# Banking panics and deflation in dynamic general equilibrium

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**Abstract**

Typically banking panics have been associated with deflation and declines in economic activity in the monetary history of the US and other countries. This paper develops a dynamic framework to study the interaction between banking and monetary policy. One result is the presence of multiple equilibria: banking panics and deflation arise at the same time and endogenously as equilibrium outcomes. Deposit contracts are written in nominal terms, so if prices fall relative to what was anticipated at the time the deposit contract was signed, then the real value of banks' existing obligations increases. So banks default, a banking panic precipitates and economic activity declines. If banks default on their deposits the demand for cash in the economy increases, because financial intermediation provided by banks disappears. The price level drops thereby leading banks to default. Friedman and Schwartz hypothesized that if the monetary authority had followed an alternative monetary policy during the early 1930s, aimed at keeping prices constant, banks would have been prevented from failing and output from falling, thus reducing the extent of the cycle. In the context of this model the Friedman-Schwartz hypothesis is correct. In this framework a mechanism like deposit insurance, when coupled with strict regulatory arrangements, achieves the same goal as the monetary policy. Absent strict regulatory arrangements however, deposit insurance amplifies business cycle fluctuations by inducing moral hazard.

JEL: E53, E58, G21, N12. Keywords: banking panics, deposit insurance .

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# 1 Introduction

This paper is motivated by the empirical observation that banking panics have been associated with deflation and declines in economic activity in the monetary history of the US and other countries. The paper develops a model in which deflation, banking panics and decline in economic activity all arise due to self fulfilling expectations. It contributes to the literature on banking and monetary policy by evaluating the Friedman and Schwartz hypothesis that a more active monetary policy during the early 1930s would have prevented deflation and, by easing banks' difficulties, it would have resulted in a milder cycle. This paper also evaluates the effectiveness of deposit insurance in preventing panics and deflation. Findings are that the Friedman and Schwartz hypothesis is true in the model: if a monetary authority commits to a policy of keeping prices constant, then in equilibrium prices do not fall and banking panics do not occur; deposit insurance can prevent banking panics. However deposit insurance may generate larger output fluctuations than the monetary policy does because it induces moral hazard.

Evidence from Sprague [11] shows that the banking panics of 1873, 1884 and 1907 in the United States were all accompanied by a fall in the price level: typically the decline in prices of agricultural goods was more relevant than others, because of the extent to which it affected the value of banks' assets. Friedman and Schwartz [9] in their "Monetary History of the United States" report that between 1865 and 1879 wholesale prices fell continuously at a rate approaching 6.5% a year, with a sharper decline between 1873 and 1879 of over 30% (p.30,32,42) when a banking panic occurred; between 1882 and 1885 they fell by over 20% with the panic starting in 1884 (p.94); between 1892 and 1894 they fell by roughly 15% with bank runs precipitating in 1893 (p.94,108); the banking panic of October 1907 was associated with a fall in prices that reached a monthly rate of 5% (p.156).

The decline in real activity was also substantial: during the panic of 1873, loans by national banks fell on average by 9% and during the panic of 1907 they fell on average by 2% (Sprague, 1910, p.305-310). For the banking panics that occurred during the Great Depression Friedman and Schwartz [9] offer a detailed description of the extent of the fall in prices and economic activity: prices fell by 36% and industrial production by roughly 50% over the course of 1929-1933 (p.303). During the same time frame banking panics were frequent: the first panic occurred in October 1930 and deposits kept falling until January 1931,the second panic lasted from March 1931 through August 1931 and the final wave of panics precipitated in January 1933 ending with the Banking Holiday in March 1933 (Friedman and Schwartz, [9], p.308-328).

More recently, during Japan's Lost Decade prices fell considerably (by 1.5% every year since mid 1990s until 2002) and real activity grew on average by only 1% every year during the period 1991-2002 (Baba et al., [1]): the existence of a deposit insurance agency prevented bank runs but banking difficulties and widespread banking failures were well known.

Research on banking panics has been very active in the last twenty years, and the available literature is very substantial. Numerous authors have argued that banking panics arise as multiple equilibria phenomena and lead to a decline in economic activity. Mostly they build on the Diamond and Dybvig [7] framework where banking panics are the result of a coordination failure among depositors, when they fear that the bank may be insolvent. Here I take the view of Calomiris and Gorton [4] who reject the validity of the Diamond and Dybvig [7] theory of banking panics based on U.S. data during the National Banking Era [1].

This paper provides a model of banking panics where there is a stationary equilibrium with banking panics and deflation arising endogenously due to self fulfilling expectations. When banking panics occur economic activity is lower than it is when there are no panics, and the public changes the composition of their portfolios switching from deposits to cash. With deposits falling also banks investment into productive projects decreases.

The economic mechanism that drives banking panics when prices are falling works through a mismatch in banks balance sheets between the value of banks assets and the value of banks liabilities. Banks can only offer nominal contracts to depositors. Therefore deposits, that are liabilities to banks, are at book value in their balance sheets: they are indexed to the price level of the time when the liability originated. Banks assets, on the other hand, are at market value because they are productive projects that banks invested in: they are indexed to the current price level. If prices unexpectedly fall then the real value of existing nominal obligations increases, whereas the real value of assets is unchanged, leading banks to be insolvent. Banks fail and depositors want to reduce deposit and increase cash holdings

[1] Calomiris and Gorton [4] find that a theory of banking panics based on random withdrawals as portrayed in Diamond and Dybvig [7] is inconsistent with the U.S. experience because the unusually large seasonal shocks it requires for the panic to start is not observed in U.S. banking panics' history.

in their portfolios: hence a banking panic occurs.

The economic mechanism that drives deflation when there is a banking panic works through a decrease in the financial intermediation provided by banks when they fail. In the model banks play two roles: they finance productive projects and they issue liabilities that can be used as a means of payment. When there is a banking panic and banks fail, the liabilities that they issued are no longer a viable means of payment: financial intermediation provided by banks disappears and the only means of payment available to households in order to complete transactions, is cash.

Therefore during a banking panic households demand for cash increases and as a consequence prices fall. Economic activity then falls because banks stop investing in productive projects no longer having funds available in the form of deposits, since households are drifting away from deposits and demanding cash. I therefore capture the main aspects of the banking panics that occurred before the onset of Federal Deposit Insurance in 1934: they took place in an environment where prices were falling, aggregate demand for liquidity increased and production fell.

Friedman and Schwartz [9] describe the contraction of the early '30s as a testimonial to the importance of monetary forces and to the role of monetary policy as a potent instrument for promoting economic stability. Their argument is based on the observation that the increased demand for liquidity in the economy was not matched by an increase in the stock of money. With the stock of money declining, prices started to fall and banks were forced to liquidate their assets to face the public's demand for currency, which further reduced the value of their portfolios forcing them into insolvency. Friedman and Schwartz hypothesize that had the Federal Reserve System adopted an expansionary monetary policy, the decline in the stock of money could have been prevented and banking difficulties appreciably eased. With no decline in the stock of money, prices would not have dropped by over one-third in the course of four years and the economic contraction might have been far less severe. In my model the Friedman and Schwartz hypothesis is true: a monetary policy aiming at keeping prices constant would prevent deflation and, by easing banks difficulties, would also prevent banking panics and result in a milder cycle.

Many researchers [2] believe that the introduction of deposit insurance at a federal level in the U.S. was the result of the failure of monetary policy to avoid the collapse of the banking system during the early 1930s. Among these authors, Friedman and Schwartz emphasize that the introduction of a federal deposit insurance scheme greatly reduced the need to rely on a response from the monetary authority to a change in the ratio of deposits to currency in households' portfolios, so that a banking panic, once begun, would not be permitted to cumulate.

This paper evaluates the effectiveness of deposit insurance in preventing panics: although they are prevented the insurance of banks deposits induces moral hazard on the side of banks. Having their liabilities always bailed out in a bad state of the world, banks choose to invest in more volatile projects that pay a higher return in the good state of the world. Therefore an economy with deposit insurance

[2] Among many, Friedman and Schwartz (1963), Calomiris and White (1994), and White (1998)

features larger aggregate output volatility than an economy with a monetary authority adopting an active monetary policy as suggested by Friedman and Schwartz. In this sense I argue that deposit insurance induces larger business cycle fluctuations.

## 2 Related literature

This paper is largely related to the literature, started with Diamond and Dybvig (1983), that investigates the self-fulfilling feature of banking panics. In particular, Chari (1989) studies a version of Diamond and Dybvig's model with bank specific risk and shows that there is a mechanism that can eliminate banking panics, conditional on the availability of a reserve technology and the existence of an interbank lending market. Chari and Jagannathan (1988) provide an information theoretic rationale for bank runs, building on Diamond and Dybvig's framework: banking panics in their environment occur because of a coordination failure among depositors who are uninformed about the state of the world affecting banks' assets' productivity, and observe a fraction of depositors withdrawing their deposits from the bank. Fearing that such withdrawals are based on information about the state of the world, uninformed depositors run on the bank. Ennis and Keister (2007) argue that in a Diamond and Dybvig framework suspension of convertibility is not a time consistent mechanism for banks: they show that waves of bank runs may occur as equilibrium outcomes of a game where a bank that promised to suspend convertibility of deposits, if facing a run finds it optimal not to suspend payments.

# 3 Model

The economy is modeled as a dynamic game between a continuum [0,1] of identical households who are anonymous and a continuum [0,1] of identical banks. Banks are not anonymous: the history of their past actions is publicly observable. Time is discrete and infinite.

## 3.1 Households

Households are modeled similarly to the Lucas-Stokey (1987) cash credit economy: their preferences are defined over two type of goods, cash goods ($c_1$) and credit goods ($c_2$) and are represented by a utility function $U : R_+^2 \rightarrow R_+$, such that $U_i > 0, i = 1, 2$ and $U_{ii} < 0, i = 1, 2$. In every period households receive an endowment $y$ and they have access to a technology that allows them to transform $y$ into either cash goods or credit goods. Households are also endowed with a non perishable good, namely money, that they can use to transfer wealth intertemporally. They can also transfer wealth from one period to another by buying another asset from banks: deposits.

Each household is divided into a worker and a shopper: at the beginning of every period the asset market opens and the worker and the shopper take their portfolio decisions together, as a household. So they decide how much money to carry into the period and how many deposits to purchase. Then the goods' market opens and the worker and the shopper are separated from each other: the shopper takes the money in his portfolio and goes to other households' location to purchase consumption goods. The shopper is constrained to purchase cash goods paying right away using money, whereas he can purchase credit goods for current consumption paying for them with the liabilities issued by banks when deposits were made. Such payments are settled in the next period using the money that the household will have at the beginning of the next period using also the return on deposits.

At the same time as the shopper purchases consumption goods the worker stays at home and produces cash or credit goods using the endowment $y$.

At the end of the period the shopper returns home and consumption takes place. Unspent cash is brought into tomorrow together with the gross return on the deposits made in the previous period and the income from the sales of the endowment.

## 3.2 Banks

The financial and productive sectors in this economy are consolidated and represented by banks. This is meant to capture banks' role as intermediaries between who supplies funds and who demands funds in the economy and I model that as banks having access to productive projects and carrying them out. Therefore banks should be thought of as banks/firms.

They have a fixed endowment $L$ in every period, and they have access to a productive technology $f : R_+^2 \rightarrow R_+, f_i > 0, i = 1, 2$. The inputs to the productive technology are an investment of cash goods and the fixed factor $L$.

Banks behave competitively. They offer deposit contracts to households and carry out production: the type of contract they can offer is such that the rate of return on deposits is fixed in nominal terms[3]. The deposit contract between households and banks allows households to hold a diversified portfolio of deposits [4].

Besides being intermediaries between lenders and borrowers, in this economy banks also play a role in the payment system: they issue liabilities, up to the face value of the gross return on deposits, that can be used as a means of payment. Therefore households who decided to deposit part of their assets in a bank, are going to be able to make payments up to the nominal value of the gross return on their deposits using banks' issued liabilities. The role of banks as providers of financial intermediation is crucial for the results.

### 3.3 Timing of players' moves

At the beginning of every period the outcome $\theta$ of a random variable (sunspot), $\Theta \in \{0, 1\}$ is publicly observed. $\Theta$ follows a stochastic process such that:

$$\begin{cases} \theta = 0 & \text{w.p.} \quad \pi \\ \theta = 1 & \text{w.p.} \quad (1-\pi) \end{cases}$$

At time $t$, after the realization of the sunspot, $\theta_t$, banks simultaneously choose whether to default or not: if they don't default they sell the output from the productive technology on the goods' market, they pay households back for the deposits they made and the interest rate that it was promised to them as a return on de-

[3]This restriction is meant to capture one of the key features of deposit contracts in reality.

[4]Results are unchanged however if the deposit contract is one-to-one: each household can choose which bank it wants to deposit at, but only one bank. So the household cannot diversify his portfolio among different banks, if he wanted to. Also, each bank can take the deposits only of a single household.

posits. If banks choose to default then depositors are not payed back, not only for the promised return but also for the actual deposits previously made. So households who deposited lose not only the return on their investment but also the assets they invested when banks default. In other words the gross interest rate on deposits when banks default is zero. The default decision of bank $j$ at time $t$ is denoted $d_t(j)$. Let $d_t = (d_t(j))_{j\in[0,1]}$ denote the vector of all banks' default decisions at time $t$.

After banks have decided whether to default or not, households move: they choose their consumption allocation $(c_{1t}, c_{2t})$ and their asset holdings $(M_t, D_t)$.

Then banks move again: using the deposits they sold to households $(D_t^b)$ they decide how much to invest in the productive technology[5]. At the end of the period, if banks did not default, then depositors get the return promised on the deposits made in the previous period $(R_{t-1}D_{t-1})$.

The timing of players' moves is represented in Figure 1:

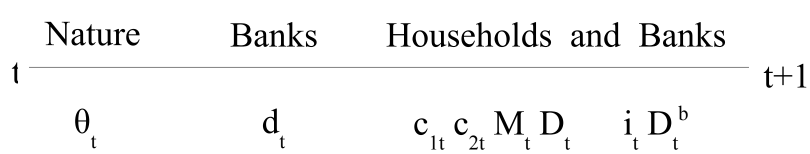


Figure 1

So for every period a stage game can be defined, where Nature first draws a

[5] One factor of production is an investment of cash good, so banks need some money to be able to purchase it and carry out production

realization of $\Theta$, then banks simultaneously take their default decision. After having observed banks default decision, households choose consumption allocation and asset holdings (in particular they choose whether to deposit or not). Then banks move again and choose how much to invest in the productive technology, and at the very end of the period households are payed back for the deposits they made in the previous period if banks did not default on their deposits at the beginning of the period.

The stage game is represented in extensive form in Figure 2, where after Nature has drawn a realization of $\Theta$, bank $j$ chooses whether to default or not without knowing what other banks $-j$ chose, and then households choose consumption allocation and asset holdings and banks choose how much to invest in the productive technology. In particular households choose whether to deposit a strictly positive amount of assets or not. For analytical tractability it is assumed that default is an absorbing state in the following sense: if a measure one of banks default ($\int_0^1 d_t(j)dj = 1$) then the banking system shuts down forever and the only source of output in the economy is households' endowment.

## 3.4 Players' actions and strategies

Let the relevant history of the game at the beginning of time $t$ be anonymous with respect to households, since they are anonymous players in the game, and be denoted:

$$h^{t-1} = (d_s(j)\mid_{j\in[0,1]}, \theta_s, p_s, R_s, A_s, c_{1s}, c_{2s}, M_s, D_s(j)\mid_{j\in[0,1]} / s \leq t-1)$$

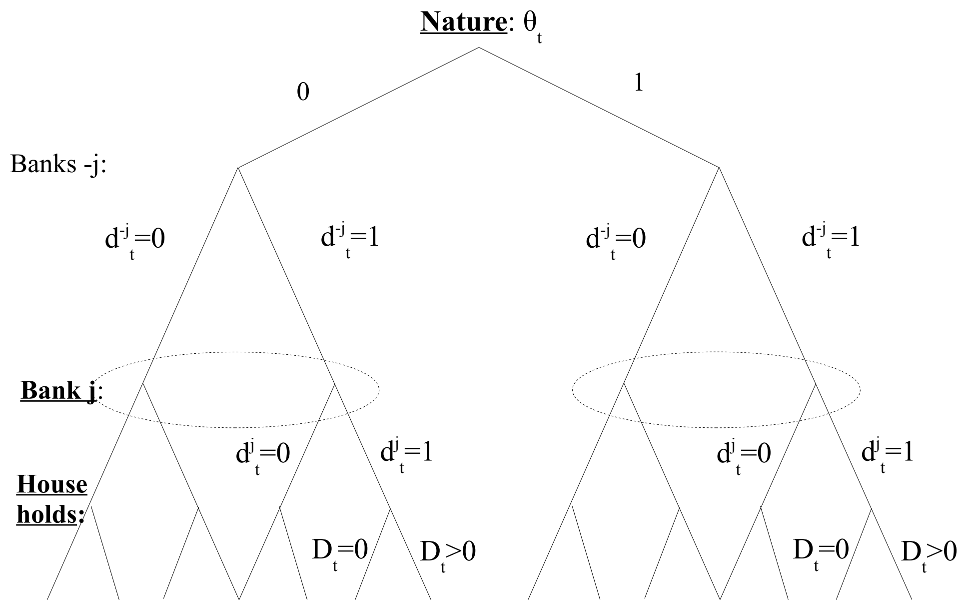


FIGURE 2

that is a list of all the past default decisions by every bank $j \in [0,1]$, sunspot realizations, prices of consumption goods ($p_s$) and deposits ($R_s$), households' assets at the beginning of every period ($A_s$), consumption of cash good ($c_{1s}$), consumption of credit good ($c_{2s}$), cash holdings ($M_s$) and deposits holdings at every bank $j$ ($D_s(j)$).

Let the history of the game at time $t$ after banks' default decisions have been taken be denoted:

$$h_1^t = (h^{t-1}, \theta_t, d_t(j) \mid_{j \in [0,1]})$$

that includes the history at the beginning of period $t$, the current realization of the sunspot ($\theta_t$) and the current default decision of every bank $j$ ($d_t(j)\mid_{j\in[0,1]}$).

Let the set of possible histories at the beginning of time $t$ be denoted $H^t$, with $H^0 = \emptyset$, and the set of possible histories at time $t$ after banks' default decisions have been taken be denoted $H_1^t$ with $H_1^0 = \{\theta_0, d_0(j)\mid_{j\in[0,1]}\}$, so that $h_1^t$ is a typical element of $H_1^t$.

An action for a household is a choice of consumption of cash and credit goods, deposits and cash holdings, and assets to carry into the next period. A strategy is a mapping $\sigma_t^H : H_1^t \to \mathbb{R}_+^5$. When history $h_1^t$ is realized, households' strategy is denoted:

$$\sigma_t^H(h_1^t) = \{(c_{1t}(h_1^t), c_{2t}(h_1^t), D_t(h_1^t), M_t(h_1^t), A_{t+1}(h_1^t)) \in \mathbb{R}_+^5\}$$

and a strategy profile for a household is denoted $\{\sigma_t^H\}_{t=0}^{\infty}$.

Let $\mu_t^H : H_1^{t+1} \to [0,1]$ denote the conditional probability [6] that history $h_1^{t+1} \succ h_1^t$ will be realized if $h_1^t$ is the realized history at time $t$. Then the value of a household when he reaches the information set where he is choosing at time $t$ is:

[6]induced by the distribution of $\Theta$ and players' strategies.

$$
\begin{aligned}
v_t(h_1^t) &= \max_{\{c_{1t},c_{2t},M_t,D_t,A_{t+1}\}} (U(c_{1t},c_{2t}) + \\
&\quad \beta \sum_{h^{t+1}} \mu_t(h_1^{t+1} \mid h_1^t) v_{t+1}(h_1^{t+1}))
\end{aligned} \tag{1}
$$

$$s.t.$$

$$
\begin{aligned}
M_t + D_t &= A_t \\
p_t(H^t)(c_{1t} + \lambda c_{2t}) &\leq M_t \qquad \text{with } \lambda = \int_0^1 d_t(j)dj \\
A_{t+1} &= M_t - p_t(H^t)(c_{1t} + (1-\lambda)c_{2t}) \\
&\quad + p_t(H^t)y_t + (1-\lambda)R_{t-1}(H^{t-1})D_{t-1}
\end{aligned}
$$

where the first constraint is a securities market constraint: the household splits his assets between cash to carry within the period and deposits. The second constraint is a cash in advance constraint: if a measure zero of banks default ($\lambda = 0$) then this constraint says that a subset of consumption goods, cash goods, must be purchased using cash. However if a positive measure of banks default ($\lambda > 0$) then not only cash goods but also a fraction of credit goods proportional to the measure of defaulting banks must be purchased using cash. Therefore if a measure one of banks default ($\lambda = 1$) then both cash goods and credit goods must be purchased using cash. These constraints are crucial: when banks default the financial intermediation they used to provide disappears. While in no default households would purchase credit goods for current consumption but settle their payments only at the beginning of the next period using also the return on deposits previously made, when banks default deposits will not be payed back at the end of the period, therefore there won't be enough resources in the next period to pay for current consumption of credit goods. So also credit goods must be purchased using cash. The last constraint is the law of motion for assets: assets at the beginning of the next period will be given by unspent cash, income from the sales of the endowment and the return on previously made deposits in banks that do not default.

An action for banks at the information set where they first move is the choice to default or not and a strategy is a mapping $\sigma_1^B : H^{t-1} \to \{0, 1\}$. At the second information set where they move, an action for banks is a choice of investment into the productive technology and a choice of deposits to offer households. A strategy is a mapping $\sigma_2^B : H_1^t \to \mathbb{R}_+^2$. When history $h_1^t$ is realized, a strategy for bank $j$ is denoted: $\sigma^B(j)(h_1^t) = (\sigma_1^B(j)(h^{t-1}), \sigma_2^B(j)(h_1^t)) = \{d_t(j)(h^{t-1}), i_t(j)(h_1^t), D_t^b(j)(h_1^t)\}$ and a strategy profile is $(\sigma_t^B(j))_{t=0}^{\infty}$.

Banks' first decision problem is to choose whether to default or not: they default if the value of their liabilities exceeds the value of their assets, they do not default otherwise[7]:

- if $f(i_{t-1}, L) - \frac{R_{t-1} D_{t-1}^b}{p_t} \geq 0$ then banks do not default

[7]This decision problem reflects the assumption that banks are not allowed to borrow against their future profits. In fact if banks stayed in business they would earn a positive expected stream of profits: therefore if expected profits were larger than the current loss, in the presence of a market where banks can borrow against their future stream of profits they would not need to default when the value of their liabilities exceeds the value of their assets. Here this is not allowed: if banks do not have enough assets at time $t$ to pay their obligations at time $t$ then they default.

- if $f(i_{t-1}, L) - \frac{R_{t-1}D^b_{t-1}}{p_t} < 0$ then banks default

The default decision is related to banks being illiquid, rather than insolvent. Banks that default in this environment may well be solvent in the sense that the expected stream of future profits exceeds the current loss. Therefore if they were allowed to borrow inter-temporally against their future assets they might not need to default. However not allowing for such inter-temporal borrowing and lending is meant to capture those banking failures due to illiquidity only. If depositors have claims with banks, that mature at time $t$ but that banks cannot meet at time $t$, then the bank has to fail.

Banks' second decision problem is to choose how many deposits to sell and how much to invest in the productive technology in order to maximize expected profits. Let bank $j$'s payoff from the default decision when history at the beginning of the period is $h^{t-1}$ and the sunspot realization is $\theta_t$ be defined as follows:

$$W^j_t(h^{t-1}, \theta_t) = \begin{cases} f(i_{t-1}, L) - \frac{R_{t-1}D^b_{t-1}}{p_t} & +\delta E_{\theta_{t+1}|\theta_t} \hat{v}^j_{t+1}(h^{t-1}, d_t(j) = 0) \quad \text{if } d_t(j) = 0 \\ \\ f(i_{t-1}, L) & +\delta E_{\theta_{t+1}|\theta_t} \hat{v}^j_{t+1}(h^{t-1}, d_t(j) = 1) \quad \text{if } d_t(j) = 1 \end{cases}$$

with $\delta$ being banks' discount factor, which is assumed to be such that $\delta r < 1$ and with $\hat{v}^j_t(h^t_1)$ being the value of bank $j$ expected profits at time $t$ after history $h^t_1$, defined as follows:

$$\begin{aligned} \hat{v}_t^j(h_1^t) = \max_{\{i_t, D_t^b\}} & \quad E_{\theta_{t+1}|\theta_t} W_{t+1}(h^t, \theta_{t+1}) \\ s.t. & \qquad p_t i_t \leq D_t^b \end{aligned}$$

The constraint to banks' expected profits maximization says that banks can finance investment into productive projects only up to the value of the deposits they sold. This constraint reflects the assumption that $\delta r < 1$, which is the same assumption as in Bernanke and Gertler [2], Bernanke, Gertler and Gilchrist [3], and Carlstrom and Fuerst [6] that captures the idea that banks are borrowing constrained when undertaking investment projects.

## 3.5 Equilibrium

The focus of the paper is on symmetric subgame perfect equilibria, therefore an equilibrium is defined as follows:

**Definition 1** *A symmetric equilibrium is:*

1. *a symmetric strategy profile for households* $\sigma^H = \{\sigma_t^H\}_{t=0}^{\infty}$
2. *a symmetric strategy profile for banks* $\sigma^B = \{\sigma_t^B\}_{t=0}^{\infty}$
3. *pricing functions* $p_t(h_1^t), R_t(h_1^t)$ [8]

[8]Notice that pricing functions are defined over aggregate histories: $\mathbb{H}^t = (h^{t-1}, \theta_t, \int_0^1 d_t(j)dj)$.

*such that for any $t, h_1^t$, households maximize; for any $t, h^t$, banks maximize and prices clear the markets:*

$$c_t^b(h_1^t) + c_{1t}(h_1^t) + c_{2t}(h_1^t) + i_t(h_1^t) = y_t + f(i_{t-1}(h_1^{t-1}), L)$$

$$M_t(h_1^t) + D_t(h_1^t) = \overline{M}_t = \overline{M}$$

where in the resource constraint $c_t^b(h_1^t)$ stands for bank's consumption when history is $h_1^t$, $c_{1t}(h_1^t)$ for households' consumption of cash good, $c_{2t}(h_1^t)$ for households' consumption of credit good, $i_t(h_1^t)$ for the investment in the productive technology, $f(i_{t-1}(h_1^t), L)$ for the output of the technology that is realized at $t$ using inputs from $t-1$. In the money market constraint $M_t(h_1^t)$ stands for the cash that households wants to carry within the period, $D_t(h_1^t)$ for the deposits that household wants to purchase, and $\overline{M}$ for the stock of money supply, which is assumed to be constant. Let $Y_t = y + f(i_t(h_1^t), L)$ denote aggregate resources at time $t+1$ in this economy: that are households' endowment and the output from the productive technology realized at time $t+1$ using the input of investment good from the previous period $t$.

## 4 Equilibrium characterization

This economy has several equilibria. However the focus of the paper is on one equilibrium where fears of a fall in prices drive banks to default and because banks default prices fall. In order to state the first result on the existence of such an

However aggregate histories are functions of $h_1^t = (h^{t-1}, \theta_t, (d_t(j))_{j\in[0,1]})$, in that they are defined over the aggregate default decisions by banks rather than on each bank $j$ default decision. Therefore ultimately pricing functions $p_t$ and $R_t$ are defined over histories $h_1^t$.

equilibrium, it is assumed that:

$$U(c_1, c_2) = \log(c_1) + \log(c_2). \tag{2}$$

$$f(i_t, L) = \begin{cases} ri_t + L & \text{if} \quad i_t > 0, \text{ with } r > 1 \\ 0 & \text{if} \quad i_t = 0 \end{cases} \tag{3}$$

$$1 > \beta r(8\beta^2 r - \beta r - 6) \tag{4}$$

Let $\underline{\pi^*} > 0$ and $\overline{\pi^*} > 0$ be the solutions to the quadratic equation:

$$\pi(1 + \frac{1}{\beta^2 r}) - \beta\pi^2 - 2 + \frac{1}{\beta^2 r} = 0 \tag{5}$$

with $\underline{\pi^*} < \overline{\pi^*}$. Under (4) such $\underline{\pi^*}$ exists [9]. Then define $\widetilde{\pi} = \min(1, 2 - \frac{1}{\beta^2 r})$ and finally let:

- $\underline{\pi} = \underline{\pi^*}$
- $\overline{\pi} = \min(1, \overline{\pi^*}, \widetilde{\pi})$

**Proposition 1** *If assumptions (2)-(4) are satisfied then* $\forall \beta \in (0,1), r > 1$ *there exists* $\pi$ *such that if* $\pi \in (\underline{\pi}, \overline{\pi})$ *then there exists a symmetric equilibrium such that:*

- *if* $\theta_t = 1$ *then* $\lambda = \int_0^1 d_t(j)dj = 1$ *and* $p_t = p^d$
- *if* $\theta_t = 0$ *then* $\lambda = \int_0^1 d_t(j)dj = 0$ *and* $p_t = p^{nd}$
- $p^d < p^{nd}$

[9] Assumption (4) is a sufficient condition for $\pi^{\max} = \max_{\pi \in [0,1]}(5)$ to be such that $\pi^{\max} > 0$.

- $Y_t^d < Y_t^{nd}$

**Proof.**

See Appendix.

■

The intuition behind this result is the following: banks default when they expect low enough prices relative to the ones their nominal liabilities are indexed to, because the real cost of paying depositors back exceeds the real value of their assets. When banks default households can no longer use the liabilities issued by those banks as a means of payment, therefore they demand more cash in order to complete consumption purchases relative to the cash they would carry in an environment with no banking failures. If the amount of consumption goods that households purchase with cash was unchanged with respect to a no default environment, then prices would increase. The reason being excess money relative to the real value of goods that it purchases, since households carry into the period more cash. However the set of goods that are purchased using cash expands in a state of the world where banks default, because certain type of transactions that used to be made with credit, now require a cash payment. This economic mechanism would push prices down if the money held by the public was unchanged relative to a state of the world where no banking failures occur. The reason begin too little cash relative to the real value of goods that is purchases. Therefore prices in equilibrium are going to be determined by a balance between these two economic forces, and if the ratio between the demand for cash and the real value of consumption goods that are purchased using cash is larger in a no default world rather than in default[10], then prices in no default are larger than prices in default. When this happens banking panics and deflation endogenously arise at the same time as equilibrium outcomes. Because households do not deposit then investment into productive technologies will not take place, since banks do not have access to any other sources of funds besides deposits, and aggregate output in the following periods falls.

# 5 The game with a Monetary authority

The goal of this section is to show that in this environment the Friedman and Schwartz hypothesis is correct: if the monetary authority commits to a policy of keeping prices constant by money injections, then banking panics and deflation are no longer an equilibrium outcome. So even when there is a sunspot prices do not fall, the banking system does not collapse and economic activity does not decline.

Let the game be modified so that there is another player, the Monetary Authority who moves after banks have decided whether to default or not. So the relevant history of the game for the Monetary Authority is $h_1^t$.

Let the Monetary Authority adopt the following policy: if a positive measure of banks default then inject cash on the securities market to households in the amount $T_t(h_1^t)$, otherwise it leaves $\overline{M}$ unchanged. The amount of the money injection $T_t(h_1^t)$ is just enough to keep current prices constant with respect to the previous period, and it depends on the measure of banks that defaulted in the current period. If all

[10] which occurs in equilibrium if $\pi \in (\underline{\pi}, \overline{\pi})$.

banks defaulted then $T_t(h_1^t) = p^{nd}y - \overline{M}$ so that the new stock of money supply is $\overline{M}' = p^{nd}y$, if a smaller measure of banks is defaulting then $T_t(h_1^t)$ is going to be smaller, but just enough to keep prices at the stationary non default level $p^{nd}$.

As far as the next proposition is concerned I am going to focus on a one time policy experiment: if monetary policy is active at time $t$ then it can no longer be such $\forall \tau > t$. Then with an active monetary policy when the sunspot hits, it is no longer optimal for banks to default, and the unique pure strategy equilibrium of the game is no default and no panics.

**Proposition 2** *Maintain the same assumptions as in Proposition 1 (Assumptions (2)-(4)). Then in any economy that starts from a time invariant equilibrium allocation before the sunspot hits, if the Monetary Authority promises to inject cash to keep prices constant at no default level when a positive measure of banks default, then no default and no panics is the unique pure strategy equilibrium and economic activity does not decline.*

**Proof.**

See appendix.

■

The result of Proposition 2 is a validation of the Friedman-Schwartz hypothesis: had the Federal Reserve System adopted an expansionary monetary policy during the early 1930s, prices would not have fallen, banking panics would not have arisen to the extent of inducing a collapse in the banking system, and the resulting cycle would have been much milder.

Monetary policy in this environment is very powerful: banking crises arise solely from a fall in prices because banks' liabilities are fixed in nominal terms, therefore they are at book value in banks' balance sheets while assets are at market value. By controlling the stock of money in the economy, the Monetary Authority is able to influence prices, and what is mostly important in this framework is that knowing this is enough for banks not to default. If there is public information about monetary policy aiming at keeping prices constant, then fears of deflation will not drive any banks to fail. Depositors will not panic and economic activity will not decline and no actual cash injection is needed.

## 6 The game with Deposit Insurance

The goal of this section is to show that in this environment a mechanism like deposit insurance, when coupled with strict regulatory arrangements, is able to prevent banking panics and deflation. Absent strict regulatory arrangements however, deposit insurance can prevent banking panics and deflation but it induces larger output fluctuations than a monetary policy similar to the one suggested by Friedman and Schwartz because it induces moral hazard on the side of banks.

Since I am interested in introducing the concept of moral hazard, then the set of productive technologies that banks can invest in is enlarged to include both a safe and a risky technology:

- safe technology

$$f_t = \begin{cases} ri_t + L \text{ if } i > 0 \\ 0 \text{ otherwise} \end{cases}$$

with $r > 1$

- risky technology

$$\hat{f}_t = \begin{cases} \hat{r}i_t + L \text{ if } i > 0 \\ 0 \text{ otherwise} \end{cases}$$

  - with being an aggregate shock with the following probability distribution:

$$\hat{r} = \begin{cases} \overline{r} & \text{w.p. } \alpha \\ \underline{r} & \text{w.p. } 1-\alpha \end{cases}$$

such that $\alpha\bar{r} + (1-\alpha)\underline{r} < r$ so that technology $\hat{f}$ is a mean reducing spread of technology $f$. The distribution of the random variable $\hat{r}$ is assumed to be independent of the distribution of the sunspot $\theta$ and is $i.i.d$ over time. Without loss of generality normalize $\underline{r} = 0$.

Let households and banks design a mechanism like deposit insurance: let them set up a deposit insurer, that seizes banks' assets if they default and pays depositors in the amount they were promised when signing the deposit contract, every time banks fail. Deposit insurance is set up after households' deposit decision and before banks' choice of technology. Similarly to the policy experiment carried out with the monetary policy I will focus on the ability of deposit insurance to stop one panic, following which the mechanism is no longer feasible to establish.

I assume that when the deposit insurer intervenes to bail out depositors, besides seizing banks' assets it takes on banks'liabilities, therefore making it still possible to use the liabilities issued by failed banks as a means of payment. In other words, the deposit insurer guarantees that those liabilities are going to be payed back. I also assume that any resources left over after paying depositors when banks fail, are lump sum transferred back to banks. On the other hand, if seizing banks' assets is not enough to cover payments to depositors, then the deposit insurer levies a lump sum tax on households' endowment to finance the remaining payments to depositors.

Further it is assumed that households can observe the technology that banks invest in, but the deposit insurer cannot.

Define:

- $\phi = \frac{(2-\pi-\frac{1}{r\beta^2})}{2(1-\pi)}$,
- $\Lambda = 1 + \frac{1}{2\beta(1-\pi)+\frac{\beta\pi}{(1-\phi)}} - \frac{r\phi}{\pi}$.

And let

$$\underline{\alpha} = \max\left(\frac{(r-\frac{r}{\pi})\frac{\phi y}{\Lambda}+\frac{L}{1-\delta\pi}}{(\overline{r}-\frac{r}{\pi})\frac{\phi y}{\Lambda}+\frac{L}{1-\delta\pi}}, \frac{r}{\pi(\frac{\Lambda L}{\phi y}+\overline{r})}\right) \tag{6}$$

$$\overline{\alpha} = \left\{\begin{array}{ccc} \alpha\in(0,1) & : & \min\left(\frac{r}{\alpha\pi},(\frac{r\Lambda}{\alpha\pi}-\overline{r})\right)\frac{\phi y}{\Lambda}=L \\ 1 & \text{if} & \min(\frac{r}{\pi},(\frac{r\Lambda}{\pi}-\overline{r}))\frac{\phi y}{\Lambda}>L \\ \underline{\alpha} & \text{if} & \min(\frac{r}{\underline{\alpha}\pi},(\frac{r\Lambda}{\underline{\alpha}\pi}-\overline{r}))\frac{\phi y}{\Lambda}<L \end{array}\right. \tag{7}$$

**Proposition 3** *Maintain the same assumptions as in Proposition 1 (Assumptions (2)-(4)). Then in any economy that starts from a time invariant equilibrium alloca-*

*tion before the sunspot hits,* $\forall y, \overline{r}, L > 0 \ \exists \alpha \in (0,1)$*:*

*if* $\alpha \in (\underline{\alpha}, \overline{\alpha})$ *then any time invariant equilibrium before the sunspot hits is such that:*

1. *without deposit insurance banks invest in the safe technology* $f$*,*

2. *with deposit insurance and with strict regulations (banks have only access to* $f$*) then no default and no panics is the unique pure strategy equilibrium of the continuation game after deposit insurance is established*

3. *with deposit insurance but without strict regulations then the unique pure strategy equilibrium of the continuation game after deposit insurance is established is such that:*

    - *banks invest in* $\widehat{f}$*,*

    - *banks do not default and households do not panic if* $\widehat{r} = \overline{r}$*,*

    - *banks default but households are payed if* $\widehat{r} = \overline{r}$*.*

**Proof.**

See appendix.

■

This result is twofold: on one hand it validates the effectiveness of deposit insurance in preventing banking panics, as it has been the case in U.S banking history since the establishment of the Federal Deposit Insurance Corporation in 1934. On the other hand it highlights the effects that the nature of such an insurance contract has on output. Because the deposit insurer takes on banks' liabilities in a bad state of the world, without affecting bank's profits in a good state of the world, it creates moral hazard on the side of banks. Banks have incentives to invest in more risky assets because they have a higher payoff in case of success of the project they invest in, but do not have to bear any loss in case of failure. Therefore because it induces moral hazard, deposit insurance while preventing banking panics, generates larger output volatility than a monetary policy *à* la Friedman and Schwartz. Because banks invest in the risky technology, in good states of the world aggregate output is high and in bad states of the world it is low: in this sense I argue that deposit insurance amplifies business cycle fluctuations. In fact if banks were not allowed to choose the risky technology, then deposit insurance would achieve the same outcome as the one induced by a monetary policy that aims at keeping prices constant, as proven in the second claim in Proposition 3. Also, the first claim in Proposition 3 guarantees that none of the previous result from Propositions 1-2 changes when banks are allowed to choose between a safe and a risky technology: without deposit insurance banks choose to invest in the safe technology $f$, and when that happens Propositions 1-2 hold.

# 7 Conclusion

This paper is motivated by the empirical observation that banking panics have typically been associated with deflation and declines in economic activity in the monetary history of the U.S. and other countries. Therefore its main contribution is that it develops a framework where these events all arise endogenously as equilibrium outcomes. None of them is taken as exogenously given, they are all the result of self-fulfilling expectations.

Two economic mechanisms that are crucial for this result. The first one is the the presence of nominal contracts between households and banks, that makes an unanticipated fall in the price level affect the real value of existing obligations to the extent that it exceeds the real value of banks' assets, thus forcing banks to default on their liabilities. The second one is the financial intermediation provided by banks: when banks are in business they issue liabilities that are used as a means of payment, so that certain transactions in the economy are carried out without the need of cash. When banks fail however such liabilities are no longer backed up by banks, so they are no longer a viable means of payment and any transaction in the economy has to be carried out using cash. The set of goods that are purchased using cash expands during banking failures, and if the amount of cash households carry in their portfolio doesn't change too much, then prices fall.

Therefore the innovation of this paper is to bring together models with nominal debt and models with cash and credit goods and to show that when these two key features coexist then banking panics and deflation coincide, and they are associated with declines in economic activity.

The paper also carries out two different policy experiments: the first concerns the effectiveness of an active monetary policy similar to the one suggested by Friedman and Schwartz for the early 1930s, in preventing banking panics, deflation and decline in economic activity. The second concerns the effectiveness of a deposit insurance mechanism in attaining the same result. Findings are that both the monetary policy and deposit insurance can prevent banking panics, deposit insurance however, by inducing moral hazard, generates larger output fluctuations.

# A Appendix

## A.1 Proof of Proposition 1:

By construction. Let:

- $d_t(j) = 0$ if $\theta_t = 0$ and if $d_t(j) = 0$ then $D_t(j) > 0$
- $d_t(j) = 1$ if $\theta_t = 1$ and if $d_t(j) = 1$ then $D_\tau(j) = 0, \forall \tau \geq t$

A strategy for bank $j$ is constructed so that if the sunspot hits then banks default, and they don't default otherwise. A strategy for a household is constructed so that if bank $j$ defaults then households will not deposit in bank $j$ forever after. Then before the sunspot hits let us look for a time invariant consumption allocation $(c_1, c_2)$ and asset holdings $(M, D)$ that solve the households' problem, investment into the productive technology and deposits offered by banks $(i, D^b)$ that maximize banks' expected profits, and clear the markets at prices $p, R$. Optimality conditions for the households' problem are:

$$
\begin{aligned}
p_t c_{1t}^{nd} &= M_t^{nd} && (8)\\
p_t(c_{1t}^d + c_{2t}^d) &= M_t^d = \overline{M}. && (9)\\
\frac{U_{1t}^{nd}}{p_t^{nd}} &\geq \beta R_t \pi \frac{U_{2t+1}^{nd}}{p_{t+1}^{nd}} \qquad \text{with } " = " \text{ if } D_t > 0 && (10)\\
\frac{U_{2t}^{nd}}{p_t^{nd}} &= \beta((1-\pi)\frac{U_{1t+1}^{d}}{p_{t+1}^{d}} + \pi \frac{U_{1t+1}^{nd}}{p_{t+1}^{nd}}) && (11)\\
\frac{U_{1t}^{nd}}{p_t^{nd}} &= \beta \pi R_t(\beta(1-\pi)\frac{U_{1t+2}^{d}}{p_{t+2}^{d}} + \beta\pi \frac{U_{1t+2}^{nd}}{p_{t+2}^{nd}}). && (12)
\end{aligned}
$$

From banks profit maximizing condition we also have that: $R_t = \frac{p_{t+1}^{nd}}{p_t^{nd}} \frac{1}{\pi} f_1(\frac{D_t}{p_t^{nd}}, L)$ which with a linear technology as specified in assumption (3) is:

$$R_t = \frac{p_{t+1}^{nd}}{p_t^{nd}} \frac{r}{\pi}. \tag{13}$$

With constant money supply, an equilibrium where consumption allocation and assets holdings are unchanged over time conditional on $\theta$ and where the optimal level of deposits chosen in the current period is the same as the deposits carried from the previous period (i.e. $D_{t+1} = D_t = D$) will have constant prices. So before the sunspot hits one Euler equation implies:

$$r\beta^2[(1-\pi)\frac{2}{\bar{M}} + \pi \frac{1}{(\bar{M}-D)}] = \frac{1}{(\bar{M}-D)}, \tag{14}$$

from which $D$ can be pinned down:

$$D = \bar{M}[\frac{(1+(1-\pi)-\frac{1}{r\beta^2})}{2(1-\pi)}],$$
$$D = \phi\overline{M} \qquad \text{with } \phi = \frac{(1+(1-\pi)-\frac{1}{r\beta^2})}{2(1-\pi)}.$$

I $\pi \in (\underline{\pi}, \overline{\pi})$ then $\phi \in (0,1)$. Before the sunspot hits consumption of cash goods is pinned down by the cash-in-advance constraint and consumption of credit good from the Euler equation (11), so that:

$$c_1 = \frac{1}{p}(\overline{M} - D),$$
$$c_2 = \frac{1}{p}\frac{1}{\beta(\frac{2(1-\pi)}{\overline{M}} + \frac{\pi}{\overline{M}-D})}.$$

Then the resource constraint: $f(\frac{D}{p}, L) - \frac{RD}{p} + \frac{\overline{M}}{p} + \frac{1}{p}\frac{1}{\beta(\frac{2(1-\pi)}{\overline{M}} + \frac{\pi}{\overline{M}(1-\phi)})} = y + f(\frac{D}{p}, L),$ implies:

$$p = \frac{\overline{M}}{y}\Lambda, \qquad \text{with } \Lambda = [1 + \frac{1}{\beta(2(1-\pi) + \frac{\pi}{(1-\phi)})} - \frac{r\phi}{\pi}]. \tag{15}$$

When the sunspot hits, the solution to the households' problem is such that:

$$c_1^{d=0} = \frac{\overline{M}}{2p^{d=0}},$$
$$c_2^{d=0} = \frac{\overline{M}}{2p^{d=0}}.$$

and the resource constraint:$f(\frac{D}{p},L)+\frac{\overline{M}}{p^{d=0}}=y+f(\frac{D}{p},L)$, implies:

$$p^{d=0}=\frac{\overline{M}}{y}. \tag{16}$$

If $\pi\in(\underline{\pi},\overline{\pi})$ then prices when banks default are lower than prices when they do not default.

Then given the time invariant allocation $(c_1,c_2,M,D,i,D^b)$ and market clearing prices $p,R$, we need to check that banks' best response is to actually play the constructed strategy:

- $d_t(j)=0$ if $\theta_t=0$
- $d_t(j)=1$ if $\theta_t=1$

Since banks default if the value of their liabilities exceeds the value of their assets, then:

- if $r\frac{D}{p^{nd}}(1-\frac{1}{\pi})+L>0$ then banks do not default
- if $r\frac{D}{p^{nd}}(1-\frac{1}{\pi}\frac{p^{nd}}{p^{d}})+L<0$ then banks default

As long as $\frac{p^{nd}}{p^{d}}>1$ can always find $L\in\mathbb{R}_+$ such that the above incentives to default are satisfied.

## A.2 Proof of Proposition 2:

When the sunspot hits, in the presence of an active monetary policy that injects cash on the securities' market if a positive measure of banks default, prices will never fall.

Therefore since prices will for sure be $p^{nd}$ then banks are able to meet their obligations because $r\frac{D}{p^{nd}}(1-\frac{1}{\pi_{11}})+L>0$. Therefore banks do not fail: since whenever banks are indifferent between defaulting or not they do not default[11], then households will keep depositing a strictly positive amount of assets. Hence no banking panic occurs.

## A.3 Proof of Proposition 3:

*1.without deposit insurance banks invest in $f$*

The proof is in two steps. First I argue that the best response to every other bank choosing to invest in the safe technology is to invest in the safe technology too, so choosing the safe technology is an equilibrium. Then I argue that choosing the risky technology is not an equilibrium: investing in the risky technology is not a best response to every other bank investing in the risky technology.

a. investing in the safe technology is an equilibrium. Proof: by contradiction.

   Suppose all banks choose to invest in the safe technology $f$ and that investing in the risky technology $\widehat{f}$ is a profitable deviation for bank $j$.

   Suppose bank $j$ offered households the same contract as banks $-j$. Then since $\widehat{f}$ is a mean reducing spread of $f$, bank $j$ would be better off by investing in $f$.

   Suppose bank $j$ offered households a competitive contract, such that the promised interest rate on deposits $\widehat{R}=\frac{r}{\alpha\pi}\frac{p_{t+1}}{p_t}$ [12]. Then $\forall\alpha\in(\underline{\alpha},\overline{\alpha})$ payoffs in each state

[11] This is equivalent to assuming that by defaulting banks incur a cost $\kappa>0$ arbitrarily small, so that when deposits are zero banks are strictly better off by not defaulting and since $\kappa$ is arbitrarily small then it does not alter banks incentives to default when deposits are strictly positive.

[12] Competitive in the sense that if banks take prices as given when maximizing expected profits, then the equilibrium interest rate would be $\widehat{R}$.

of the world are such that:

1 if $\widehat{r}_t = \overline{r}$ and $p_t = p^{nd}$ then $\widehat{r}_t i_t + L - \frac{r}{\alpha\pi}\frac{D}{p^{nd}} > 0$ so banks do not default,

2 if $\widehat{r}_t = \overline{r}$ and $p_t = p^{d}$ then $\widehat{r}_t i_t + L - \frac{r}{\alpha\pi}\frac{p^{nd}}{p^{d}}\frac{D}{p^{nd}} < 0$ so banks default,

3 if $\widehat{r}_t = \underline{r} = 0$ and $p_t = p^{nd}$ then $\widehat{r}_t i_t + L - \frac{r}{\alpha\pi}\frac{D}{p^{nd}} < 0$ so banks default,

4 if $\widehat{r}_t = \underline{r} = 0$ and $p_t = p^{d}$ then $\widehat{r}_t i_t + L - \frac{r}{\alpha\pi}\frac{p^{nd}}{p^{d}}\frac{D}{p^{nd}} < 0$ so banks default.

Therefore, since payments to households are smaller in expected value and more volatile[13], by concavity of the households' value function no household deposits in bank $j$.

Suppose bank$j$ offered households a contract such that $\widehat{R}' > \frac{r}{\alpha\pi}$. Then inequalities 1-4 still hold, so that bank $j$ will default at least with the same probability as when offering $\widehat{R} = \frac{r}{\alpha\pi}$. With $\widehat{R}' > \frac{r}{\alpha\pi}$ however bank $j$ makes smaller profits than under $\widehat{R} = \frac{r}{\alpha\pi}$. Therefore offering $\widehat{R}' > \frac{r}{\alpha\pi}$ would not be a profitable deviation.

b. investing in the risky technology is not an equilibrium. Proof: by contradiction.

Suppose all banks choose to invest in the risky technology $\widehat{f}$ and that investing in $\widehat{f}$ is a best response for bank $j$. Then it is possible to construct a profitable deviation for bank $j$ as follows:

[13]Households get payed with probability $\pi\alpha$ an interest rate $\widehat{R} = \frac{r}{\alpha\pi}$ but do not get payed with probability $(1 - \alpha\pi)$. And the expected payment under $\widehat{f}$ is smaller than under $f$ because $\widehat{f}$ is a mean reducing spread of $f$, so that after normalizing $\underline{r} = 0$: $\alpha\overline{r} < r$.

– invest in the safe technology $f$ today and then follow the same strategy played by all other banks from tomorrow onwards,

– offer households the same contract as other banks offer.

Then the expected continuation payoff of being in business for bank $j$ is the same as for banks $-j$, whatever choice of technology they all will follow from tomorrow onwards. However banks $-j$ invested today in $\widehat{f}$ that is a mean reducing spread of $f$, therefore the expected return from $\widehat{f}$ is strictly smaller than the expected return from $f$. Letting $W$ denote the continuation payoff of being in business, then the total expected payoff for bank $j$ from:

– investing in $\widehat{f}$ is $\alpha\bar{r}\frac{D_t}{p_t} + L - \frac{R_t D_t}{p_{t+1}} + \delta W$,

– investing in $f$ is $r\frac{D_t}{p_t} + L - \frac{R_t D_t}{p_{t+1}} + \delta W$,

where $\alpha\bar{r} < r$. Therefore it is a profitable deviation for bank $j$ to invest in the safe technology $f$.

*2. with strict regulations deposit insurance can stop a panic-default*

By assumption the deposit insurer takes on banks liabilities when banks default and seizes their assets. Therefore if the sunspot hits and banks default, the real value of assets seized by the deposit insurer is $ri_t + L$. The real value of the liabilities is takes on is $\frac{R_t D_t}{p_{t+1}}$. Since liabilities are back up by the deposit insurer then they are still a viable means of payment for households, who can still use them to complete purchases of credit goods exactly as if banks did not default. The deposit insurer in fact guarantees that households will get payed in the amount they were promised when they signed the deposit contract. Therefore equilibrium prices are still $p^{nd}$.

Even if all banks defaulted, since the price level is not going to drop then $r\frac{D}{p^{nd}}(1-\frac{1}{\pi})+L>0$: so that if bank $j$ does not default, it is going to be liquid and able to meet its obligations. Therefore with deposit insurance and strict regulations banks do not default and banking panics do not occur.

*3.without strict regulations, deposit insurance can stop a panic-default but aggregate output fluctuates*

First I show that deposit insurance can stop a panic and that households get payed the return on their deposits. Then I argue that aggregate output fluctuates because with deposit insurance banks invest in the risky technology $\widehat{f}$.

Deposit insurance by assumption is designed so that the insurer seizes banks' assets if they fail, and levies lump sum taxes on households' endowment if the value of banks' assets is not sufficient to cover payments to households who hold claims at the bank. Therefore households are always payed the interest rate on their deposits, so that banking panics do not occur.

When deposit insurance is not coupled with strict regulatory arrangements however, banks can choose to invest in either $f$ or $\widehat{f}$. Banks choice of productive technology is taken as follows:

- banks' expected payoff under $\widehat{f}$:

$$\begin{array}{ll}\alpha & \Big(\max(\overline{r}\dfrac{D_t}{p_t}+L-\dfrac{R_tD_t}{p_{t+1}},0)+\dfrac{\delta\pi L}{1-\delta\pi}\Big)+\\ (1-\alpha) & \Big(\max(\underline{r}\dfrac{D_t}{p_t}+L-\dfrac{R_tD_t}{p_{t+1}},0)\Big)\end{array}$$

- banks' expected payoff under $f$:

$$\Big(\max(r\frac{D_t}{p_t}+L-\frac{R_tD_t}{p_{t+1}},0)+\frac{\delta\pi L}{1-\delta\pi}\Big)$$

where the present expected continuation payoff from being in business ($\frac{\delta\pi L}{1-\delta\pi}$) takes into account the assumption that it is not feasible to set up again in the future a mechanism like deposit insurance. Then from tomorrow onwards if a bank is still in business[14] in any time invariant equilibrium before the sunspot hits it will earn a discounted stream of profits given by: $\frac{\delta L}{1-\delta\pi}$.

Then given $y,\overline{r},L>0\,\forall\alpha\in(\underline{\alpha},\overline{\alpha})$ the expected payoff when investing in $\widehat{f}$ exceeds the expected payoff when investing in $f$: $\alpha(\overline{r}i_t+L-\frac{R_tD_t}{p_{t+1}}+\frac{\delta\pi L}{1-\delta\pi})>ri_t+L-\frac{R_tD_t}{p_{t+1}}+\frac{\delta\pi L}{1-\delta\pi}$.

[14]This event occurs with probability $\pi$.

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