# Financial Intermediation, Capital Spillovers and Business Fluctuations

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**Abstract**

We study how the financial intermediation sector interacts with the real sector over the business cycle. We identify the conditions under which deteriorating balance sheets of firms affect future lending of intermediaries and induce a lending channel effect. We obtain a negative relationship between the extent of agency problems and the size and persistence of output fluctuations. The persistence of shocks is the mirror image of the time used to work out banking crises by interest rate policies of the central bank. Finally, our model generates a set of predictions about the behavior of macroeconomic variables such as monitoring intensity, deposit and lending rates as well as interest rate spreads over the business cycle.

Keywords: Financial intermediation, business cycles, capital spillovers, regulation.

JEL-Classification: E32, E44, E51, G21, G28

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# 1 Introduction

*Motivation*

An important characteristic of many banking crises is that when the firms' ability to pay back loans deteriorates, this aggravation spills over to the balance sheets of financial intermediaries and affects their lending behavior. In this paper we study how financial intermediation interacts with the real sector over the business cycle. In particular, we examine how productivity and cash flow shocks to firms affect intermediation, the future lending ability of banks, and real output. The novelty of our analysis lies in the interaction of firms' balance sheets and the balance of intermediaries in a dynamic equilibrium model where both sides of financial intermediation are endogenized.

From a policy perspective, we will further examine whether and how central banks can resolve banking crises by lowering short-term interest rates. There are famous historical examples for this approach. The Bank of Japan, for instance, lowered nominal interest rates quite drastically in the nineties, cf. Hoshi and Kashyap [2004]. The nominal short-term interest rate virtually attained zero in February 1999 and remained close to zero for many years, except for a brief period. Real interest rates, which were high in the first half of the nineties, declined and fluctuated between zero and two percent in the second half.

Regarding the literature, the paper follows earlier contributions on how credit constraints interact with aggregate economic activity. Starting from the seminal work of Bernanke and Gertler [1989], Greenwald and Stiglitz [1993] and Kiyotaki and Moore [1997], the literature has examined dynamic general equilibrium models where informational frictions in capital markets cause temporary shocks to technology to generate large, persistent fluctuations in output and asset prices. Fuerst [1995] provides assessments of the quantitative extent to which agency costs expand the propagation mechanism in the basic real business cycle framework. Ortalo-Magné and Rady [1998] construct a life-cycle model of housing markets in which agents face varying credit constraints over their lifetime. They show that the magnitude of housing price fluctuations can exceed those of GDP.

However, none of these models contain a financial intermediation sector with an own balance sheet, and hence the problem of capital spillovers, which is the focus of this paper, does not occur in the current literature.

*Model and Results*

We use an overlapping generations model in which entrepreneurs have access to investment projects whose returns cannot be observed ex ante by consumers or other entrepreneurs.

Moreover, the investment decisions of entrepreneurs are not verifiable. Adverse selection and moral hazard can be alleviated by financial intermediation. Financial intermediaries act as delegated monitors. They have access to a monitoring technology that can help to either secure repayments if cash flows are sufficiently high or can help to recover part of the loaned funds if entrepreneurs fail to generate cash flow sufficient to pay back. We distinguish two cases. In the friction case, banks can only partially alleviate adverse selection and moral hazard problems. In the frictionless case, banks have access to monitoring technologies that allow them to eliminate the agency problems of entrepreneurs completely. Our model has the following implications.

First, in both cases, unanticipated negative aggregate shocks can lead to negative capital spillovers from the balance sheets of firms to those of intermediaries. Negative capital spillovers arise endogenously when the firms' balance sheets deteriorate below a certain threshold. These spillovers constrain future lending of intermediaries and cause the persistence of shocks. The extent of negative capital spillovers and thus the persistence of the shocks is inversely related to those agency problems that are not eliminated by financial intermediaries: the persistence of shocks is larger in the presence of small capital market imperfections. On average, in the presence of large moral hazard and adverse selection problems, banks will anticipate that firms only invest if their repayment capacity is sufficiently high. Thus, unanticipated cash flow shocks can be absorbed more easily by firms until they spill over to banks if agency problems are severe.

Second, the persistence of shocks in both the frictionless and the friction case is the mirror image of the time used to work out banking crises. A rapid workout associated with drastic interest rate cuts by the central bank implies a drop in aggregate income over two periods. Aggregate income then returns to the previous level. An infinite workout associated with moderate interest rate cuts leads to a decline of aggregate income in all future periods. Infinite workouts will always lead to larger losses in aggregate income since the decline is equal to immediate workout in the first two periods. Utilities however, are affected in a different way. As infinite workout can have higher deposit rates and lower lending rates in the first workout period because loss recovery can be postponed, the utility of consumers as well as of entrepreneurs who are born in the initial period is higher under an infinite workout than under immediate workout. Hence, we obtain a preference of the first workout generation for infinite workout which, however, implies larger income losses than immediate workouts over the whole time period.

Third, the decline in lending of banks because of negative capital spillovers can be associated with a lending channel phenomenon caused by balance sheet problems of firms.[1]

[1]Traditionally, the lending channel [Bernanke and Blinder 1992, Kashyap, Stein and Wilcox, 1993, Kashyap and Stein 1994, Repullo and Suarez 1995] rests on the imperfect substitutability between Treasury bills and commercial papers. In our model, the lending channel exists because macroeconomic shocks

The empirical literature has identified separate "balance sheet channels" and "lending channels" [see Bernanke 1993 for an early survey], depending on changes in demand or supply factors in the credit market. Our analysis suggests that a lending channel can simply be the dynamic consequence of firms' balance sheet problems if both the balance sheets of firms as well as the intermediaries are endogenized.

Fourth, we provide a set of theoretical predictions about the behavior of macroeconomic variables over the business cycle when agents anticipate aggregate productivity shocks. If the productivity of entrepreneurs declines, banks react by lowering their deposit rates and by increasing their monitoring intensity. Lending rates also drop if monitoring does not increase too much, but the interest rate spread increases in any case. Lending declines due to declining interest rates and because a larger share of resources are used for monitoring. These predictions appear to be consistent with the experiences in several OECD countries suffering credit crunches during the late 1980s and early 1990s [Friedman and Kuttner 1993, Gertler and Gilchrist 1994]. However, because interest spreads across periods are not empirically comparable as there are selection effects in the pool of borrowers, the evidence on interest rate spreads remains ambiguous [see Bernanke 1993 and Miron, Romer and Weil 1994].

The paper is organized as follows. The next section describes the model. In the third section, we derive the equilibrium in the intermediation market and the overall equilibrium. Section four contains the equilibrium in the economy under the condition that intermediation can completely eliminate agency problems as benchmark. Sections five and six contain the major results. Section seven concludes.

# 2 Model

We consider an overlapping generations (OG) model with financial intermediation. Time is infinite in the forward direction and is divided into discrete periods indexed by $t$. There are overlapping generations of agents living two periods and an initial "old" generation in period zero. There is a continuum of agents in each generation, indexed by [0,1]. There are two classes of agents in each generation. A fraction $\eta$ of individuals are potential entrepreneurs. The rest $1-\eta$ of the population are consumers. Potential entrepreneurs and consumers differ in the fact that only the former have access to investment technologies. There is one physical good that can be used for consumption or investment. Each individual in each generation receives an endowment $e$ of the goods when young, and none when old.

Each entrepreneur has access to a production project that converts time $t$ goods into

spill over to banks and decrease future lending.

time $t + 1$ goods. The required funds for an investment project are $F = e + I$. Hence, an entrepreneur must borrow $I$ units of the goods in order to undertake the investment project. The class of entrepreneurs is not homogeneous. We assume that entrepreneurs are indexed by a quality parameter $q$ uniformly distributed on $[\overline{q} - 1, \overline{q}]$, $\overline{q} > 1$, in the population of entrepreneurs. If an entrepreneur of type $q$ obtains additional resources $I$ and decides to invest, he realizes investment returns in the next period of

$$q(I + e). \tag{1}$$

For simplicity, we assume that potential entrepreneurs only care about consumption when old, i.e. they do not consume when young, whereas consumers consume in both periods. They have the utility functions $u(c_t^1, c_t^2)$ defined over consumption in the two periods, where $c_t^1(c_t^2)$ is the consumption of the period $t$ consumer when young and old, respectively. $u(\cdot)$ is assumed to be strictly concave. If a household can transfer wealth between the two periods at an interest rate, denoted by $r_t$, the solution of the household problem generates the saving function, denoted by $s\{1 + r_t\}$. We follow the standard assumptions in the *OG* literature that the substitution effect (weakly) dominates the income effect, i.e. savings are an increasing function of the interest rate. We drop the time index whenever convenient.

We focus solely on indirect financing in order to study the interaction between the financial intermediation sector and firms.[2] We assume that there are potentially infinitely many banks that can finance entrepreneurs. For most of our arguments, it will be sufficient that two banks exist. Banks face the following informational asymmetries. The quality $q$ is known to the entrepreneur, but not to banks. Moreover, banks cannot verify whether or not an entrepreneur invests. Thus, banks face a fixed pool of observationally identical borrowers.

We consider financial intermediation to be delegated monitoring in the sense of Diamond [1984].[3] Banks are assumed to have access to a monitoring technology. If a bank invests $m$ units of resources into the monitoring of an entrepreneur, the bank expects the following repayments:

- If the entrepreneur has invested, the bank can secure repayment by the entrepreneur to the extent that funds have been generated. We assume that securing repayment

[2]Our model could be complemented by a second category of entrepreneurs where no asymmetric information problems are present. These entrepreneurs could obtain their funds through direct finance. Such an extension would not change the qualitative insights of the paper. It would, however, increase the difficulties of working out banking crises since a larger share of capital would move to the sector with less frictions if deposit rates fall.

[3]A succinct discussion about the underlying frictions in markets that lead to intermediation can be found in Hellwig [1994].

conditional on investment is possible with any level of monitoring intensity $m$.

- If the entrepreneur does not invest and simply tries to consume the funds granted to him, the banks can reduce private benefits and can expect a repayment of $R(m)$.

Monitoring in order to secure repayments takes many forms in the second case: inspection of firms' cash flow when customers pay, efforts to collateralize assets if they have been created in the process of investing or selling products. Monitoring intensity is measured by the amount of resources spent per loan which, in practice, corresponds mainly to costs of capital (including computer facilities) and personnel in the loan and credit risk management units of a bank. We assume:

$$R(0) = 0, R' > 0, R'' < 0, \lim_{m \to \infty} R(m) < I \tag{2}$$

Our model is somewhat orthogonal to the incomplete contract literature on financial contracts, e.g. Hart [1995], where it is assumed that the output is not or only partially verifiable, regardless of whether the entrepreneurs invest. Note that the bank has to invest $m$ before they can observe the investment decisions of firms. If firms invest, monitoring simply secures repayment. If the firm does not invest, monitoring helps to increase the liquidation value of the credit for the bank.

It may be useful to discuss the main assumptions of our model in more detail.[4] The non-verifiability of the investment decision is a standard scenario. Often, projects require specific human capital or may need the design of blueprints for machinery, buildings or logistics. An inventor for example may require a lot of time for reading and designing. Whether the efforts are directed towards the project or whether blueprints are competently drafted is unlikely to be observed by an outsider.

The second assumption of our model is that the verification of output conditional on investment is possible at low or zero costs while entrepreneurs can have large private benefits if they do not invest. The assumption is justified by better possibilities for banks to secure repayments if entrepreneurs invest. If the final products of the projects are physical goods such as houses or machines this is obvious and the banks can secure repayment conditional on investment at very low costs. For simplicity, we assume that the costs of verifying output are zero if the entrepreneur has invested.

Note that monitoring decisions must be taken before the bank knows whether an entrepreneur will invest. Therefore, $m$ cannot be conditioned on investment decisions. If a bank observes that an entrepreneur does not invest, it has the possibility of recovering some of the money, captured by $R(m)$, if it has invested $m$ in monitoring.

[4] A more detailed discussion and justification is given in Gersbach and Uhlig (1997).

Entrepreneurs who do not want to invest are indifferent across banks that offer credits and that choose the same monitoring intensity after credit contracts are written. As a tie-breaking rule, we assume that such indifferent non-investing entrepreneurs will randomize across the banks so as to mimic the investing entrepreneurs.[5]

We next discuss the nature of contracts that banks can offer. Bank $j$ can sign deposit contracts $D(r_j^d)$ where $1 + r_j^d$ is the repayment offered for 1 unit of resources. Loan contracts of bank $j$ are denoted by $C(r_j^c)$ where $1 + r_j^c$ is the repayment required from entrepreneurs for 1 unit of funds.[6]

Throughout the paper, we will distinguish two cases. A friction case, denoted as $F - case$, corresponding to the model outlined above. As a benchmark, we also consider the non-friction case, denoted as $NF-case$. In the $NF-case$, we assume that banks have access to a very efficient monitoring technology that allows them to reduce the agency problems of entrepreneurs completely. That is, banks can observe the quality of the investment projects at very low costs, that can be neglected, and can enforce investment if credits are taken.

[5] Justifications of this assumption are discussed in Gersbach and Uhlig [1997].

[6] A natural question arises in this context: can banks condition the repayment on the final output and thus on the quality of the investment projects? It is obvious that a monopoly bank would write such contracts. When banks compete for a single entrepreneur and no funding restrictions are present, Gersbach and Uhlig [1997] have shown that debt contracts arise as the unique type of contract. In this paper, we assume directly that banks compete with pure debt contracts.

# 3 Equilibrium in the Friction Case

## 3.1 Equilibrium in the Intermediation Market

We first derive the equilibrium in the intermediation market in each period. Obviously, deposit and loan contracts will have a length of one period. We denote the interest rate bank $j$ offers to depositors by $r_j^d$, and the interest rate bank $j$ requires from borrowers by $r_j^c$. $\Delta_j = r_j^c - r_j^d$ denotes the interest rate spread bank $j$ offers. We examine the following intermediation game.

Period $t$

1. Banks offer deposit contracts to consumers and potential entrepreneurs.
2. Banks offer credit contracts to entrepreneurs, conditional on available funds.
3. Resources are exchanged. Bank $j$ decides on its monitoring intensity $m_j$.
4. Funded entrepreneurs decide whether to invest.

Period $t+1$

5. Entrepreneurs who have invested pay back. Banks pay back depositors.

Banks compete in deposit rates in the first stage and for credit contracts in the second stage. The nature of competition in credit contracts depends on whether entrepreneurs are rationed or not.[7] We first consider the investment problem of an entrepreneur of quality $q$, given that he observes $r_j^d$ and $r_j^c$ of bank $j$ and conditional on receiving a credit from bank $j$. If he invests, his terminal wealth $W(q)$ will amount to:

$$W(q) = q(e+I) - I(1+r_j^c) \tag{3}$$

If he does not invest, he obtains $(e+I) - R(m_j)$. Thus, there is a critical quality parameter, denoted by $q^*(r_j^c, m_j)$:

$$q^*(r_j^c, m_j) = \frac{I(1+r_j^c) + (I + e - R(m_j))}{e+I} \tag{4}$$

so that entrepreneurs with $q \geq q^*$ invest while entrepreneurs with $q < q^*$ will not invest and consume their funds in the next period.[8] In the following, we will drop the index $j$ for convenience.

[7] As it is well known, two-sided competition can lead to non-competitive outcomes as banks may corner one side of the market to obtain a monopoly position. In our case, the sequential nature of the game and the rationing of entrepreneurs yield competitive outcomes.

[8] We assume that if an entrepreneur has obtained credit and chooses not to invest then he can store the resources at no cost.

We must also check whether entrepreneurs want to apply for credit contracts. As long as $(e+I) - R(m) \geq e(1+r^d)$ for any conceivable deposit rates, all entrepreneurs apply for credit contracts since saving the endowment yields less than the lowest profits under a credit contract. In the following, we assume that this condition is satisfied for any constellation considered. Since deposit rates can never exceed $\overline{q}$, a sufficient condition is $(e+I) - R(m) \geq e\overline{q}$ for all $m$ or $(e+I) - \lim_{m\to\infty}(R(m)) \geq e\overline{q}$.

In order to derive the intermediation equilibrium, we proceed in two steps. First, we derive the equilibrium conditions under the assumption that banks cannot avoid non-investing entrepreneurs. Second, we will show that in equilibrium banks can, indeed, not avoid an amount of shirkers in proportion to their shares of investing entrepreneurs.

Conditional on granting a credit to an entrepreneur and under the assumption that non-investing entrepreneurs cannot be avoided, we can calculate expected profits per credit of a bank $j$. For convenience, we omit the index $j$:

$$G = (\overline{q} - q^*)I(1+r^c) + (q^* - \overline{q} + 1)R(m) - (I+m)(1+r^d) \tag{5}$$

$$\begin{aligned} G = &\left\{\overline{q} - 1 - \frac{I(1+r^c) - R(m)}{e+I}\right\}I(1+r^c) \\ &+ \left\{\frac{I(1+r^c) - R(m)}{e+I} - \overline{q} + 2\right\}R(m) - (I+m)(1+r^d) \end{aligned} \tag{6}$$

Since entrepreneurs live only two periods, the distributions of project returns of different entrepreneur generations are independent of each other. Moreover, by applying the law of large numbers for the uniformly distributed project returns, banks can fully diversify the risk associated with an individual project and therefore only care about expected profits. This does not mean, however, that intermediation can be carried out without own capital. The money devoted towards monitoring in period $t$ can be viewed as intermediary or informed capital that must be put up by banks in the sense of Holmström and Tirole [1997]. The intermediary capital is necessary because monitoring takes place in period $t$ while repayments from borrowers occur later. However, banks do not need to raise equity in order to generate intermediary capital. The intermediary capital decreases the amount of funds that can be granted for credits and hence constrains the aggregate investment activity.

Note that a bank only expects a repayment if the entrepreneur has a project of a quality at least equal to $q^*$. Since all entrepreneurs will apply for credit contracts, we assume that available savings are not sufficient to fund all entrepreneurs. Since $1+r^d$ cannot exceed $\overline{q}$, a sufficient condition is:

$$(1-\eta)s\{\bar{q}\} \leq \eta I \tag{7}$$

Banks expect an excess supply of entrepreneurs in the second stage of the intermediation game, regardless of all conceivable lending rates. Hence, when banks compete for deposit contracts in the first stage, they anticipate that they can set lending rates at any desired level while still attracting borrowers. In the appendix, we show:

**Proposition 1**

*There exists a unique equilibrium $r^{c*}, r^{d*}, m^*$ of the intermediation game.*

*(i) Banks choose monitoring intensity $m^*$ given by:*

$$R'(m^*) = 1 + r^{d*} \tag{8}$$

*(ii) Interest rates on loans are given by*

$$1 + r^{c*} = \frac{(\bar{q}-1)(e+I) + 2R(m^*)}{2I} \tag{9}$$

*(iii) The critical entrepreneur is given by:*

$$q^*(r^{c*}, m^*) = \frac{\bar{q}+1}{2} \tag{10}$$

*(iv) Banks offer deposit contracts with deposit rates implicitly defined as:*

$$(I+m^*)(1+r^{d*}) = \frac{1}{4}\left\{(\bar{q}-1)^2(e+I) + 4R(m^*)\right\} \tag{11}$$

As discussed in the proof, banks cannot avoid shirkers, i.e., entrepreneurs who do not want to invest. First, banks cannot commit to a particular value of monitoring when credit contracts are written and hence entrepreneurs anticipate that banks set $m^*$ after loans have been made, but before entrepreneurs decide whether to invest. Second, raising interest rates on loans in order to credibly induce higher levels of monitoring will deter not only shirkers but also investing entrepreneurs.

## 3.2 Overall Equilibrium

The overall equilibrium in period $t$ is determined by the savings investment balance. This in turn yields the separation of the entrepreneurs into those who obtain credits and those who do not receive additional funds and thus save their endowments. Suppose that a fraction $k$ of entrepreneurs receive credits. The savings and investment balance requires

$$(1-\eta)s\{1+r^d\} + (1-k)\eta e = k \cdot \eta(I+m) \tag{12}$$

$s\{1+r^d\}$ is the savings function of the consumers. Equation (12) endogenously determines the fraction $k$ of entrepreneurs who receive credits and thus the number of projects that are undertaken. Note that non-funded entrepreneurs save their endowments and contribute to the funds available for granting credits.

GDP in period $t$ is given by aggregate consumption and investing and is denoted by $y_t^f$. It is thus equal to the available funds

$$
\begin{aligned}
y_t^f &= e + k\eta\Big\{(q^* - \overline{q} + 1)(I+e) + (\overline{q} - q^*)\frac{1}{\overline{q} - q^*}\int_{q^*}^{\overline{q}} q(I+e)dq\Big\} \\
&= e + k\eta(I+e)\Big\{\frac{\overline{q}^2}{2} - \frac{q^{*2}}{2} + (q^* - \overline{q} + 1)\Big\} \\
&= e + k\eta(I+e)\Big\{\frac{3}{8}\overline{q}^2 - \frac{3}{4}\overline{q} + \frac{11}{8}\Big\}
\end{aligned} \tag{13}
$$

where $q^*$ has been inserted from proposition 1.

# 4 Equilibrium in Frictionless Case

As a benchmark, we consider the competitive equilibrium resulting when banks are able to observe the quality of the investment projects at zero costs and can enforce or induce investment if credits are taken. For instance, banks may be able to screen loan applicants by almost costless credit-worthiness tests. We still assume that only banks can reduce the agency problems in financial contracting. In the frictionless case, banks only offer credits to entrepreneurs whose returns from investment are equal or higher than refinancing costs. Bertrand competition among banks yields $r^c = r^d = r$.[9] Moreover, entrepreneurs only apply for credits if they earn at least the same returns on their investments as the deposit rates, since non-funded entrepreneurs will deposit their endowments at the banks and earn interest. Thus, the critical quality level, denoted by $q^0$, above which banks and entrepreneurs are willing to sign loan contracts is given by:

$$q^0 = 1 + r \tag{14}$$

Finally, the saving and investment balance amounts to:

$$
\begin{aligned}
&(1-\eta)s\{1+r\} + \eta e(1 + r - \overline{q} + 1) \\
&= \eta(\overline{q} - (1+r))I
\end{aligned} \tag{15}
$$

Since the left side is increasing in $r$ and the right side is decreasing in $r$, a unique equilibrium exists for the interest rate in the economy, denoted by $r^0$. All entrepreneurs with

[9] A detailed proof can be found in Gersbach [1998].

projects whose returns are equal or above $r^0$ will obtain funds and invest. Hence, overall income, denoted by $y^0$, is given by:

$$y^0 = e + \eta(I + e) \cdot \left\{ \frac{\overline{q}^2 - (1 + r^0)^2}{2} \right\} \tag{16}$$

# 5 Unanticipated Shocks

We first consider unanticipated shocks to aggregate productivity. That is, the shocks are not anticipated when lending and deposit contracts are written. We are interested in which cases the health of the financial sector is undermined by unanticipated productivity shocks. Then we compare the magnitude of output changes for both cases $F$ and $NF$.

The literature discussed in the introduction has suggested that the presence of agency problems magnifies the output changes arising from productivity shocks. In the following example we demonstrate that this is not true when the problem of capital spillovers is considered.

## 5.1 Capital Spillovers

Suppose that in period $t$ agents learn that the productivity of all projects is smaller than assumed in the contracts written previously in period $t-1$. In period $t-1$, the upper bound of the productivity distribution has been assumed to be $\overline{q}$. In period $t$, agents learn that $\overline{q}_t < \overline{q}$ is the upper bound. All projects experience a negative productivity shock, denoted by $\delta$. $\delta$ is defined as $\overline{q} - \overline{q}_t$. We obtain:

**Proposition 2**
*Suppose that $R(m^*) < I - er^0$. Then, quality levels $q^f$ and $q^{nf}$ exist, with $q^f < q^{nf} < \bar{q}$, such that*

*(i) if $\bar{q}_t \in [q^{nf}, \bar{q}]$, banks can pay back depositors in both cases F and NF*

*(ii) if $\bar{q}_t \in [q^f, q^{nf}]$, banks can pay back depositors only in the case of F*

*(iii) if $\bar{q}_t \in [0, q^f]$, banks cannot pay back depositors in both cases F and NF.*

Proposition 2 implies that banks are more able to absorb productivity shocks of firms in the $F - case$. The reasoning is as follows: If agency problems can only be partially alleviated by banks, firms will only invest if marginal returns are sufficiently above lending rates. Otherwise, private benefits from non-investing are larger. Since marginal returns for investing firms are high, the repayment capacity is larger than in the case with no frictions. Therefore, negative spillovers from productivity shocks to firms on the balance sheet of banks are smaller in the presence of frictions. Hence, we obtain our first major result. Negative capital spillovers, i.e. deteriorating balance sheets of firms, yield losses for financial intermediaries and are more likely when no agency problems remain in the economy.

## 5.2 Workouts of Banking Crises and Persistence

In this section we examine how the banking system reacts to unanticipated shocks in both scenarios $F$ and $NF$. If there are no negative capital spillovers, the balance sheets of banks are obviously unaffected and banks do not face any financial problems. If negative capital spillovers occur, banks can only pay back deposits obtained from new contracts from the next generation.

However, such attempts to pay back deposits with new funds are infeasible, regardless of whether or not frictions are present. This is illustrated by the following proposition.

**Proposition 3**

*Suppose that $\bar{q}_t < q^f$, then the banking system collapses in both scenarios $F$ and $NF$.*

**Proof :**

Suppose that all banks are affected by a negative unanticipated productivity shock and therefore, all banks can either fulfill their deposit obligations or not. Suppose that a typical bank $j$ has suffered a loss $L_t^j < 0$ because $\bar{q}_t < q^f$. Due to standard undercutting reasons, Bertrand competition for new deposit and loan contracts does not allow a spread between $r^d$ and $r^c$. Given any positive spread, a bank could always offer a slightly smaller spread and gain all of the new depositors. Suppose that bank $j$ obtains $D_j^{t+1}$ deposits in period $t+1$. The amount of credits is given by:

$$C_j^{t+1} = D_j^{t+1} + L_t^j$$

However, in the next period, bank $j$ suffers a loss of:

$$L_j^{t+1} = (1+r^0)(D_j^{t+1} - C_j^{t+1}) = (1+r^0)L_t^j$$

Hence, losses of bank $j$ increase over time. At one point the losses will exceed the available amount of new funds and bank $j$ will collapse.

Since depositors anticipate that bank $j$ cannot pay back, they will refuse to take deposit contracts. The standard backward argument leads to an immediate refusal of depositors and bank $j$ goes bankrupt.

■

Since the banking system collapses under sufficiently negative productivity shocks, working out of banking crises requires governmental actions. In line with the New-Keynesian models, we assume that the central bank can vary real interest rates as prices only adjust gradually when nominal interest rates are set. Changes in real interest rates by the central banks translate into changes of financing costs of banks and thus into changes of the deposit rates. We therefore associate changes in the real deposit rate to changes in the central bank interest rate policy. We call $r^d_{CB}$ the deposit rate induced or set by the central bank.[10] The induced spread is denoted by $\triangle := r^c - r^d_{CB}$.

The costs of such workouts of banking crises are distributed across future generations, depending on the size of $\Delta$. If $\Delta$ is sufficiently large, the next generation bears all the costs resulting from negative productivity shocks and monetary policy can return to normal times in future periods. Alternatively, $\Delta$ can be set so that banks' losses remain constant over time and therefore the costs of workouts are distributed equally across all future generations. The degree of the persistence hence depends on the laxness of the central bank policy as it will be illustrated in the example described in the next section.

Furthermore, as proposition 2 indicates, the likelihood of persistence is larger in the case of $NF$ for any given central bank policy as the likelihood of capital spillovers is larger under $NF$. Hence the standard presumption that shocks are more persistent the larger the agency problems are does not hold if we consider balance sheets of firms and banks.

## 5.3 An Example

To illustrate the persistence of macroeconomic shocks and its dependency on the workout approach, let us consider the case $NF$. We assume that the interest rate elasticity of savings is zero, as it is when utility in consumption is logarithmic. Suppose that an unanticipated shock $\delta = \overline{q} - q_1 > 0$ occurs in period 1 creating losses for banks. Income in period 1 is given by

$$y_1^0 = e + \eta(I+e)\Big\{\frac{(\overline{q}-\delta)^2 - (1+r^0-\delta)^2}{2}\Big\}$$

Losses for the banking system amount to:

$$L_1 = \int_{1+r^0-\delta}^{\frac{I(1+r^0)}{I+e}} \Big\{q(I+e) - I(1+r^0)\Big\} dq$$

The upper bound of the integral $\frac{I(1+r^0)}{I+e}$ corresponds to the quality level of the entrepreneur who can just pay back his debt obligations. $1 + r^0 - \delta$ is the lowest quality level of an entrepreneur who has obtained a bank loan in the last period and has invested. We assume $\delta > \frac{(1+r^0)e}{I+e}$, so that the integral is defined and $L_1 < 0$. The banking crisis is

[10] The interest rate set by the central bank and the deposit rates could be identical. For instance, if banks can refinance themselves unboundedly at the central bank, it would not be profitable for banks to offer a higher deposit rate than the interest rate set by the central bank. Moreover, competition among banks will induce that they do not offer a lower deposit rate than the one set by the central bank.

worked out by the central bank. $r^d_{CB,t}$ denotes the deposit rate induced by the central bank in period $t$ $(t = 1, 2, \ldots,)$. We denote by $L_t$ the losses generated in the banking sector in period $t$ $(t = 1, 2, \ldots,)$ where the first loss occurs through the productivity shock. The losses in future periods are the result of the initial loss and the profits generated by the interest rate cut by the central bank. An entrepreneur, whose quality is denoted by $q^0_t$, is indifferent between saving and investing in period $t$ if

$$q^0_t(I + e) - I(1 + r^c_t) = e(1 + r^d_{CB,t})$$

and therefore

$$q^0_t = 1 + \frac{I\, r^c_t + e\, r^d_{CB,t}}{I + e}$$

Capital market equilibrium in period $t$ requires that loan rates are set such that[11]

$$(1 - \eta)s + \eta\, e(q^0_t - \overline{q} + 1) = \eta\, (\overline{q} - q^0_t)I - L_t$$

Inserting $q^0_t$ yields

$$\begin{aligned}
&(1 - \eta)\, s + \eta\, e - \eta\, \overline{q}(e + I) + \eta(I + e) + \eta\, I r^c_t + \eta\, e r^d_{CB,t} = -L_t \\
&r^c_t = \frac{1}{I}\Big\{\frac{-L_t}{\eta} - e\big(1 + r^d_{CB,t}\big) + \big(e + I\big)\big(\overline{q} - 1\big) - \frac{1 - \eta}{\eta}\, s\Big\}
\end{aligned}$$

Hence, the indifferent entrepreneur in the capital market equilibrium is given by:

$$q^0_t = \overline{q} - \frac{e + \frac{1-\eta}{\eta}\, s + \frac{L_t}{\eta}}{I + e}$$

Note that $q^0_t$ is independent of $r^d_{CB,t}$ (and $r^c_t$) because savings and investment must be balanced for every choice $r^d_{CB,t}$. However, $q^0_t$ obviously depends on $L_t$ since funds covering the losses cannot be used for investment. Losses $L_t$ generated in the banking sector in periods $t$ $(t > 1)$ evolve according to:

$$\begin{aligned}
L_t &= \eta(\overline{q} - q^0_{t-1})\, I(1 + r^c_{t-1}) \\
&\quad - (1 - \eta)\, s(1 + r^d_{CB,t-1}) - \eta\, e(q^0_{t-1} - \overline{q} + 1)(1 + r^d_{CB,t-1})
\end{aligned}$$

The corresponding aggregate income $y_t$ $(t = 2, 3, \ldots,)$ amounts to:

$$y_t = e + (e + I) \cdot \Big\{\frac{\overline{q}^2 - (q^0_{t-1})^2}{2}\Big\},$$

where $q^0_t$ is given by the expression above:

We can distinguish between two extreme approaches to workouts.

- the immediate workout. The central bank sets $r^d_{CB,1}$ so that

  $L_2 = L_3 = \ldots = 0$

[11] In Gersbach [1998] it is shown that this is indeed an equilibrium among banks.

- the infinite workout. The central bank chooses $r^d_{CB,1} = r^d_{CB,2} = \ldots =$ so that

  $L_2 = L_3 = \ldots = L_1$

While in the first case a negative productivity shock only lowers $y^0_1$ and $y^0_2$, the persistence in the latter case is infinite. Let us illustrate the impulse response functions for both approaches to workouts by a numerical example. Let's choose $\overline{q} = 1.3, e = 1, s = \frac{1}{2}, \eta = 0.71$.

For $L_t = 0$ we have $q^0_t = 1.15$, $r^0_t = r^c_t = r^d_t = 0.15$. Suppose that an unanticipated productivity shock occurs in period 1. As long as $\delta \leq \frac{(1+r^0)e}{I+e} = 0.14$, the decline of entrepreneurs' cash flows does not affect banks and no negative capital spillovers occur.

Suppose that a negative productivity shock occurs that is larger than $\delta = 0.14$. The following figures represent the impulse response for both workout approaches for the shock value $\delta = 0.3$. Figure (1) shows that an immediate workout implies a drop in aggregate income over two periods. Then aggregate income returns to the previous level. An infinite workout leads to a decline of aggregate income in all future periods. Interestingly, the decline of income in the first two periods under infinite workout is equal to the decline under an immediate workout. This follows from the observation that aggregate income in period 2 depends only on $q^0_1$, which, however, does not depend on the workout approach. Hence, infinite workouts will always lead to larger losses in aggregate income since the decline is equal to immediate workout in the first two periods.

However, utilities are affected in a different way. Since infinite workout can have higher deposit rates and lower lending rates in period 1 because loss recovery can be postponed, the utility of the consumers, as well as of saving and investing entrepreneurs born in period 1 is higher under infinite workout than under immediate workout. In figure (2), we compare the aggregate utility across generations under both workout approaches for the shock $\delta = 0.3$. Infinite workout lowers utility of all future generations, but the utility loss for the agents born in period 1 is smaller than under an immediate workout approach. Hence, we obtain a preference of the generation born in period 1 for infinite workout which, however, implies larger income losses than immediate workout over the whole time period.

### 5.4 The Lending Channel

The persistence of unanticipated macroeconomic shocks in the last sections results from the decline of bank lending. Banks need new funds to pay back existing obligations and, therefore, cannot fund new projects to the same extent as before. The decline in bank lending can be associated with a lending channel phenomena caused by the balance sheet problems of firms. Traditionally, the lending channel (Bernanke and Blinder [1992], Kashyap, Stein and Wilcox, [1993], Kashyap and Stein [1994], Repullo and Suarez [1995]) rests on the imperfect substitutability between Treasury bills and commercial paper. In our model, the lending channel exists because macroeconomic shocks spill over to banks and decrease future lending.

## 6 Anticipated Productivity Shocks and Macroeconomic Variables over the Business Cycle

With anticipated productivity shocks, negative capital spillovers can no longer occur and shocks are not persistent.[12] Therefore our main interest is the behavior of macroeconomic variables to anticipated shocks which we will explore in this section.

An aggregate productivity shock in period $t$ is a shift of the investment project distribution, i.e., each project is affected by the same decline or increase of productivity. An endowment shock corresponds to a change of $e$, but does not reduce the overall amount of funds $F = e + I$ needed to undertake projects. Hence, a negative endowment shock corresponds to larger reliance on outside financing.[13] We denote the share of inside finance by $if$, given by:

$$if = \frac{e}{F}$$

Moreover, we denote the equilibrium functions by $r^{c*}(\bar{q}, if), m^*(\bar{q}, if), r^{d*}(\bar{q}, if)$, depending on the productivity distribution and on the share of inside finance $if$.

[12] One can still compare the magnitude of output changes in both cases $F$ and $NF$. One can show that relative output changes in response to anticipated productivity shocks are smaller in the $F - case$ than in the $NF - case$ as long as the monitoring efficiency is not very high.

[13] A natural example of endowment shocks are productivity shocks in the last period when entrepreneurs leave bequests in the firms for future entrepreneurs

## 6.1 Productivity Shocks

We first discuss productivity changes. In the appendix, we show for the $F$ case:

**Proposition 4**

*(i)*

$$\frac{\partial r^{d*}}{\partial \bar{q}} = \frac{\frac{1}{2}(\bar{q}-1)(e+I)}{I+m^*} > 0$$

*(ii)*

$$\frac{\partial m^*}{\partial \bar{q}} = \frac{1}{R''(m^*)} \frac{\partial r^{d*}}{\partial \bar{q}} < 0$$

*(iii)*

$$\frac{\partial q^*}{\partial \bar{q}} = \frac{1}{2}$$

The above proposition illustrates how banks react to a worsening pool of investors. They increase monitoring intensity which, therefore, is countercyclical. Deposit rates are reduced and the quality of the critical entrepreneur falls by one half of the value of the shock. However, the reaction of lending rates is still ambiguous. Banks can counteract rising agency problems by raising monitoring intensity or by lowering interest rates. Whether or not an additional cut in lending rates is necessary depends on the reaction of the monitoring intensity to negative productivity shocks. In the following proposition, we establish the necessary and sufficient conditions under which banks also cut lending rates when productivity declines.

**Proposition 5**
*Suppose that for all $m$:*

$$\frac{-R'(m)}{R''(m)} < \frac{I+m}{\bar{q}-1}$$

*Then:*

$$\frac{\partial r^{c*}}{\partial \bar{q}} > 0$$

The proof is given in the appendix. Finally, the intermediation margin $\Delta^* = r^{c*} - r^{d*}$ is countercyclical if the lending rate does not drop too sharply when productivity slows down. In the appendix we show:

**Proposition 6**
*Suppose that for all $m$:*

$$\frac{-R'(m)}{R''(m)} > \frac{I+m}{\bar{q}-1} - I$$

*Then*

$$\frac{\partial \Delta^*}{\partial \bar{q}} < 0$$

Hence, the intermediation margin is countercyclical if the marginal returns to monitoring do not decrease too sharply. If e.g. $\overline{q} = 2$, the condition in proposition 6 is equivalent to:

$$\frac{-R''(m)m}{R'(m)} < 1$$

The expression $\frac{-R''(m)m}{R'(m)}$ would be equivalent to the measure of relative risk aversion if $R(m)$ were a utility function and $m$ represented the amount of resources consumed. Therefore, if the "relative risk aversion" embodied by the function $R(m)$ is smaller than 1, intermediation margins are countercyclical. And this means that $|R''(m)|$ should not be too large.

In the $NF - case$, we obtain directly from equations (14) and (15):

**Proposition 7**

*(i)*

$$\frac{\partial r^0}{\partial \bar{q}} > 0$$

*(ii)*

$$\frac{\partial q^0}{\partial \bar{q}} > 0$$

Hence, interest rates fall in the $NF - case$, which in turn lowers the critical quality level above which entrepreneurs obtain funds.

## 6.2 Endowment Shocks

Shocks to endowments, and thus to the need for outside finance, have very different implications, depending on the presence of agency problems. We obtain for the $F - case$:

**Proposition 8**

*(i)*

$$\frac{\partial r^{d*}}{\partial if} > 0$$

*(ii)*

$$\frac{\partial m^*}{\partial if} < 0$$

*iii)*

$$\frac{\partial q^*}{\partial if} = 0$$

The proof is given in the appendix. The reaction of $r^{c*}$ to shocks in $if$ again depends on the behavior of $R(m)$. In the $NF - case$ we obtain:

**Proposition 9**

*(i)*

$$\frac{\partial r^0}{\partial if} < 0$$

*(ii)*

$$\frac{\partial q^0}{\partial if} < 0$$

Proposition 9 follows immediately from equations (14) and (15).

Hence, the behavior of interest rates in response to endowment shocks depends crucially on the nature of frictions in the economy. A negative endowment shock induces banks to lower deposit rates and to increase their monitoring activities in the $F - case$. The quality level of the critical investor remains the same. In the $NF - case$, interest rates rise due to a shortage of savings. A rising interest rate induces more entrepreneurs to save their endowments, which rebalances savings and investments. The critical quality level that distinguishes investing from non-investing entrepreneurs rises.

# 7 Discussion and Conclusion

We have identified that the extent of capital market frictions is negatively related to negative capital spillovers. Negative capital spillovers generate a lending channel effect through the persistence of productivity shocks. The extent of the persistence depends on the chosen approach towards banking crises.

Our main result in this paper has shown that there is a negative relationship between the likelihood of capital spillovers and the agency problems not eliminated by financial intermediaries. Our analysis and arguments could be extended in various other directions. First, one could introduce a further sector in which informational frictions are less important or not important at all. In this sector, firms could use direct financing. The coexistence of indirect and direct financing would make workouts of banking crises more difficult as capital would move to the sector with less frictions to some extent if deposit rates fall. However, the qualitative conclusions appear to remain the same.

Second, it would be useful to consider long-term investments next to short-term projects. This would introduce liquidity constraints and refinancing considerations for banks and would increase the exposure to macroeconomic risk related to productivity shocks of short-term or long-term investments. While possibilities of collapse increase, we still expect that the probability of banking crises is inversely related to the agency problems that are not eliminated by financial intermediation.

# 8 Appendix

**Proof of Proposition 1:**

If a bank $j$ has obtained funds in the first stage, it tries to maximize the return from a credit arrangement since the number of potential entrepreneurs is sufficiently large. The first-order-condition for the choice $r_j^c$ amounts to:

$$\frac{\partial G}{\partial r^c} = I(\overline{q}-1) - I\frac{I(1+r^c)-R(m)}{e+I} - \frac{I}{e+I}I(1+r^c) + \frac{I}{e+I}R(m) = 0$$

This implies that:

$$1 + r^{c*} = \frac{(\overline{q}-1)(e+I) + 2R(m)}{2I}$$

The critical investor is given by:

$$q^* = \frac{\overline{q}+1}{2}$$

We next determine the optimal intensity of monitoring. The first-order condition amounts to:

$$\frac{\partial G}{\partial m} = \frac{R'(m)}{e+I}\{I(1+r^c) - R(m) + I(1+r^c) - R(m) - (\overline{q}-2)(e+I)\} - (1+r^d) = 0$$

Inserting the optimal loan interest rate simplifies the first-order condition to:

$$R'(m) = 1 + r^d$$

For an interior solution we have to check the second conditions. We obtain:

$$\frac{\partial^2 G}{\partial r^{c2}} = \frac{-2I^2}{I+e} < 0$$

$$\frac{\partial^2 G(r^c = r^{c*})}{\partial m^2} = R''(m) < 0$$

Inserting the optimal interest rate yields the following expression of banks' profits:

$$4G(m, r^d) = (e+I)(\overline{q}-1)^2 - 4(m+I)(1+r^d) + 4R(m)$$

Bertrand competition of banks for deposit contracts in stage 1 drives profits of banks to zero, i.e., $G = 0$. Thus, banks offer deposit rates implicitly defined as:

$$(I + m^*)(1 + r^{d*}) = \frac{1}{4}(\overline{q}-1)^2(e+I) + R(m^*)$$

This is an implicit equation for the deposit rate when we use $R'(m) = 1 + r^d$. We first show existence. The left side is zero for $r^{d*} = -1$ while the right side is positive. For large values of $r^{d*}$, we obtain $\frac{1}{4}(\overline{q}-1)^2(e+I)$ for the right side since $m^*$ will approach zero. The left side is monotonically increasing in $r^{d*}$. Hence, the mean value theorem establishes the existence of at least one solution for the deposit rate. If more than one solution exists, the deposit in equilibrium is determined by:

$$r^{d*} = \max\{r^d | G\big(R'^{-1}(1 + r^d), r^d\big) = 0\}$$

Banks would choose the highest possible deposit rate with which they still make non-negative profits. Hence, the equilibrium is unique.

The preceding equilibrium values have been derived by assuming that banks cannot avoid shirkers. In the next step, we examine whether banks could deviate from the candidate equilibrium values in order to avoid shirkers.

Since the monitoring intensity $m$ will be chosen after credit contracts have been written, banks cannot deter shirkers by simply announcing a higher monitoring intensity. Such announcements would not be credible.

Suppose a bank offers higher deposit rates than $r^{d*}$. Such a bank would receive all resources. Thus, shirkers cannot be avoided since no other banks can offer credit contracts. Suppose a bank deviates by offering different credit contract conditions. If a bank demands higher interest rates for borrowers, $r^c > r^{c*}$, it could credibly signal that it will increase monitoring intensity after credit contracts have been written. However, under $r^c > r^{c*}$, all investing entrepreneurs and all shirkers would like to receive credits from the remaining banks. Hence, some entrepreneurs are rejected by the other banks in stage 2 because of limited resources. Rationed entrepreneurs will apply for credits at the deviating bank. Therefore, the distribution of the qualities of entrepreneurs is the same as in the population of entrepreneurs and hence shirkers cannot be avoided. If a bank offers $r^c < r^{c*}$, investing and non-investing entrepreneurs alike line up to obtain credit contracts from the deviating bank. Investing entrepreneurs fare better with lower interest payments. Shirkers are better off since they expect lower monitoring intensity.

Hence, no bank can deviate from the candidate equilibrium in order to induce shirkers to select other banks. Hence, the set of equations determines the intermediation equilibrium.

■

**Proof of Proposition 2:**

We examine the repayment capacity of the investing entrepreneur with the lowest project quality. In the friction case, an entrepreneur with the originally assumed quality $q^*$ has invested. He can pay back if the productivity shock $\delta = \bar{q} - \bar{q}_t$ satisfies:

$$(q^* - \delta)(I + e) \geq I(1 + r^{*c})$$

Inserting $q^*$ and $r^{*c}$ yields:

$$\left(\frac{\bar{q}+1}{2} - \delta\right)(I + e) \geq \frac{\bar{q}-1}{2}(e + I) + R(m^*)$$

For the critical size of the productivity shock we obtain:

$$\delta = \frac{e + I - R(m^*)}{e + I}$$

Therefore:

$$\bar{q}_t^f = \bar{q} - \frac{e + I - R(m^*)}{e + I}$$

In the $NF$ case, we receive:

$$(1 + r^0 - \delta)(I + e) \geq I(1 + r^0)$$

and hence:

$$\delta = \frac{(1 + r^0)e}{I + e}$$

which implies

$$\bar{q}_t^{nf} = \bar{q} - \frac{(1 + r^0)e}{I + e}$$

$\bar{q}_t^f$ is smaller than $\bar{q}_t^{nf}$ if

$$I - R(m^*) > er^0.$$

■

**Proof of Proposition 4:**

Consider equation 11 in proposition 1. Differentiating with respect to $\bar{q}$ yields:

$$\frac{\partial m^*}{\partial \bar{q}}(1 + r^{d*}) + \frac{\partial r^{d*}}{\partial \bar{q}}(I + m^*) = \frac{1}{2}(\bar{q} - 1)(e + I) + R'(m^*)\frac{\partial m^*}{\partial \bar{q}}$$

Using $R'(m^*) = 1 + r^{d*}$ from (i) in proposition 1 leads to

$$\frac{\partial r^{d*}}{\partial \bar{q}}(I + m^*) = \frac{1}{2}(\bar{q} - 1)(e + I)$$

Hence:

$$\frac{\partial r^{d*}}{\partial \bar{q}} = \frac{\frac{1}{2}(\bar{q}-1)(e+I)}{I+m^*} > 0$$

From $R'(m^*) = 1 + r^{d*}$ we obtain:

$$R''(m^*)\frac{\partial m^*}{\partial \bar{q}} = \frac{\partial r^{d*}}{\partial \bar{q}},$$

which yields:

$$\frac{\partial m^*}{\partial \bar{q}} < 0$$

Finally, from proposition 1 we obtain $\frac{\partial q^*}{\partial \bar{q}} = \frac{1}{2}$

■

**Proof of Proposition 5:**

We calculate:

$$\frac{\partial r^{c*} I}{\partial \bar{q}} = \frac{1}{2}(e+I) + R'(m^*) \cdot \frac{1}{R''(m^*)} \cdot \frac{\partial r^{d*}}{\partial \bar{q}}$$

Inserting (i) from proposition 4, we obtain:

$$\frac{\partial r^{c*}}{\partial \bar{q}} = \frac{1}{2}\frac{e+I}{I}\left\{1 + \frac{R'(m^*)}{R''(m^*)} \cdot \frac{\bar{q}-1}{I+m^*}\right\}$$

$$\frac{\partial r^{c*}}{\partial \bar{q}} > 0$$

if, and only if,

$$-\frac{R'(m^*)}{R''(m^*)} < \frac{I+m^*}{\bar{q}-1}$$

which is implied by the assumption of the proposition

■

**Proof of Proposition 6:**

We examine the conditions for:

$$\frac{\partial r^{c*}}{\partial \bar{q}} - \frac{\partial r^{d*}}{\partial \bar{q}} < 0$$

Using proposition 4 and the proof of proposition 5 we obtain the condition on the monitoring function R(m).

■

**Proof of Proposition 8:**

The third part follows immediately from proposition 1. Differentiating *(iv)* in proposition 1 with respect to $if$ yields:

$$-(I+e)(1+r^{d*})+\frac{\partial m^*}{\partial if}(1+r^{d*})+(I+m^*)\frac{\partial r^{d*}}{\partial if}=R'(m^*)\frac{\partial m^*}{\partial if}$$

where we have used:

$$\frac{\partial I}{\partial if}=\frac{\partial I}{\partial e}\frac{\partial e}{\partial if}=-1\cdot F=-F$$

Again using $R'(m^*)=1+r^{d*}$, we receive:

$$(I+m^*)\frac{\partial r^{d*}}{\partial if}=(I+e)(1+r^{d*})>0$$

which proves (i). (ii) follows from (i) and proposition 1. (iii) follows from proposition 1 (iii).

■

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