{E}} - R_t^{\mathrm{B}}.$$

To understand the entrepreneur's share of return, think of $R_t^{\mathrm{E}} + q_{t+1}^{e}/v_{t+1}^{e}$ as the gross return to the entrepreneur when he succeeds. In this case, in addition to the share of project return, he keeps control of the asset. Since the contract terms depend on the expected prices of intermediate goods and the durable asset, when the asset prices are expected to be higher relative to the intermediate goods prices (q_{t+1}^{e}/v_{t+1}^{e} is higher), the entrepreneur's expected gross incomes are larger and the entrepreneur's share of project return can be made smaller without violating the incentive compatibility.

The market-clearing condition for the bank credit market is given by the aggregation of (15) and (16). The labor market equilibrium is given by $N_t = N$, the asset market by $K_t^{\mathrm{E}} + N k_t^{\mathrm{H}} = \bar{K}$, and the intermediate goods market by $M_t = p_{\mathrm{H}} R K_{t-1}^{\mathrm{E}}$ for all t. The markets for deposits and final goods are cleared according to Walras' law. Aggregating (15) and (16), together with (19) and (20), we can solve for the equilibrium loan interest rate, capital–asset ratio and leverage as follows:

$$r_t^{\mathrm{L}} = \frac{p_{\mathrm{H}} c(W_t/A_t + 1)}{\Delta p Z_t}, \tag{21}$$

$$CA_t \equiv \frac{Z_t}{Z_t + \beta[p_{\mathrm{H}} v_{t+1}^{e}(R - b/\Delta p) - bc/\Delta p + q_{t+1}^{e}](1 + W_t/A_t)}, \tag{22}$$

$$LEV_t = \frac{q_t(1 + A_t/W_t)}{Z_t}, \tag{23}$$

where $Z_t \equiv q_t + c - \beta[p_{\mathrm{H}} v_{t+1}^{e}(R - b/\Delta p) - p_{\mathrm{H}} c/\Delta p + q_{t+1}^{e}]$.

An important difference from the results in the basic model is that these are functions of the current and expected prices of the asset. If, for example, current and expected prices of the asset increase by the same proportion, then the loan interest rate and capital–asset ratio fall and the entrepreneurial leverage rises, which unambiguously result in higher levels of bank lending and investment.

When the date $t+1$ productivity shock is realized, the entrepreneurs trade assets with the households and receive a small amount of endowment e^{E}. Thus, the date $t+1$ net worth of an entrepreneur is $q_{t+1}k_t^{\mathrm{E}} + v_{t+1}R_t^{\mathrm{E}}K_t^{\mathrm{E}} + e^{\mathrm{E}}$ if the project succeeds and e^{E} if it fails. The accumulation of aggregate bank capital and entrepreneurial net worth are now:

$$A_{t+1} = \pi^{\mathrm{B}} p_{\mathrm{H}} v_{t+1} R_t^{\mathrm{B}} K_t^{\mathrm{E}} + (1-\eta)e^{\mathrm{B}}, \tag{24}$$

$$W_{t+1} = \pi^{\mathrm{E}} p_{\mathrm{H}} q_{t+1} K_t^{\mathrm{E}} + \pi^{\mathrm{E}} p_{\mathrm{H}} v_{t+1} R_t^{\mathrm{E}} K_t^{\mathrm{E}} + \eta e^{\mathrm{E}}. \tag{25}$$

Using the asset market equilibrium condition and the arbitrage condition, we have

$$q_t - \frac{q_{t+1}^e}{r} = \frac{H'[(\bar{K} - K_t^{\mathrm{E}})/N]}{r}. \tag{26}$$

Market equilibrium of the model from date t onwards is characterized by the path of asset prices, aggregate bank capital and aggregate entrepreneurial net worth, $\{q_{t+s}, A_{t+s}, W_{t+s} \mid s \geqslant 0\}$ satisfying (24)–(26), given A_{t-1} and W_{t-1}. The exploding bubbles in asset prices are ruled out by assuming $\lim_{s\to\infty} \mathrm{E}_t(r^{-s}q_{t+s}) = 0$.

3.3. Quantitative properties of the model

We now report the numerical simulation of the full model. The goal is not to match data, but rather to provide some qualitative properties of the dynamic path of the model. The first step is to specify the form of the home production function and final goods production function and then compute the model's steady state. I next linearize the system (24)–(26) around the steady state and compute the linear decision rules following the method by King et al. (1987). The procedures are briefly described in Appendix B. The stochastic process of the aggregate shock is assumed to take the form $\theta_t = (1-\rho) + \rho\theta_{t-1} + \varepsilon_t$, where ε_t is a serially uncorrelated random variable, and ρ is the autocorrelation coefficient. I simulate the impulse responses of this economy to a negative, once-and-for-all productivity shock.

Simulation results are presented in Fig. 1. In response to a negative productivity shock, the asset prices, bank capital and entrepreneurial net worth continue to fall for some time before returning to the steady state. The key point why the impacts build up over time is that the value of assets which constitutes the net worth of entrepreneurs as well as banks are interrelated with the amount of bank loan and investment. At first, investment returns to all agents fall, thus impaired capital position of banks and net worth of

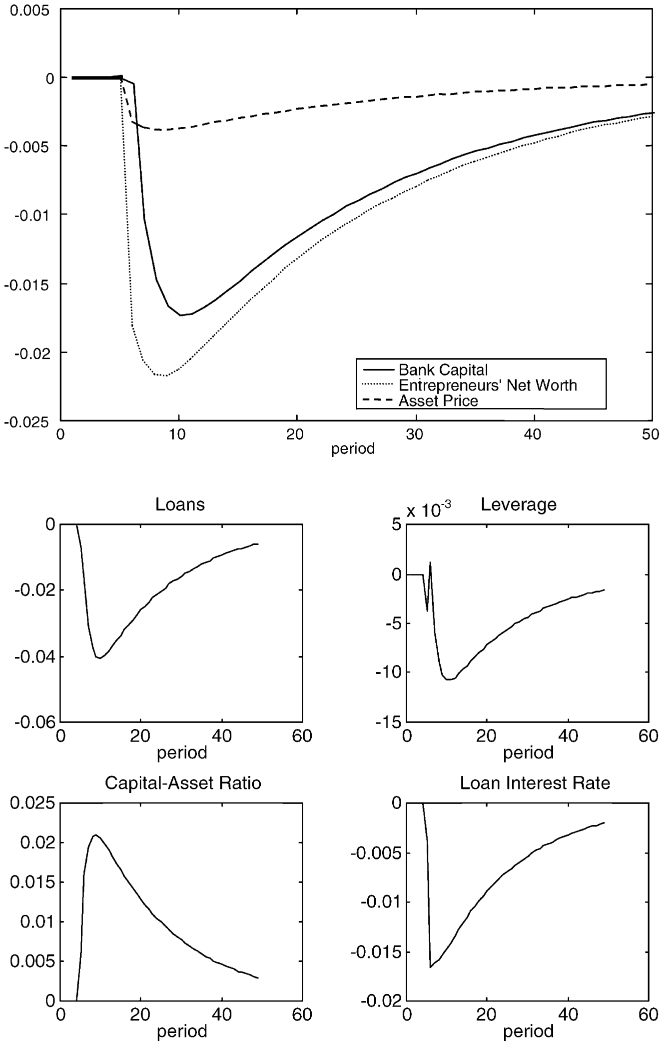

Fig. 1. Simulation results.

entrepreneurs reduce lending and investment. Lower demand for the asset then depresses its price and in turn further lessens the value of collateral. Due to the additional effect of asset price on collateral value, the capital–asset ratio increases and the leverage decreases, which is different from the result due to a wealth shock where both ratios move in the same direction. This feedback effect further restrain the amount of bank loans and investment by higher capitalization requirement for lending and stricter collateral requirement for borrowing. The propagation mechanism is thus strengthened through changes in the asset prices, leading to an even bigger contraction in economic activity.

The loan interest rate falls in response to a negative productivity shock. To see why, note that the interest rate in (9) of the basic model depends only upon the ratio of bank capital to entrepreneurial net worth. In the full model, however, the movement of interest rate in Eq. (21) is dominated by the fall in asset prices.[11]

4. Policy implications and final remarks

In the basic model the market-generated bank capital–asset ratio and the leverage are both procyclical if an exogenous shock hits the banking sector, while they are counter-cyclical if the shock hits the investment sector. When a durable asset is introduced into the model, however, fluctuations of the asset prices cause the capital–asset ratio to be counter-cyclical and the leverage to be procyclical following a productivity shock. Therefore, the contraction of bank credit is strengthened by the interaction of a more stringent bank capitalization requirement and higher collateral requirement for loans. This amplifies and prolongs the propagation of the initial shock.

The above results bear policy implications for the recent debate over bank capital regulation and credit control policies. It has been advocated recently that certain prudential regulations may unduly increase fluctuations of the economy when these regulations become binding. Firstly, regarding the effect and policy implication of a rigid bank capital adequacy requirement, Bernanke and Lown (1991) and Furlong (1992) argue that the U.S. economy suffered from a credit crunch in the early 1990s, because the BIS risk-adjusted capital adequacy requirement came into effect at a time when many banks experienced huge loan losses and erosion of bank capital. Blum and Hellwig (1995) find that a rigid bank capital adequacy requirement is more likely to bind when the economy is going into a downturn, which increases the volatility of economic activity to an exogenous shock. Our basic model without asset reaches the same implication: the regulatory capital adequacy ratios, if any, should be procyclical in case of a "capital crunch", because the market capital–asset ratio is allowed to be lower in response to a shock hitting the banking sector. A rigid

[11] The behavior of capital–asset ratio, leverage, and loan interest rate described above are quite robust within a reasonable range of parameters. A wealth shock exercise as in Section 2, however, indicates that the movements of the above three endogenous variables are not as clear cut as before, but are rather sensitive to changes in parameter values.

capital adequacy requirement does nothing but further restrict the capability of banks to extend loans and deepen the recession.[12]

In our full model where the fluctuations of asset prices are taken into account, however, the market capital–asset ratio must be higher in response to a negative productivity shock, meaning that banks are required to pledge a higher stake in lending.[13] Our full model thus implies that a credit slowdown and the subsequent recession may result from the optimal response of the market, rather than due to the regulatory capital adequacy requirement. This provides a rationale that the monetary authority need not lower the capital adequacy requirement at a time when the banking sector is in trouble. In fact, a procyclical capital adequacy policy is ineffective in alleviating credit crunch.[14]

Secondly, regarding credit control policies, Aiyagari and Gertler (1999) find that the "overreaction" in asset prices can be explained by the existence of margin requirement. In particular, when the asset price goes down and triggers the margin requirement, the investors have to shed a larger stock of asset holdings. The sale spree forces the asset prices to fall below their "fundamental" values. Our full model, however, shows that banks lower the leverage of an entrepreneur following a negative productivity shock by imposing a more stringent collateral requirement for borrowing, which conforms with the casual observation that banks ask for more collateral for a given amount of lending during bad times. Thus, the fall in asset prices due to the interaction of both credit constraints can be substantial even without this credit control policy.

In sum, the full model implies that the episodes of credit crunch or excess volatility in asset prices would have caused by the working of market discipline, even in the absence of bank capital adequacy requirement that restricts lending and other regulatory and tax policies that discourage borrowing. This result can be ascribed to the nature of collateralized financial contracts in which the value of collateral per se is procyclical. This in turn points out an alternative arrangement where a certain type or a combination of collateral with a relatively stable value over the business fluctuations could reduce the volatility of economy activity.[15]

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[12] It is not surprising that the policy implication in our basic model also conforms with Holmstrom and Tirole's (1997) proposal due to the resemblance of the contracting problem between these two models. See Chen (1997) for details of a variant of the basic model that explicitly incorporates regulatory bank capital adequacy requirement. The simulation shows that the economy is more sensitive to an exogenous shock.

[13] Given the existing level of bank capital, the depositors can withdraw a fraction of deposits to raise the market capital–asset ratio.

[14] Dewatripont and Tirole (1994) are also against procyclical capital adequacy ratios on the account that this policy gives the bank managers wrong incentives to take excess risk.

[15] Mortgage-backed securities, to a certain degree, can do the job by way of diversification.

The framework in this paper is highly simplified in which some important elements in the dynamics of business cycles, such as consumption, nominal interest rates, and price level, are not included. The model can be extended to incorporate a government sector where the responses of these variables to a monetary policy shock can be analyzed. Furthermore, in this paper bank credit is the only financing available for firms. Thus, the transmission mechanism outlined above can be best ascribed to economies where bank credit is the primary source of financing. In an economy where direct financing is non-trivial, Gertler and Gilchrist (1994) and Bernanke et al. (1996) find that small and medium-sized firms, which are mostly bank-dependent, bear a disproportional share of declines in the availability of outside financing when monetary policy tightens. It would be an interesting extension to capture this asymmetry between different categories of firms in responding to shocks.

For further reading

Berger et al., 1995; Bernanke and Gertler, 1989; Hart and Moore, 1994; Kashyap et al., 1993.

Appendix A

This appendix states the conditions for the existence of a steady state and the conditions under which the bankers and entrepreneurs continue to postpone consumption. Steady states are denoted by variables without time subscripts. The existence of a steady state requires that the probabilities of survival for bankers and entrepreneurs be small enough:

$$\pi^j < \beta - \frac{\Delta p(\beta p_{\mathrm{H}} R - 1 - c)}{p_{\mathrm{H}}(b + c)} \equiv \pi_1, \tag{A.1}$$

where $j = \mathrm{B},\ \mathrm{E}$. By (1), $(\beta p_{\mathrm{H}} R - 1 - c)$ is positive. It can also be checked that by (1) and (10), these assumptions assure π_1 to be positive. The bankers and the entrepreneurs repeatedly postpone consumption, evaluated at the steady state, if

$$\pi^{\mathrm{B}} p_{\mathrm{H}} \mu < \beta p_{\mathrm{H}} \mu + (1 - \eta) e^{\mathrm{B}} (\beta p_{\mathrm{H}} R - 1 - c), \tag{A.2}$$

$$\pi^{\mathrm{E}} p_{\mathrm{H}} \mu < \beta p_{\mathrm{H}} \mu - \eta e^{\mathrm{E}} (\beta p_{\mathrm{H}} R - 1 - c), \tag{A.3}$$

where $\mu \equiv [c\eta e^{\mathrm{E}} - b(1 - \eta) e^{\mathrm{B}}]/\Delta p$. It turns out that the sign of μ depends on the relative rate of returns between bankers and entrepreneurs in steady state which is given by

$$\frac{RET^{\mathrm{B}}}{RET^{\mathrm{E}}}=\frac{\pi pbc[(1-\eta)e^{\mathrm{B}}+\eta e^{\mathrm{E}}]+c\eta e^{\mathrm{E}}[\Delta pZ-\pi P(b+c)]}{\pi pbc[(1-\eta)e^{\mathrm{B}}+\eta e^{\mathrm{E}}]+b(1-\eta)e^{\mathrm{B}}[\Delta pZ-\pi P(b+c)]}.$$

I assume that the population of the entrepreneurs η is large enough compared to the population of bankers, so that μ is strictly positive. Thus, Eqs. (A.2) and (A.3) further restrict the range of the survival rates. Together with (A.1), the conditions that bankers and entrepreneurs repeatedly postpone consumption become:

$$\pi^{\mathrm{B}}<\pi_1, \qquad \pi^{\mathrm{E}}<\pi_2, \tag{A.4}$$

where $\pi_2 \equiv \beta-\eta e^{\mathrm{E}}(\beta p_{\mathrm{H}}R-1-c)/(p_{\mathrm{H}}\mu)$ and $\pi_1>\pi_2$. When the life expectancies of the agents are longer, they have a better chance to accumulate more capital in their lifetime. Thus, if the survival rate is large enough, these agents expect that they can be wealthy enough during their lifetime so that there is no need to rely on external financing. At the same time, they start to consume. Therefore, the survival rate must be low enough to induce them to postpone consumption until the time right before they die.

Appendix B

This appendix describes the linearization of the model and the procedure of simulation. I specify the final goods production function $F(M_t,N_t)=AM_t^{\gamma}N_t^{1-\gamma}$, $0<\gamma<1$, and the marginal productivity of home production $u_t=H'(k_t^{\mathrm{H}})/r=(K_t^{\mathrm{E}}-\kappa)/\bar{K}$, where κ is a constant and is set to make the elasticity of residual supply of asset from households to be equal to 50% in the steady state. Following Kiyotaki and Moore (1997), the total stock of asset $\bar{K}$ is chosen such that the entrepreneurs hold two-thirds of the total asset stock in the steady state. Furthermore, I assume that $H'<p_{\mathrm{H}}Rv_{t+1}^{e}$ for all t, which means that the marginal product of home production is small enough so that the asset is more productive when used in investment projects.

The system of three equations (24)–(26) is then linearized around the nonstochastic steady state values. After tedious calculations, I can compute the linear decision rules following the method by King et al. (1987). Finally, I choose values of parameters of the model. The values are chosen either from the literature or, if not available, they are chosen to satisfy those restrictions stated in the main text. For example, monitoring cost c, private benefit b, and the probabilities of success p_{H} and p_{L} are chosen so that all agents receive positive returns, and the probabilities of survival for bankers and entrepreneurs are chosen so that the restrictions from (A.1) to (A.4) are satisfied. To examine the impulse response functions, I specify the stochastic process of the aggregate shock $\theta_t = (1-\rho) + \rho\theta_{t-1} + \varepsilon_t$, where ε_t is a serially uncorrelated random variable, and ρ is the autocorrelation coefficient and set to be 0.95. The once-and-for-all shock is set to be $\varepsilon_t = -0.01$.

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