# The Interaction of Monetary Policy and Financial Stability:

# Lessons from the 2007 Crisis

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(Preliminary version)

February 2011

## Abstract

The financial crisis motivated thinking about interaction between financial and monetary stability policies. These policies are more interrelated than previously thought. The purpose develops an analytical framework that analyzes these interactions. We use an overlapping-generations model in which an aggregate financial risk is endogenous. It embeds negative externalities in the perceived risk, and integrates banking into our DSGE model. The results include (i) monetary policy's effectiveness is affected by financial stability policy; (ii) institutional constraints on central bank's lending affect the operation of monetary policy transmission mechanism; (iii) policy makers will conceivably face tradeoffs between price stability and financial stability.

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## I. Introduction

The recent financial crisis poses challenges for academics and policy makers about monetary policy and motivated thinking about the interconnection between financial stability and monetary policy (Adrian and Shin, 2008).

According to the conventional view up to the crisis "there is no general trade-off between monetary and financial stability" (Issing, 2003)[1]. This view also led to the argument that conducting monetary policy and the regulation and supervision of banks and capital markets under one roof creates a potential for a conflict of interest. Before the recent crisis it was natural to view the basic tool of monetary policy - the key monetary policy rate (henceforth KPR) as *orthogonal* to the regulatory financial stability tools such as liquidity and bank capital requirements. Therefore, in some countries like the UK, the responsibility for safeguarding financial stability was assigned to special institutions such as the FSA (separated from the Bank of England).

The recent crisis, however, vividly demonstrated that a financial crisis can occur even after a relatively long period of world-wide low inflation and even where the task of financial stability is separated from the central bank (henceforth CB) and assigned to a special institution. It seems, therefore, that the trend towards separation of the two functions may have to be reexamined.[2]

In fact the crisis has caused many to begin to pay closer attention to the interaction and the interrelation between the KPR and the regulatory tools aimed at safeguarding financial stability, and to rethink the wisdom of the institutional separation of monetary policy and financial stability. Together monetary policy and

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[1] Likewise it was argued that a central bank "that was able to maintain price stability would also incidentally minimize the need for lender-of-last-resort" intervention (Schwartz, 1998).

[2] The UK government announced in June 2010 the restructuring of its regulatory system that will consolidate power within the Bank of England, abolishing the FSA.

financial regulation provide a set of cyclical tools that may be best coordinated under one roof of the CB, see Blanchard et al (2010).[3] As recently stated succinctly by Paul Volcker (2010) "Monetary policy and concerns about the structure and condition of banks and the financial system more generally are inextricably intertwined". Some economists hold the hypothesis that the long period during which CBs have kept low interest rates, contributed to the eruption of the financial crisis in 2007[4]. At the same time, the disconnection between the KPR and interbank rates during the crisis in many economies, demonstrated the adverse impact that financial instability has on the effectiveness of monetary policy.[5]

The purpose of this paper is to develop an analytical framework, backed by simulations, where the risk of the financial system is endogenous, the interaction between the CB monetary policy tool and financial stability regulatory tools (such as capital and reserve requirements) are clearly laid out, and where possible trade-offs between controlling inflation and safeguarding financial stability can be explicitly examined.

Our analytical framework, which uses an overlapping-generations model, is innovative in three main respects. First, it embeds a negative externality inherent in physical investments. This externality is a result of a wedge between the actual aggregate risks and that seen by the agents. This wedge gives rise to the need for financial stability (macro-prudential) policy making. Second, it integrates financial frictions in the form of banking financial intermediation into a simple dynamic

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[3] Chairman Bernanke (2010) argued that "The Federal Reserve's participation in the oversight of banks of all sizes significantly improves its ability to carry out its central banking functions, including making monetary policy, lending through the discount window, and fostering financial stability,"

[4] For a taxonomy of the various ways in which the risk taking channel operates, see for example Rajan (2005), Borio and Zhu (2008) and Gamacorta (2009). For some empirical evidence of the existence of the risk taking channel, see Jiménez, Ongena, Peydró and Saurina, 2009

[5] Leijonhufvud (2007) brings Japan up to the end of the 1980's as an example of monetary stability does not guarantee financial stability. He argues that inflation targeting might mislead the CB into pursuing a policy that damages financial stability.

stochastic general equilibrium (DSGE) model. Third, it clearly shows how the monetary policy transmission mechanism depends on regulatory and institutional constraints.

We let the CB in our model pursue both price and financial stability. Price stability is defined as achieving inflation target. Financial stability policy aims to contain the systemic risk[6] of the collapse of financial intermediation. Systemic risk in our model is the aggregate risk to which the financial system is exposed. Financial stability policy is implemented by (i) Reacting to changes in systemic risk, taking account of the above referred wedge, which is known to the CB. (ii) Preserving the CB's capacity to maintain a credible partial deposit-insurance scheme, where the proportion of deposit insurance is predetermined[7].

The capacity of the CB to prevent a run on financial intermediaries, is not unlimited however. It depends on two important factors: the size of financial resources it commands,[8] and its lending operations. The CB lending is extended only against safe collaterals which in our model are reserve requirements deposited at the CB. This arrangement of the CB lending to commercial banks plays an important role in the model[9].

We address explicitly the limits to which CB's can expand their balance sheets in response to financial crisis. Doing so is important because in the 2008 crisis the Federal Reserve, the European Central Bank, the Bank of England and other CB have

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[6] It has been observed that banking crises have occurred as a result of aggregate shocks see Gorton, G.(`1988) "Banking Panics and Business Cycles*" Oxford Economic Papers*, 40,751-781

[7] The level of this ratio reflects two opposing forces, on the one hand a higher ratio enhances financial stability by reducing the probability of idiosyncratic deposit withdrawals from turning into systemic run on the banks. On the other hand, a higher ratio impairs financial stability by encouraging moral hazard, because banks will extend loans to higher leveraged borrowers.

[8] In our model the possibility of the CB to be financed by the government is excluded. Therefore, the capital of the CB relative to the level of bank deposits and loans represents this capacity and is a key variable.

[9] One can think of an economy with no government debt and in which all CB lending must be backed by the safest collaterals.

not only expanded their balance sheets on very large scale, but have also, by acquiring non-government obligations (such as commercial paper in the US), exposed themselves to unprecedented levels of credit risk. This risk may impinge adversely on their future operational independence, because it raises the question of legitimacy of these actions and should thus be an integral part of an analysis which considers the interaction between monetary and financial stability[10] (see Buiter, 2009).

The main results of the paper are that monetary policy targets and financial stability goals are not orthogonal. Achieving one may require the use of other policy tools to maintain both goals. Furthermore, our model (or models of this type) could guide policymakers in the particular use of diversified tools in order to achieve the policy goals. In addition our model allows the explicit examination of the effects of policy tools on the monetary policy transmission mechanism (including financial stability tools).

The main policy implications are: (1) the effectiveness of monetary policy is affected by capital and reserve requirements (the financial stability tools) as well as by the extent of the partial deposit insurance; (2) Institutional constraints on the ability of banks to obtain funding sources from the CB, such as collateral limitations, strongly affect the way the monetary transmission mechanism operates.

The plan of the paper is as follows: section 2 presents a simple DSGE model, followed by analyses of the equilibrium characteristics of the model (Section 3). In the next section we illustrate these characteristics by using a semi-log linear utility function. Section 5 deals with the interaction of monetary policy and financial

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stability, supported by the model's simulations. Concluding remarks are presented in the last section 6.

## 2. The Model

We consider an overlapping-generations model reflecting an economy comprises of households, commercial banks and a central bank (CB). There exists a storable good that in each period can either be consumed or be stored as capital good. In each period $t$ there are markets for consumption good, real money balances, commercial bank deposits and loans, capital good, and CB secured loans to banks.

### 2.a. Households

A new generation of $N$ young people is born in each period $t$ and lives for two periods. Young individuals of type $j$, $j=1,2$, are each endowed with $w_j$ units of the storable good, where $w_1 < w_2$. There are $N/2$ young individuals of type 1 and similarly $N/2$ of type 2. In all respects the two types of individuals are identical except for their initial endowments. Old individuals (in their second period of life), rely on the assets' returns that they accumulated in period 1 for consumption in period 2.

Let $\beta$ denotes the time preferences of the households, and let $c_{st}^j$ denotes period $t$ consumption of type $s$ households, $s=1,2$, who belongs to generation $j$, $j=y$ (young), $o$ (old) [11]. There is uncertainty about the return on the investment (specified below) and for simplicity we assume that the households are all risk neutral. Formally, the preferences of household $j$ in period $t$ are represented by the following expected utility function based on information at period $t$

(1)     $E_t\{u(c_{st}^y, c_{st+1}^o)\} = v(c_{st}^y) + \boldsymbol{b}E_t\{c_{st+1}^o\}$   $j = 1,2.$

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[11] In what follows we will omit these subscripts or superscripts unless we deem it necessary to avoid confusion.

Where the function $v : \Re^+ \rightarrow \Re^+$ satisfies the standard characteristics[12]: continuous, twice differentiable with $v' > 0, v'' < 0, \lim v'(c) = \infty$ as $c \rightarrow 0$. As will be discussed shortly, it turns out that the choice of $c_{st}^y$ can not be contingent on the realizations of the state of nature, while the choice of $c_{st+1}^o$ can. $E$ is the mathematical expectations operator.

There are nominal money balances that potentially circulate in the economy, $m_t$, which is exclusively issued by a central bank and bears zero nominal interest. To avoid corner solutions in the asset portfolio choice, we assume that there are transaction costs, $y$ , involved in holding money balances (as opposed to other assets), which are proportional to the level of real money balances held, $y_t = y_m \dfrac{m_t}{p_t}$ with a constant $y_m > 0$, where $p$ is the price of the consumption good. These transaction cost are non-tangible in the sense that they do not exchange hands but rather are reflected in the reduction of the return on holding real money balances.

In order to smooth consumption young individuals can also deposit financial nominal savings, $d_t$, at commercial banks. These deposits bear a nonnegative one period nominal interest rate, $i_{dt}$. They are subject to uncertainty that is realized when banks become insolvent, but the losses are bounded for there exists a *partial* deposit insurance. The CB provides guarantee to a (exogenous) fraction $q$ of the household's deposited funds in case where the commercial bank becomes insolvent.

There is also a real channel through which households can shift purchasing power from one period to another. The young individual can use the endowment or part of it to productively invest under the following conditions: if $k_t$ units of the good

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[12] This functional form of the utility function reflects the assumed risk neutrality of the individuals.

are invested in $t$, then $f(k_t)$ units become available at time $t+1$. We assume that the gross return $f(k_t)$ follows the stochastic process

(2)     $f(k_t) = \begin{cases} Ak_t^a, 0 < a < 1, & \text{with probabilty } l(k_t) \\ 0 & \text{otherwise} \end{cases}$

Where we further assume that $l$ evolves according to the following process

(2a)     $l(k_t) = g e^{-gk_t}, \quad 0 < g \le 1,$

satisfying $?'(k) < 0$, $?(0) = ?$, and $?(k_t) \to 0$ as $k \to \infty$ [13]. We assume that individuals in the economy (with the exception of the CB policymakers) are not aware of (2a).

The specification (2a) of the risk in the investment demonstrates diminishing marginal quality in terms of risk. That is, we assume increasing risk embedded in the marginal investment, where the risk is contagious (i.e. affecting total investment).

There are several important features regarding this physical investment opportunity. First, the realization of period $t$ gross return $f(k_t)$, takes place at the beginning of period $t+1$ [14]. Second, neither the households nor commercial banks are aware of the aforementioned relationship (2a), that is, in making their choices they all take the level of $?$ as given, and we will refer to it as the *perceived* $?$.[15] This assumption potentially introduces a wedge between the actual $?$ and the perceived one, and thereby creates an externality. The CB, however, is aware of (2a) and its effects and does take it into considerations in making its macro-prudential policy decisions. The last feature is that there is a minimum amount of capital $K_{\min}$ (a

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[13] Note that $?$ is the upper bound of the value of $?(k_t)$.

[14] The uncertainty here is not related to the financing of the project, but rather to physical characteristics of the gross return. For example, the greater complexity and limited flexibility of larger project may increase the likelihood of failure.

[15] In contrast to the CB, individuals and banks form their assessment of aggregate risk based on the perceived $?$.

threshold) needed to be invested for this channel to be operative. We assume that the $K_{\min}$ satisfies the inequality

(2b) $\qquad w_1(1+t) < K_{\min} \leq w_2 ,$

where $t$ is a parameter that will be introduced later on. This $K_{\min}$ is instrumental for the resulting separating equilibrium.

To bridge between the individuals' available resources, and their consumption and investment decisions, young individuals can borrow from commercial banks and get one-period, nominal loans, $l_t$, that bear a non-negative, one period nominal interest rate, $i_{Lt}$. The collateral for this loan is the borrower's realized return $f(k_t)$, and/or his/her bank deposit if it exists. We assume however that his/her real money balances and dividends receipts (from the commercial banks' profits) remain available for consumption[16] in all states.

Since the commercial banking system is assumed imperfectly competitive in the market for loans, we have to consider the allocation of the commercial bank's expected profit, $?_{t+1}$. For that end we assume that old individual $h$, $h=1,\ldots,N$, inherits at the beginning of the period $t+1$ bank $i$'s equity, $s_t^{hi}$, $i=1,...,I$, which entitle him/her to a share of bank's $i$ profits (dividends). We further assume for simplicity that

$\dfrac{s_t^{hi}}{\displaystyle\sum_{h=1}^{N} s_t^{hi}} = \dfrac{1}{N}$, all $i$. Finally, we let a fraction $d$ of the banks profits to be paid out as

dividends to the shareholders and the rest remains as retained earnings.

Since the realization of period $t$ physical investment's return takes place at the beginning of period $t+1$, individuals' choice of period $t$ variables can not be

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[16] This default arrangement is assumed for simplicity. Conceptually we could model an arrangement that takes account of the individuals' assets, but in return to a much more complicated model. i.e. use the stock holding as collateral.

contingent on the realization of $?$, that is, $c_{1t}$, $c_{2t}$, $m_{1t}$, $m_{2t}$, $k_t$, $d_t$, $l_t$, $d_t$ are all non-contingent. Since the choice of some of these variables depends on period $t$ expectations of $p_{t+1}$, the latter can not be contingent on the realization of $?$ either. In fact, all of these variables are dependent on a predetermined (exogenous) perceived $?$. On the other hand period $t+1$ consumption is contingent on the realization of the true $?(k_t)$.

It is useful at this point (before households' budget constraints are presented) to assume that there exists a separating equilibrium for our model economy such that individuals of type 1 use the bank deposits and real money balances in order to smooth their consumption, while individuals of type 2 use the investment in the physical capital and the real money balances for the same purpose. We later on prove that if there exists an equilibrium for our model with banking financial intermediation, it is a separating one.

**2.a.1. Households' budget constraints**

The households' budget constraints of young and old individuals in periods $t$ and $t+1$ are specified for depositors, denoted $j=1$, and for investors, $j=2$, as follows.

(i) For the young individuals:

(3a) $\quad c_t + \dfrac{m_{1t}}{p_t}(1+\mathbf{y}_{1t}) + \dfrac{d_t}{p_t} = w_1,$ (for "poor" depositors),

where $p_t$ is the price of the consumption good in period $t$.

(3b) $\quad c_t + k_t + \dfrac{m_{2t}}{p_t}(1+\mathbf{y}_{2t}) - \dfrac{l_t}{p_t} = w_2,$ (for "rich" investors).

The state unconditional budget constraints of the old individuals (in expected values terms) are as follows:

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(3c) $\quad E_t c_{t+1} = \dfrac{m_{1t}}{p_{t+1}} + d\,\dfrac{\Pi_{t+1}}{Np_{t+1}} I + (1 - (1-\boldsymbol{q})q_{t+1})\dfrac{(1+i_{dt})}{p_{t+1}/p_t}\dfrac{d_t}{p_t}$ $\qquad$ (for depositors),

(3d) $\quad E_t c_{t+1} = \dfrac{m_{2t}}{p_{t+1}} + d\,\dfrac{\Pi_{t+1}}{Np_{t+1}} I + \boldsymbol{l}(f(k_t) - \dfrac{(1+i_{Lt})}{p_{t+1}/p_t}\dfrac{l_t}{p_t})$ $\quad$ (for investors).

Where $q_{t+1}$ is period $t$ conditional probability of commercial banks to become insolvent in period $t+1$. This probability is known and is determined in equilibrium[17] (see a detailed analysis below). Banking insolvency entails the activation of the deposit insurance by the central bank, so we let $?$ (a policy variable) be the share of deposits that is recovered after activating the CB deposits insurance. $I$ is the number of commercial banks[18].

Note that $p_{t+1}$ in (3c) and (3d) is the expected price of the consumption good, given the perceived values of $?_t$ and $q_{t+1}$. For both types of individuals the ex-post period $t+1$ consumption may deviate from the expected consumption due to the difference between the perceived and actual values of $?$ and $q_{t+1}$.

Given $\{s_t, \Pi_{t+1}, p_t, p_{t+1}, i_{dt}, i_{Lt}, w_1, w_2, \boldsymbol{q}, q_{t+1}, \boldsymbol{d}, \boldsymbol{y}_m, \boldsymbol{1}, f(k)\}$, young depositors choose $\{c_t, E_t c_{t+1}, m_t, d_t\}$ to maximize (1) subject to (3a) and (3c), and young investors choose $\{c_t, E_t c_{t+1}, m_t, k_t, l_t\}$ to maximize (1) subject to (3b) and (3d).

**b. Commercial Banks**

There are $I$ identical financial intermediaries[19] (commercial banks) in the economy. Each of which accepts one-period nominal deposits, $d_t$, that pay a nominal interest rate, $i_{dt}$. We assume that the deposit market is perfectly competitive where banks and

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[17] See equation (8) for the determination of $q_{t+1}$.
[18] Derivations of these budget constraints in more detail appear in Appendix A (can be received upon request).
[19] They are identical in the sense that they have the same shareholders and they each begin period $t$ with the same equity capital.

depositors are price taker. On the other hand we assume that the loan market is imperfectly competitive. Banks offer investors one-period nominal loans, $l_t$, at a nominal interest rate, $i_{Lt}$. Similarly to households, commercial banks also are not aware of the externalities and they base their decisions on the perceived risk $I$ and $q_{t+1}$.

Each bank makes use in the financial intermediation of its (beginning of period) equity capital, $FK_t$ that was accumulated from retained earnings of past periods and it is thus predetermined. Commercial banks are managed by the young individuals in each period. They are motivated to optimize profits since they will enjoy the fruits of their choices (the dividends) when they become old. Banks choose the share, d, $0 \leq d \leq 1$, of their profits that are to be distributed to their shareholders as dividends. A share (1- d) of their profits will be retained by the intermediaries and will augment the stock of equity capital.

Commercial banks can borrow from the CB a fully secured one-period loan $l_{mt}$, from the CB lending facility (henceforth, monetary loan) supplied perfectly elastically at a nominal rate $i_{mt}$[20] (*KPR*). Banks can use this borrowing source any way they choose, but the amount borrowed is *limited* to the amount of collateral they have in the form of total reserves they hold at the CB.

Banks are subject to two additional balance sheet constraints: (i) For financial stability reasons, they must maintain a required capital ratio - *expected* end-of-period equity capital[21], $E_tFK_{t+1}$ to total assets at time $t$, $AS_t$, of *?* percents. Note that $FK_t$ is a state and predetermined variable at period $t$ and depends merely on previous period

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[20] Technically CB in many countries extend secured loans to commercial banks through reverse repurchase agreement operations. Such operations are the major day-to-day monetary policy instrument.

[21] Note that in period $t$, the financial intermediary has no control over the existing stock of financial capital, $FK_t$, and thus we enter the end-of-period $FK_{t+1}$ into the capital constraint of time $t$.

action. Therefore, any change in capital requirements refers to $\dfrac{E_t FK_{t+1}}{AS_t}$ rather than to

the current period capital ratio. Banks comply with this requirement through the

accumulation of retained earnings, as well as by changing $AS_t$. (ii) For both monetary

and financial stability goals, banks must comply with the CB imposed nominal

reserve requirement at a rate of $rr_t$ (see below). We assume that this constraint is

binding at all times, i.e. total reserves equal the required reserves, $RR_t = rrD_t$ where $D_t$

is the total deposits at the bank.

The resource constraint (balance sheet) of the commercial bank before the

realization of the uncertainty is

(4a) $\quad AS_t \equiv L_t^i + RR_t^i = D_t^i + FK_t^i + l_{mt}$

where $RR_t = rr_t D_t$ and $l_{mt} = rr_t D_t$.

When the systemic risk is realized and the banks become insolvent, the CB

activates the deposit insurance where it pays off depositors through the commercial

banks such that for each bank the following condition is satisfied:

(4b) $\quad \boldsymbol{l}(k_t)(1 + i_{Lt})L_t^i + RR_t^i = \boldsymbol{q}(1 + i_d)D_t^i + (1 + i_{mt})l_{mt}$

where $\boldsymbol{l}(k_t)$ is the realization of the true $\boldsymbol{l}$. Note that when systemic risk is realized,

the total (period $t$) financial capital of the commercial bank is completely depleted.

Following a period in which commercial banks become insolvent, they continue on to

the next period operating as new financial intermediaries[22].

The *conditional* expected period $t+1$ profit when the realization of the

systemic risk has not occurred (with probability $1-q_{t+1}$) is given by

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[22] Note that in our model all assets and obligations are of one-period duration. Therefore, the next period everything starts all over again. Alternatively, we can assume that a new bank is established every period.

(5a) $\quad E_t \prod_{t+1}^{1-q} = \mathbf{1}\, i_{Lt} L_t^i - i_{dt} D_t^i - i_{mt} l_{mt}$.

Similarly, the *conditional* expected period $t+1$ profit/loss when the realization of the systemic risk does occur (with probability $q_{t+1}$) and the bank becomes insolvent is given by[23]

(5b) $\quad E_t \prod_{t+1}^{q} = \mathbf{1}\, i_{Lt} L_t^i - i_{dt} \mathbf{q} D_t^i - i_{mt} l_{mt}$.

The term $i_{dt} \mathbf{q} D_t$ in (5b) is part of the obligations of the CB to depositors when deposit insurance arrangement is activated.

The *state unconditional* expected period $t+1$ profit is then given by

(5c) $\quad E_t \prod_{t+1} = \mathbf{1}\, i_{Lt} L_t^i - (1 - (1 - \mathbf{q})q_{t+1}) i_{dt} D_t^i - i_{mt} l_{mt}$

We assume for simplicity that the commercial banks' shareholders seek to maximize their period $t+1$ expected dividends payment which they receive in all states of nature in which they have positive profits. Accordingly, in each period $t$ the commercial bank maximizes the expected dividends payment, $d_t E_t ?_t$, where the expected profit is defined in (5c), and is subjected to the following constraints (5d-(5h) [24]

The maximum leverage constraint, which is set by the bank's management and is given by

(5d) $\quad \dfrac{l_t}{p_t w_j} \le \mathbf{t}$, $j = 1,2$.

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[23] We assume here that even when there is a realization of systemic risk and the deposit insurance has been activated, still due to the "haircut" of the depositor return the commercial bank may realizes positive profits which are then distributed to the shareholders.

[24] Note that the maximization of $d_t E_t ?_t$ relies on the banks' perceived level of aggregate risk which depends on $?$ and $q_{t+1}$. It further relies on the policy parameters such as $i_m$, $rr$ and $?$, set by CB which is aware of the externalities.

We refer to this constraint as a risk-management constraint. The risk-neutral bank management imposes this constraint to contain the exposure to credit risk such that a vicious cycle[25] would not emerge[26]. Note that $tw_j$ is the upper bound on the amount of bank loan (in real terms) an individual of type $j$ can get. Note further that individuals of type 1 can not acquire $k_{min}$ that is required for the operation of the real investment because of (2b) and constraint (5d).

The minimum capital requirement is applied to $FK_{t+1}$ of period $t+1$ relative to the total loans $L_t$. and is given by

(5e)     $$\frac{E_t FK_{t+1}^i}{AS_t^i} \geq k$$

The limit on the amount a financial intermediary can borrow from the CB in the form of monetary loans. The collateral constraint is

(5f)     $$l_{mt}^i \leq RR_t^i .$$

We assume that the CB has priority over the commercial bank assets in time of insolvency.

For simplicity we require a strict equality in the following reserve requirement constraint, (i.e. banks do not hold excess reserves)

(5g)     $$RR_t^i = rrD_t^i .$$

Finally, banks accumulate financial capital according to the following dynamic process:

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[25] A cycle in which following a growth of the economy borrowers demand for loans increases, the banks exposure to credit risk increase both due to the expansion of the loans but also because of the assumed increase of the credit risk itself. Consequently, the probability of systemic crisis increases in time of rapid growth.

[26] One could perceive the rate of $t$ to be less restrictive (higher) the greater is the proportion of deposits insured by the CB, but for simplicity we leave it independent.

(5h)    $E_t FK_{t+1} = FK_t - (1 - \boldsymbol{l})L_t + (1 - \boldsymbol{d}_t)E_t \Pi_{t+1}$

where the second term on the RHS of (5h) is the total period $t$ loans written off and the last term is the retained earnings.

Thus the financial intermediary in period $t$ chooses $i_{Lt}$, $l_{mt}$, $FK_{t+1}$, and $d_t$ to maximize its expected dividends payment subject to (4a), (5d)-(5h). Since all commercial banks are assumed to be identical we will refer in the analysis to a *representative* bank.

## c. Central bank

The CB pursues two goals: reducing the deviations of the inflation from its target, and maintaining financial stability, which in our setup means controlling $q_{t+1}$ and maintaining enough resources, *SR*, to meet the deposit insurance obligations. The target inflation rate is determined exogenously. Inflation can deviate from its target due to shocks and to bring it back on target, the CB adjusts its KPR $i_{mt}$. The CB sets a perfectly elastic supply of monetary loans at the KPR, with the required provision of collateral.

To safeguard financial stability the CB can resort to the following: (i) Limits credit expansion by imposing a minimum capital adequacy ratio. The capital ratio requirement aims at containing the exposure of commercial banks to credit risk and serving as a cushion to absorb losses. (ii) Provides a safety net in the form of partial deposits insurance, when the commercial banks fail. The CB guarantees a share *?*,

$0 \leq q \leq 1$, of each household's deposit at the commercial banks[27], where *?* is predetermined[28].

(iii) In addition, the CB imposes a reserve requirements constraint, *rr*, which is important in our setting for both the effective control of the monetary interest rate, as well as for enhancing financial stability.

Since the reserves held by the commercial banks are the only eligible collateral for CB loans in our model, they in effect create a sustained demand for the CB monetary loan, thus ensuring that the CB has effective control over the policy interest rate. Furthermore, this collateral arrangement enables the CB to expand or contract the supply of liquidity to the banks as needed. We note that this arrangement increases the potential outstanding commercial banking loans to individuals from a maximum amount of $L_t=(1-rr_t)D_t+FK_t$, when monetary loans are not available, to a maximum of $L_t=D_t+FK_t$. when the full amount of the monetary loan is extended.

The CB accumulates seigniorage revenue (*SR*) in our model from the banks' reserves $rrD_t$, and the outstanding balances of the monetary loans, $l_{mt}$ on which it charge a positive interest rate. The accumulated *SR* at the CB, given that last period the deposit insurance has not been activated, is

$$(6) \quad SR_t = \frac{rr_t D_t - L_{mt} - (rrD_{t-1} - L_{mt-1})}{p_t} + \frac{i_{mt-1}L_{mt-1}}{p_t} + \frac{p_{t-1}}{p_t} SR_{t-1}$$

The CB net worth is increased by the flow of $SR_t - \frac{p_{t-1}}{p_t} SR_{t-1}$ and is depleted when deposit insurance is activated[29]

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[27] Given an expected inflation rate, this structure provides (if *?*<1) certainty dominance to holding cash over banks' deposits. Of course it may also give rise to an interest rate differential between the two financial assets.

[28] The choice of *?* could reflect two opposing forces which are at the back round of the model. A higher *?* enhances financial stability by reducing the correlation of shocks to deposits and a systemic shock, while at the same time it enhances risk taking by the commercial banks (moral hazard).

## d. Market Clearing

In conducting its monetary policy operations, the CB supplies just enough monetary loan balances to meet the commercial banks demand at the predetermined KPR. Commercial banks accept all deposits supplied by the individuals at the market deposit rate $i_{dt}$, where the latter is determined in accordance with the KPR. On the other hand, commercial banks have market power in the loan market, thus given the investor demand for loans and the deposit interest rate, they set the loan rate $i_{Lt}$ at a level that satisfies the investors' demand for loans as well as maximizes their expected profits (see Figure 1). $D = L - FK_t$ is the commercial bank's resource constraint and point A (in Figure 1) is the pair $(L_m, i_m)$ that equilibrates the monetary loan market.

Figure 1.

Bank deposit and loan and monetary loan demands



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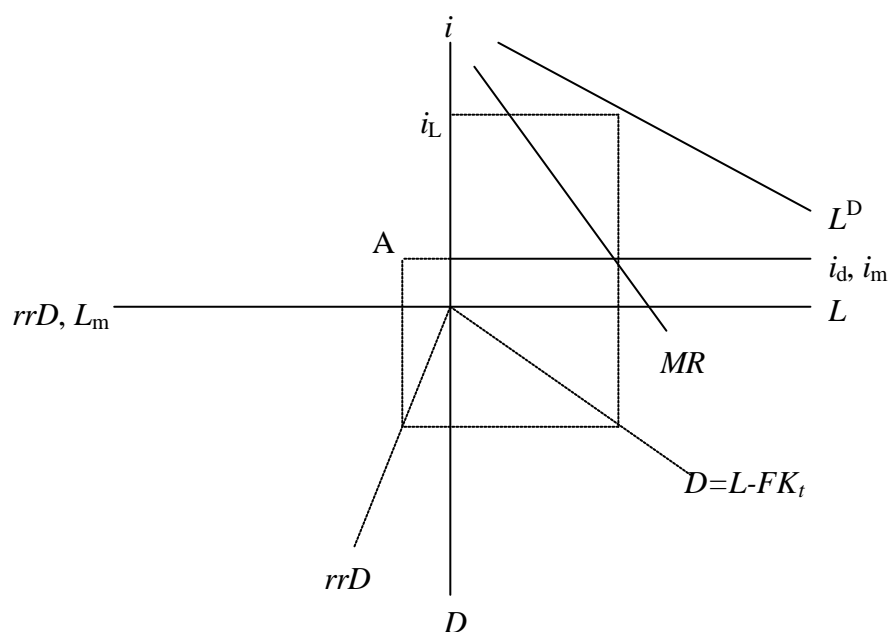
[29] Note that money balances held by the individuals generate distributional effects (between the old and the young individuals) but do not affect the seigniorage revenues at the CB.

Investors determine their investments in physical capital based on the expected real return (which is derived from the nominal $i_{Lt}$ and the expected inflation). The stock of capital invested last period together with the current aggregate endowments of the young individuals, determine the current aggregate supply of the consumption good. Finally inflation expectations clear the consumption good market.

**e. Information Setup and Equilibrium Conditions**

Households in our economy make decisions when they are young (at period $t$) for both periods $t$ and $t+1$ choices. These decisions are based on the information available at period $t$. This set of information includes all perceived probabilities but not the actual realizations. The realizations of $I(k_t)$ and $q_{t+1}$ become known to households, to commercial banks and to the CB only at the beginning of period $t+1$, when the individuals are old. Note that the inflation $\dfrac{p_{t+1}}{p_t}$ in our economy is actually the *expected* inflation rate at date $t$.

The clearing condition for the consumption good market is

(7)
$$c_{1t}^y + c_{2t}^y + c_{1t}^o + c_{2t}^o + k_t + \boldsymbol{y}_m\left(\frac{m_{1t}}{p_t}\right)^2 + \boldsymbol{y}_m\left(\frac{m_{2t}}{p_t}\right)^2 + \frac{SR_t}{N} - \frac{p_{t-1}}{p_t}\frac{SR_{t-1}}{N}$$
$$+ \frac{FK_t}{p_t} - \frac{FK_{t-1}}{p_t} = w_1 + w_2 + I(k_t)y_t + \frac{FK_{t-1}}{p_{t-1}}(1 - \frac{p_{t-1}}{p_t})$$

In equilibrium the perceived probability of commercial bank failure $q_{t+1}$ by individuals should be consistent with the fundamentals and the perceived $I$ since they determine the conditions under which the commercial banks go bankrupt. Hence it must satisfy the following

(8)  $q_{t+1} = H\{FK_t + (1+i_{Lt})IL_t^i + RR_t - (1+i_{dt})D_t^i - (1+i_{mt})l_m \leq 0\},$

where $H$ is the cumulative probability distribution of the default on loans granted by the bank a period ago[30]. The term in the curly brackets is the state in which the banks' equity capital is negative.

Substituting the resource constraint (4a) and the conditional expected profit when the systemic risk has not yet occurred (5a) into (8) yields the following

(8a) $\qquad q_{t+1} = H\{FK_t + E_t\Pi_{t+1}^{1-q} - (1-\mathbf{1})L_t \leq 0\}$

The expression within the curly brackets is easier to understand, it indicates the state in which the beginning of period level of equity capital in addition to the conditional next period's expected profit are just not enough to cover the expected loan losses. Clearly the function $H$ is a monotonic function with $H' < 0$. Since $FK_t$ is predetermined in period $t$, $q_{t+1}$ is determined by the conditional expected next period profits of banks and the expected loan defaults. A larger $q_{t+1}$ means less financial stability.

In order to fulfill its deposit insurance obligation, the CB needs to generate sufficient $SR$ and/or to restrain commercial banks' exposure to credit risk. Since the CB is aware of systemic risk (through equation (2a)) and takes it into considerations in determining its policy parameters, the following incentive compatible constraint is satisfied.

(9) $\qquad \sum_{i=1}^{I}(\mathbf{q}(1+i_{dt})\frac{D_t}{p_t} - (\mathbf{1}(k_t)(1+i_{Lt})\frac{L_t}{p_t} + \frac{RR_t}{p_t} - (1+i_{mt})\frac{l_{mt}}{p_t})) \leq SR_t,$

---

[30] The expression $(1+i_{Lt})\mathbf{1}(k_t)L_t^i + RR_t$ is the nominal value of the commercial bank's total assets, expected to be realized in period $t+1$, while $(1+i_{dt})D_t^i + (1+i_{mt})l_m$ is the nominal value of its total liabilities (to the individuals and the CB), expected to be realized in period $t+1$. When the latter exceeds the former the addition to the commercial bank equity capital is negative.

That is, the SR accumulated up to period $t$ should be no less than the sum (over all banks) of the absolute values of banks' net worth in states where systemic risk is realized, evaluated by the true $I(k_t)$.

## 3. Equilibrium characteristics

### a. Households

We begin with the first order conditions characterizing the various individuals in our economy. Let $v_{ct}$ denote the marginal utility with respect to $c_t$. Given that investors take the probability $?$ as given, the condition characterizing their choice is

$$(10a) \quad \frac{n_{c_t}}{b} = I(k_t)f_k,$$

where $f_k$ is the marginal productivity of capital. The marginal rate of substitution in consumption equals the expected marginal productivity of capital. We further get for the investors that

$$(10b) \quad If_k = I \frac{1+i_{Lt}}{p_{t+1}/p_t} \equiv R_{Lt},$$

i.e. the expected real interest rate on loans equals the expected marginal productivity of capital.

Since there is a positive probability for realizing zero net return on the physical investment, investors may hold money balances for precautionary motives[31]. So from the FOC with respect to the money balances we get that if indeed money balances are held we have

$$(10c) \quad R_{Lt} = \frac{p_t}{p_{t+1}} \frac{1}{1+2y_{2t}} \quad \text{or} \quad I(1+i_{Lt}) = \frac{1}{1+2y_{2t}}, \quad \text{with } y_{2t} = y_m \frac{m_{2t}}{p_t}.$$

---

[31] Recall that holding commercial bank liabilities could not by assumption be of help when the return on the investment is zero.

Next from the FOC characterizing the depositors' choices, we get

(11a) $\quad \dfrac{\boldsymbol{n}_{c_t}}{\boldsymbol{b}_1} = (1 - (1 - \boldsymbol{q})q_{t+1})\dfrac{1 + i_{dt}}{p_{t+1}/p_t} \equiv R_{dt},$

Namely, the marginal rate of substitution in consumption equals the expected real return on deposits at the banks. If money is held then we further obtain for depositors

(11b) $\quad R_{dt} = \dfrac{p_t}{p_{t+1}}\dfrac{1}{1 + 2\boldsymbol{y}_{1t}}$ or $(1 - (1 - \boldsymbol{q})q_{t+1})(1 + i_{dt}) = \dfrac{1}{1 + 2\boldsymbol{y}_{1t}}$, with $\boldsymbol{y}_{1t} = \boldsymbol{y}_m \dfrac{m_{1t}}{p_t}.$

That is, if money balances are held by the depositors, then the expected real return on deposits equals the real return on money balances adjusted for the transaction cost.

From (10b) after rearranging terms and solving for the inflation rate we get the following equilibrium condition

(11c) $\quad \dfrac{p_{t+1}}{p_t} = \dfrac{1 + i_{Lt}}{f_{kt}}.$

This equilibrium condition guarantees the satisfaction of the Fisherian relationship between the nominal interest rate, $i_{Lt}$, the real (gross) rate $f_k$ and the rate of expected inflation. The inflation in our model is determined in accordance with the asset portfolio selection framework. This approach to modeling inflation is in line with Sims (2009).

These equilibrium conditions imply a separating equilibrium results[32]:

***Result 1.*** *If the following perceived probabilities ? and 1-(1-?)q_{t+1} are of similar magnitudes, and if there exists an equilibrium for our economy with L_t > 0, D_t > 0, then it is a separating equilibrium where the low-endowed individuals (of type 1) deposit funds in the banks, hold real money balances and do not invest in the physical*

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[32] Proofs of propositions that support Result1 through Result 7 can be received upon request.

*capital, while the high-endowed individuals (type 2) invest in the physical capital, hold real money balances and do not deposit at the banks.*

**b. Financial Intermediaries**

In this section we derive the conditions characterizing the representative financial intermediary choices. We begin by the elimination of $AS_t$ and $D_t$ in (5c) utilizing the resource constraint (4a). We then use constraints (5d)-(5h) to set the Lagrangian for the representative bank as follows

(12)

$$
\Psi = \boldsymbol{d}_t[\boldsymbol{l}\, i_{Lt}L_t - (1-(1-\boldsymbol{q})q_{t+1})\frac{i_{dt}}{1-rr}(L_t - FK_t - l_{mt}) - i_{mt}l_{mt}]
$$
$$
+ \boldsymbol{j}_{1t}(\boldsymbol{t}p_t wN/2 - L_t) + \boldsymbol{j}_{2t}(E_t FK_{t+1} - \frac{\boldsymbol{k}}{1-rr}(L_t - rr(FK_t + l_{mt})))
$$
$$
+ \frac{\boldsymbol{j}_{3t}}{1-rr}(rr(L_t - FK_t) - l_{mt}) + \boldsymbol{j}_{4t}(FK_t - (1-\boldsymbol{l})L_t + (1-\boldsymbol{d}_t)E_t\Pi_{t+1} - E_t FK_{t+1})
$$

where $\boldsymbol{j}_j, j = 1,2,3,4,$ are the Lagrange multipliers associated with constraints (5d), (5e), (5f) and (5h), respectively, $N/2$ is the number of individuals who borrow from the commercial bank (the investors).

Next we derive the FOC for the maximization of the expected dividends payments of the representative bank. For convenience we begin with the FOC derived for the ratio $d$ and get

(13a) $\quad E_t\Pi_{t+1} - \boldsymbol{j}_{4t}E_t\Pi_{t+1} = 0.$

So if $0 < d < 1$ such that (13a) is binding, then $\boldsymbol{j}_{4t} = 1$, all $t$, where $\boldsymbol{j}_{4t}$ is the shadow price (in terms of the expected profit) of the financial capital accumulation constraint.

Note that both (5e) and (5h) restrict $E_t FK_{t+1}$ and they are in fact linear in it, so in the case where they are both binding we have that

(13b) $\quad \boldsymbol{j}_{2t} = \boldsymbol{j}_{4t} = 1$

where $\boldsymbol{j}_{2t}$ is the shadow price of the minimum capital requirement constraint[33].

**b1. The Pass-through and the effectiveness of the monetary policy**

We derive the pass-through from the CB KPR to the banking deposit and loan rates from the FOC corresponding to the commercial bank's choice of $l_{mt}$ and get the following equilibrium relationship.

$$(13c) \quad (1-(1-\boldsymbol{q})q_{t+1})\frac{i_{dt}}{1-rr} = i_{mt} - \boldsymbol{k}\frac{rr}{1-rr} + \frac{\boldsymbol{j}_{3t}}{1-rr}.$$

Next we derive from the FOC corresponding to the commercial bank's choice of $i_{Lt}$, the relationship between the loan interest rate and the deposit interest rate, obtaining

$$(13d) \quad \boldsymbol{l}(1+\frac{1}{\boldsymbol{h}_t})i_{Lt} = (1-(1-\boldsymbol{q})q_{t+1})\frac{i_{dt}}{1-rr} + \boldsymbol{j}_{1t} + \frac{\boldsymbol{k}}{1-rr} - \frac{rr}{1-rr}\boldsymbol{j}_{3t} + (1-\boldsymbol{l})$$

where $\boldsymbol{h}_t = \frac{i_{Lt}}{L_t}\frac{\partial L_t}{\partial i_{Lt}}$ is the interest rate elasticity of the demand for loans.

Finally we combine (13c) and (13d) to eliminate $(1-(1-?)q_{t+1})$ and have the transmission mechanism from the CB $i_{mt}$ to the market $i_{Lt}$ of the following

$$(13e) \quad \boldsymbol{l}(1+\frac{1}{\boldsymbol{h}_t})i_{Lt} = i_{mt} + \boldsymbol{j}_{1t} + \boldsymbol{k} + \boldsymbol{j}_{3t} + (1-\boldsymbol{l}).$$

One of the hypothesis of the paper is that monetary policy is interconnected with financial stability. It indeed turns out that the pass-through from the $\boldsymbol{i}_{mt}$ to $\boldsymbol{i}_{dt}$ depends, not only on whether constraint (5f) is binding or not (i.e. $f_3 > 0$ or not), but also on the extent to which the required reserves ratio and capital ratio are used as

---

[33] The financial capital accumulation (5h) is always binding, while the minimum capital ratio (5e) may not be binding, in which case banks hold financial capital in excess of the required amount.

policy instruments (see (13c) and (13d)). If, for example, in time of a trough where deflationary pressures emerge, the CB implements an expansionary monetary policy (by reducing $i_{mt}$) and simultaneously raises the minimum capital requirement ratio $?$ for financial stability purposes, the combined effects on $i_{dt}$ and $i_{Lt}$ could offset each other (13c and 13e). This case demonstrates clearly a possible conflict between the two CB goals of attaining the inflation target and safeguarding financial stability[34].

We define the effectiveness of the transmission mechanism of monetary policy as the partial derivative $\dfrac{\partial i_{kt}}{\partial i_{mt}}$ , where $i_k$ is the market interest rates, $k=d,L$. The larger and the more stable $\dfrac{\partial i_{kt}}{\partial i_{mt}}$ is, the greater will be the effectiveness of monetary policy[35]. (i.e. the effectiveness of the monetary policy is the extent to which a change in $i_{mt}$ affects the market rates in a predictable and stable way.)

From equations (13c)-13(e) it is apparent that the effectiveness of monetary policy is affected by financial stability tools, $rr$, $?$ and $?$, by the leverage constraint (5d) as well as by the collateral constraint imposed on the use of monetary loans (5f). Also we get from this transmission mechanism that when the CB interest rate or the deposit rate reach the zero bound, the CB can affect $i_{Lt}$ by adjusting the reserve ratio or/and the capital requirements, as well as by loosening the collateral constraint on the monetary loans, (reflected in $f_3$). In this situation, if a reduction in the lending rate is warranted to offset say a deflationary shock, then the viable monetary policy tools are ones which in normal circumstances are financial stability instruments. This clearly

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[34] Regarding the pass-through from the policy rate to the market rates, we note from (13d) that if the risk management relaxes its constraint on the leverage (increases $t$), then $j_{1t}$ will decreases and the interest rate on loans will be (ceteris paribus) lowered, given the CB rate, $i_{mt}$.

[35] Note in this regard (13c and 13d) that monetary policy becomes particularly effective when there is full deposit insurance ($?=1$). But this in turn may, ceteris paribus, expose the banking system to more systemic risk, as the commercial bank's willingness to expand loans increases. This example reflects a trade-off between monetary policy effectiveness and systemic risk.

demonstrates how inextricably interlocked are the tools of monetary policy and financial stability[36].

**b2. Commercial banks use monetary loans up to their collateral constraints**

Let the expected real dividends paid out by the banks to the representative old consumer be denoted by $\Gamma_{t+1} \equiv d \dfrac{E_t \Pi_{t+1}}{N_t p_{t+1}} I$ and without loss of generality we assume $I$=1 (there is one representative commercial bank). Note that we can combine the expression for the expected profits (5c) and the resource constraint for the bank (4a) to get the following expression for the expected dividends payment

$$
\begin{aligned}
\Gamma_{t+1} = d_t \frac{p_t}{p_{t+1}} \Big\{ & \big[\boldsymbol{1} i_{Lt} - (1-(1-\boldsymbol{q})q_{t+1}) \frac{i_{dt}}{1-rr} \big] \frac{l_t}{p_t} \\
& + \big[(1-(1-\boldsymbol{q})q_{t+1}) \frac{i_{dt}}{1-rr} - i_{mt} \big] \frac{l_{mt}}{Np_t} \\
& + (1-(1-\boldsymbol{q})q_{t+1}) \frac{i_{dt}}{1-rr} \frac{FK_t}{Np_t} \Big\}
\end{aligned}
$$

(14)

where the optimal $d_t$ is chosen to have constraint (5h) satisfied with equality. There are two expressions in the RHS of (14) that appear in squared brackets. The first one can be analyzed using equilibrium condition (13d) and the second one can be analyzed using condition (13c). For now we deal only with the latter, that is, substituting from (13c) into (14) to yield

$$
\begin{aligned}
\Gamma_{t+1} = d_t \frac{p_t}{p_{t+1}} \Big\{ & \big[\boldsymbol{1} i_{Lt} - (1-(1-\boldsymbol{q})q_{t+1}) \frac{i_{dt}}{1-rr} \big] \frac{l_t}{p_t} \\
& + \big[-\boldsymbol{k} \frac{rr}{1-rr} + \frac{\boldsymbol{j}_{3t}}{1-rr} \big] \frac{l_{mt}}{Np_t} \\
& + (1-(1-\boldsymbol{q})q_{t+1}) \frac{i_{dt}}{1-rr} \frac{FK_t}{Np_t} \Big\}
\end{aligned}
$$

(14a)

---

[36] While the recent relaxation of the collateral requirements by many CBs may have increased the pass-through from the CB interest rate to the deposit rates, it involves a cost of putting the taxpayer money at greater risk and raising questions as to the extent of instrument independence that CB should have.

From which we get the following result regarding the commercial bank use of the CB monetary loans.

**Result 2**. *It turns out from (14a) that there is no partial use of the commercial bank's collateral for the CB monetary loans. Either there is no use of the collateral at all, or the commercial banks utilizes all of its collateral such that* $l_{mt} = rrD_t$.

**Corollary**

Result 2 implies that the *SR* boils down to the following

(6a)　　$SR_t = \dfrac{i_{mt-1}L_{mt-1}}{p_t} + \dfrac{p_{t-1}}{p_t} SR_{t-1}$

Namely, the sources for the seigniorage accumulation at the CB are the monetary loans granted to the commercial banks, the *KPR* and the inflation.

　　In what follows we focus on the equilibrium where banks use all of their collateral such that $l_{mt} = rrD_t$, the resource constraint of the commercial bank (4a) implies that

(14b)　$L_t = D_t + FK_t$, all $t$.

**5. Semi-Log linear consumer's preferences**

In order to analytically trace better some of the equilibrium characteristics in our model economy, we utilize the case where the consumers' preferences are semi-log linear, that is, take the form

(15)　　$u(c_t, c_{t+1}) = \log c_t + \boldsymbol{b} c_{t+1}$.

In this case the MRS is $\dfrac{1}{\boldsymbol{b}c_t}$. Individuals with these preferences are *risk neutral*. For simplicity and without loss of generality we further assume that the number of banks $I = 1$.

We begin the derivation of the equilibrium by solving for both types money demands. Given $i_{\mathrm{mt}}$, $R_{\mathrm{dt}}$, $R_{\mathrm{Lt}}$ and $\dfrac{p_{t+1}}{p_t}$, we can utilize (11b) to solve for $\dfrac{m_{1t}}{p_t}$ and get

(16a)    $\dfrac{m_{1t}}{p_t} = \dfrac{1}{2\boldsymbol{y}_m}\left[\dfrac{p_t}{p_{t+1}}\dfrac{1}{R_{dt}} - 1\right] = \dfrac{1}{2\boldsymbol{y}_m}\left[\dfrac{1}{(1-(1-\boldsymbol{q})q_{t+1})(1+i_{dt})} - 1\right]$, all $t$.

And from (10d) we get

(16b)    $\dfrac{m_{2t}}{p_t} = \dfrac{1}{2\boldsymbol{y}_m}\left[\dfrac{p_t}{p_{t+1}}\dfrac{1}{R_{Lt}} - 1\right] = \dfrac{1}{2\boldsymbol{y}_m}\left[\dfrac{1}{\boldsymbol{l}(k_t)(1+i_{Lt})} - 1\right]$, all $t$.

Note that these money demands of both types depend on the expected *nominal* interest rates (see the definitions of $R_{\mathrm{dt}}$ and $R_{\mathrm{Lt}}$) and not directly on the inflation. Furthermore, the demand for the real money balances of individuals of type 1 (the depositors) is positive iff the expected gross return on deposit $(1-(1-\boldsymbol{q})q_{t+1})(1+i_{dt}) < 1$. And the individuals of type 2 demand for real money balances is positive iff the expected gross interest rate on loan $\boldsymbol{l}(1+i_{Lt}) < 1$.

Next we utilize (3a) and (11a) to get the individual's supply of bank deposits

(16c)    $\dfrac{d_t}{p_t} = w_1 - \dfrac{1}{\boldsymbol{b}_1 R_{dt}} - (1+\boldsymbol{y}_{1t})\dfrac{m_{1t}}{p_t}$,

where the money demand in (16c) is solved by (16a).

Next we solve for the investor's demand for the capital stock, we get from the definitions of the functions $f(k_t)$ and (10b)

$$(16d) \quad k_t = (Aa)^{\frac{1}{1-a}} \frac{1}{(\frac{1+i_{Lt}}{p_{t+1}/p_t})^{\frac{1}{1-a}}}, \quad \text{all } t.$$

With this solution we use (2) to solve for the return on the physical investment

$$(16e) \quad f(k_t) = A(Aa)^{\frac{a}{1-a}} \frac{1}{(\frac{1+i_{Lt}}{p_{t+1}/p_t})^{\frac{a}{1-a}}}, \quad \text{all } t.$$

We can now use (3b), (10a) and (10b) to get the investor's demand for bank loans as follows

$$(16f) \quad \frac{l_t}{p_t} = \begin{cases} -w_2 + \dfrac{1}{b_2 R_{Lt}} + (1 + y_{2t})\dfrac{m_{2t}}{p_t} + k_t & \text{if } j_{1t} = 0 \\ tw_2 & \text{otherwise} \end{cases}$$

And finally equating the $R_{Lt+1}$ to the expected marginal productivity of capital, as is required from (10b) yields

$$(16g) \quad 1a\frac{f(k_t)}{k_t} = R_{Lt}$$

## 6. Interaction of monetary policy and financial stability

In this section we derive explicitly the interaction between monetary policy and financial stability policy in achieving the CB goals. To that end we examine two shocks: first, a negative shock to the return on the physical investment, which is translated in our model to a shock to inflation, to which the CB reacts by adjusting the KPR while overlooking the effects on financial stability. Second, a negative shock to $?(k_t)$ which is interpreted as a shock to financial stability to which the CB reacts by adjusting the capital requirement ?, while overlooking the effects on inflation.

We conduct two complemented types of analyses: an analytical one and one in which we simulate our model economy. In the former we use the solutions described in equations (16) and the first-order conditions to analytically study the effects of the aforementioned shocks on our economy. In the latter we simulated our model, and use it to derive the effects of the shocks on the economy. We turn to the simulations since there are non-linearities in the model and thereby the analytical analysis is often impossible to implement or produces ambiguous results. The simulations enable us to identify the conditions under which certain desirable effects exist.

**6.a. Effects of the aforementioned shocks on inflation and aggregate risk absence the CB reaction**

For these effects we simulate our model economy. For the sake of tractability, and without loss of generality we look for an equilibrium in the simulations where only individuals of type 1 (the depositors) hold real money balances while type 2 (the investors) do not.

The values of the parameters and the state variables we use in the simulations are presented in Table 1. The *KPR* $i_m$ is chosen to have the inflation rate be on target. In the range of values specified in Table 1 the following relationships came out of the simulations: (i) a positive relationship between the parameter *A* (in (2)) and the expected inflation (Figure 2); (ii) a negative relationship between the CB interest rate $i_{mt}$ and the expected inflation (Figure 3); (iii) a negative and a positive relationship between *?* and $k_t$ and $?(k_t)$, respectively (Figure 4).

**Table 1:**

**The parameter's values used in the simulations**

| Parameter | Value | Parameter | Value |
|:---:|:---:|:---:|:---:|
| $a$ | 0.20 | $t$ | 0.4 |
| $A$ | 5.95-6 | $K_{min}$ | 1.7 |
| *Perceived ?* | 0.90 | $FK_0$ | * |
| $\beta$ | 0.975 | $\dfrac{m_0}{p_0}$ | * |
| $W_1$ | 1.2 | $\dfrac{d_0}{p_0}$ | * |
| $W_2$ | 1.75 | $\dfrac{L_{m0}}{p_0}$ | 0.01 |
| $y_m$ | 0.15 | $p_0$ | Inflation target |
| $q$ | 0.60 | $SR_0$ | 0.1 |
| $?$ | 0.9-1 | $rr$ | 0.2 |
| $N$ | 1 | $?$ | 0.06-0.079 |
| $I$ | 1 | $i_{mt}$ | 0.06-0.1 |

* indicates that the initial value (in period $t$-1) was taken to equal period $t$ value.
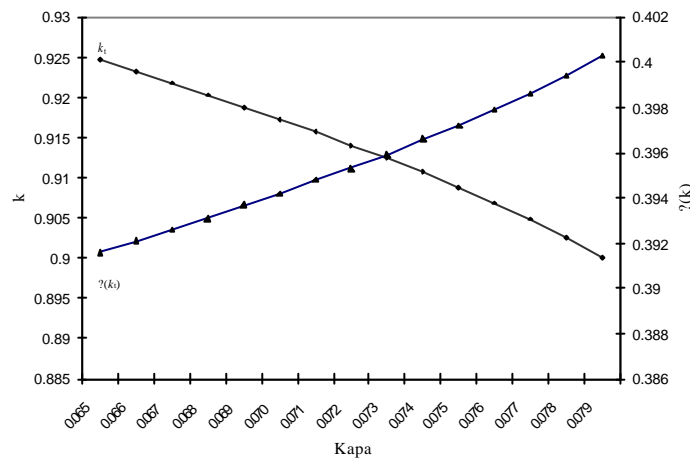
**Figure 2:**

**The effect of a change in the parameter $A$ (see (2)) on the inflation**
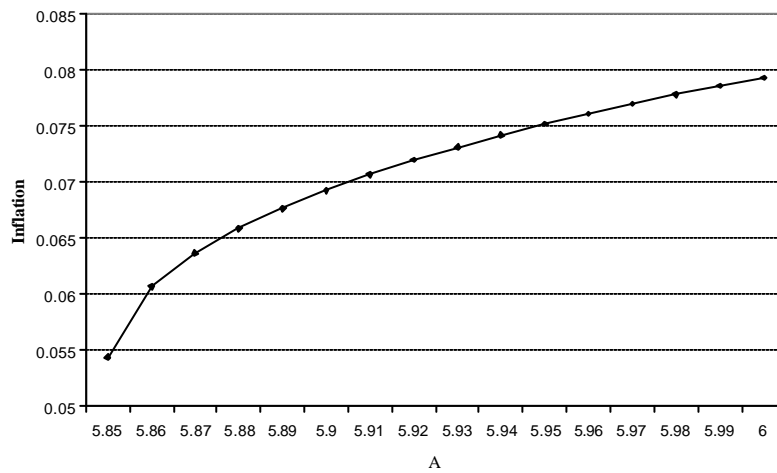
**Figure 3:**

**The effect of a change in $i_m$ on the inflation**
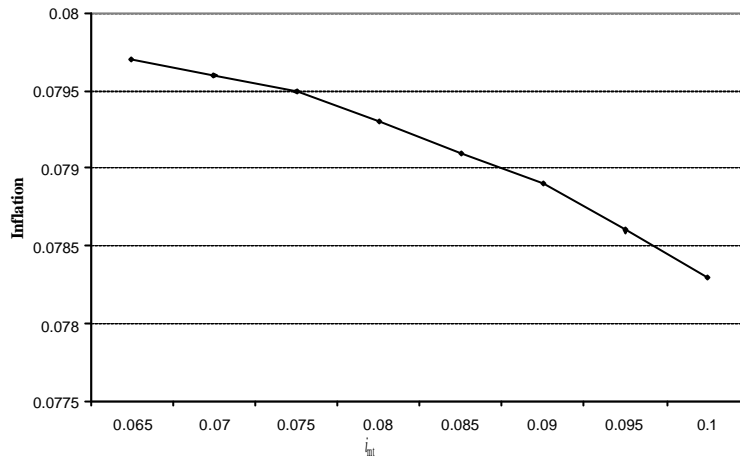


**Figure 4:**

**The effects of a change in *?* on $k_t$ and on *?*($k_t$)**



Finally in this section we identify the condition under which the CB monetary rate, $i_{mt}$ should be raised (lowered) in order for the expected inflation to be lowered (raised) to reach its target.

***Result 3****. For the reduction (increase) in the CB monetary policy rate to generate an increase (decrease) in the expected inflation, the following condition has to be satisfied*

(17) $\qquad -\dfrac{\partial \log(k_t)}{\partial \log(1+i_{Lt})} > \dfrac{1}{1-a}$ .

Namely, for this condition to be satisfied, the interest rate elasticity of the demand for $k_t$ needs be relatively large. We note that condition (17) can also be expressed in terms of the elasticity of the real investment with respect to the *real* interest rate on loans in which case condition (17) is equivalent to[37]

(17a)   $-\dfrac{\partial \log(k_t)}{\partial \log(r_{Lt})} > \dfrac{1}{1-a}\dfrac{r_{Lt}}{1+r_{Lt}}$, where $1+r_{Lt} \equiv \dfrac{1+i_{Lt}}{p_{t+1}/p_t}$

### 6.b. A negative shock to the return on the real investment

Suppose a persisting[38] negative shock to the return on the physical investment (a decrease of the parameter $A$ in (2)) hit the economy in period $t$. It can be verified from (11c) that this shock may affect the expected inflation. Therefore in reaction, the CB adjusts its KPR in order to maintain the inflation expectations at its target.

We can derive analytically the conditions under which, in the absence of monetary policy reaction, a negative shock to $A$ lowers expected inflation and pushes downward the demand for $k_t$ thus yielding a lower $i_{Lt}$. However, for our purpose it is sufficient to have these results materialized in the simulations following the shock as indeed they do (see Figure 1 and Table 2).

Following the fall in the inflation expectations and assuming condition (17) holds, the CB lowers its KPR in order to achieve the inflation target. The effectiveness of the monetary policy is derived by comparing the equilibrium following the CB reaction relative to an equilibrium that would have been realized in the absence of policy reaction. The next result refers to this latter comparison.

***Result 4.*** *Following the negative shock to the return on the physical investment, which drives the inflation below its target, the CB lowers its $i_{mt}$ to bring back inflation to its*

---

[37] With the real interest rate on loans of 5% and a=0.32 we have that the elasticity of the demand for $k_t$ with respect to the real rate should be greater than 0.07 which is consistent with empirical findings.

[38] Persistence in our model environment means during the whole period when the individual is young.

*target. As a result the lending rate $i_{Lt}$ decreases, while the return on deposits $i_{dt}$ rises.*

*Given that the perceived ? and $\mathbf{q}$ remain constant, then the effectiveness of the*

*monetary policy transmission mechanism is partially worn out since. the expected*

*return on deposits $(1-(1-\mathbf{q})q_{t+1})i_{dt}$ increases. (See the simulation results in Table 2).*

The lower effectiveness of the monetary policy is reflected, for example, in a fall in the demand for money of type 1 individuals (see equation 16a), when the CB lowers its $i_{mt}$ and the expected return on deposits $(1-(1-?)q_{t+1})i_{dt}$ increases. The reason for obtaining this somewhat counter-intuitive result in our model is due to the binding constraint of the collateral needed for receiving CB monetary loans and the assumption of zero excess reserves held by banks[39].

Next we examine the consequences of the CB policy reaction to the aforementioned shock on the financial stability.

***Result 5.*** *Suppose condition (17) holds and following the shock, the CB lowers $i_{mt}$ to maintain inflation expectations at its pre-shock rate. Then the total defaulting loans $(1-?(k_t))l_t$ increases as well as the expected conditional profits $E_t \Pi_{t+1}^{1-q}$. According to equation (8a) the total net effect of these two determines the effect of the shock on $q_{t+1}$. In the simulations we get that the defaulting loans increases by more than the expected profits, thus raising $q_{t+1}$. Finally, there is an increase in the monetary loans along a decrease in $i_{mt}$. So the change in the product $i_m L_m$ (which determines the change in SR) depends on the interest rate elasticity of Lm. We get in our simulation a small reduction in the SR. Hence both financial stability indicators are deteriorated. (See table 2).*

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[39] Note that if the individuals' deposits are the main source that allows banks to extend its supply of loans, then a persisting change in $i_{mt}$ that gives rise to a change in $L_t$ must be accompanied by a similar change in the deposits $D_t$, which implies that $i_{dt}$ and $i_{Lt}$ must change in *opposite* directions.

**Table 2:**

**The simulation results following a persisting shock to the return on the real investment**

| Endogenous variables | Values prior to the shock | Values after the shock but prior to the monetary policy reaction | Values following the monetary policy reaction |
|---|---|---|---|
| A | 6 | 5.99 | 5.99 |
| $i_{mt}$ | 0.1 | 0.1 | 0.075 |
| $p_t$ | 0.0811 | 0.0804 | 0.0810 |
| $h$ | -4.5 | -4.5 | -4.5 |
| $\dfrac{l_t}{p_t}$ | 0.0511 | 0.0490 | 0.0569 |
| $\dfrac{d_t}{p_t}$ | 0.0475 | 0.0456 | 0.0529 |
| $k_t$ | 0.9159 | 0.9139 | 0.9183 |
| $\dfrac{m_t^1}{p_t}$ | 0.0327 | 0.0346 | 0.0287 |
| $\dfrac{L_{mt}}{p_t}$ | 0.0095 | 0.0091 | 0.0106 |
| $j_{3t}$ | 0.0043 | 0.0037 | 0.0255 |
| $i_{dt}$ | 0.0764 | 0.0758 | 0.0777 |
| $i_{Lt}$ | 0.3919 | 0.3910 | 0.3864 |
| $f_{kt}$ | 1.2874 | 1.2875 | 1.2825 |
| $E_t\Pi_{t+1}^{1-q} q_{t+1}$ | 0.0034 | 0.0033 | 0.0038 |
| $(1-\boldsymbol{I}(k_t))\dfrac{L_t}{p_t}$ | 0.0307 | 0.0295 | 0.0343 |
| $SR_t$ | 0.0934 | 0.0935 | 0.0933 |

It should be noted that these results are sensitive to the range of values (Table 1) we used in the simulations. However, for our purpose it is enough to show an example in our model that produces the trade-off between price stability and financial stability goals. Indeed we get that once the monetary authority takes measures to

achieve the inflation target, it may worsen the financial stability stance as indeed is reflected in the higher $q_{t+1}$ and the lower $SR_t$ (see table 2).

### 6.c. A negative shock to $?(k_t)$

In this section we examine the effects of a negative shock to $?(k_t)$ (a decrease in the parameter $?$ in the definition of $?(k_t)$) which is interpreted as a shock to credit risk. We further assume that the individuals in the economy are not aware of the reduction in $?(k_t)$, that is, the perceived $?$ remains unchanged. However, the CB identify the rise in the credit risk and thus responds by raising the capital requirements, $?$, to fully offset the decrease in $?(k_t)$. (Recall that the CB knows the true relationship $?(k_t)$). The following results summarize the effects of the shock and the CB reaction to it.

***Result 6***. *Assume that constraint (5d) is not binding and there is a negative shock to $?(k_t)$. In reaction, the CB increases the minimum capital requirement $?$ just enough to increase $i_{Lt}$, such that the demand for investment $k_t$ falls and $?(k_t)$ increases back to its pre-shock level. If condition (17) is satisfied, the inflation expectations fall below the target (assumed to be the pre-shock inflation rate). According to our simulations, indeed the inflation expectations falls, the expected profits, $E_t \Pi_{t+1}^{1-q}$, decrease by less then do the defaulting loans, and thus $q_{t+1}$ gets smaller compared with its pre-shock value. In this case the decrease in the monetary loans together with the constant $i_m$ operate to reduce the SR, but the fall in inflation increases the real value of last period SR. Hence the net effect depends on the amount of SR accumulated in the past. In our example last period SR is large enough to dominate the effect of the fall in the monetary loans, such that the SR increases.* (See table 3).

**Table 3:**
**The simulation results following a persisting**
**negative shock to ?($k_t$)**

| Endogenous variables | Values prior to the shock | Values following the shock and the policy reaction |
|---|---|---|
| ? | 0.95 | 0.90 |
| ? | 0.07 | 0.0755 |
| Perceived ? | 0.90 | 0.90 |
| $k_t$ | 0.9159 | 0.9070 |
| ?($k_t$) | 0.3980 | 0.3979 |
| $i_{mt}$ | 0.1 | 0.1 |
| $p_t$ | 0.0811 | 0.0749 |
| $\boldsymbol{h}$ | -4.5 | -4.5 |
| $\dfrac{l_t}{p_t}$ | 0.0511 | 0.0353 |
| $\dfrac{d_t}{p_t}$ | 0.0475 | 0.0326 |
| $\dfrac{m_t^1}{p_t}$ | 0.0327 | 0.0485 |
| $\dfrac{L_{mt}}{p_t}$ | 0.0095 | 0.0065 |
| $\boldsymbol{j}_{3t}$ | 0.0043 | 0.0008 |
| $i_{dt}$ | 0.0764 | 0.0714 |
| $i_{Lt}$ | 0.3919 | 0.3946 |
| $f_{kt}$ | 1.2874 | 1.2975 |
| $\dfrac{q_{t+1}}{E_t\Pi_{t+1}^{1-q}}$ | 0.0034 | 0.0026 |
| $(1-\boldsymbol{l}(k_t))\dfrac{L_t}{p_t}$ | 0.0307 | 0.0213 |
| $SR_t$ | 0.0934 | 0.0937 |

Note that in this case the financial stability policy is successful in enhancing

the financial stability stance after the hit of the negative shock, as is reflected in the

improvement in both financial stability indicators.

# 7. The risk-management (leverage) constraint and the monetary policy transmission mechanism

Finally we examine the effect of the risk-management constraint (5d) on the effectiveness of the monetary policy in bringing the inflation back to its pre-shock level. For that we change the endowment of type 2 individuals such that constraint (5d) is binding. Assume further that $K_{min}$ is adjusted too so that the individuals (the investors) can get loans to finance the investment in the real channel.

**Result 7**. *Suppose there is a negative shock to the return on the physical investment such that A in (2) decreases. As a consequence the inflation expectations fall. Assume further that condition (17) is satisfied and that constraint (5d) is binding, i.e.*

$$\frac{l_t}{p_t} = w_2 t$$ *(see (16f). Lowering $i_{mt}$ to bring the inflation back to its pre-shock level will have no effect on $i_{Lt}$ (the supply of loans does not depend on the $i_{Lt}$) and thus will have neither effect on $k_t$ nor on the expected inflation.*

## 7. Concluding Remarks

We develop in the paper an overlapping-generation monetary model in which there exists interrelations and reciprocity between the implementation of monetary policy to achieve inflation target and of macro-prudential policy to maintain and safeguard financial stability. Policy considerations that are relevant for one policy appear to have impact and to influence the considerations of the other to the extent that *coordination* is needed to avoid (possibly) substantial loss in one of the policy goals.

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