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2 WHY DOES THE FED SMOOTH INTEREST RATES?

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1. Introduction

Except for relatively short episodes, the most notable of which is the 1979–1982 period, the Fed has geared monetary policy to reduce fluctuations in short-term interest rates. Even Volcker's successful monetary experiment did not produce a permanent shift to a nominal money stock rule as advocated by monetarists. This is puzzling for several reasons, not the least of which is the fact that monetarists' prescriptions have proven to be effective in delivering price stability. The tendency to revert to a policy of interest rate smoothing seems to be rather tenacious and as old as the Fed. Thus Miron (1986) and Mankiw, Miron, and Weil (1987) report that there

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has been a substantial change in the behavior of interest rates after the establishment of the Federal Reserve in 1914. After 1914 interest rates became substantially more persistent than prior to the founding of the Fed. Moreover, the Fed was widely expected to dampen fluctuations in interest rates. Goodfriend and King (1988) note that, prior to the Fed's creation, fluctuations in the monthly average call money rate on short-term broker loans exhibited much wider irregular and seasonal fluctuations than after 1914. Donaldson (1989a) finds that, after the foundation of the Fed, violent spikes in interest rates during financial panics virtually disappeared.

This article proposes a positive explanation for the Fed's tendency to smooth interest rates. This explanation relies on two presumptions. One is that the Fed is concerned about the stability of the financial system as well as about price stability. The other is that banks commit to loan contracts that normally stretch over longer periods than the term for which deposits are committed to them. There is little doubt that the Fed is concerned about the stability of the financial system in general and that of the banking system in particular.[1] The Fed was founded to a large extent in order to avoid financial crises (Mankiw, Miron, and Weil 1987). Its charter makes it responsible for averting such crises, and it is widely expected to do so by Congress and the public. As a bureaucracy the Fed may reasonably be expected to be more sensitive to the risks of banking failures than to adverse general economic conditions like unemployment. After all, the responsibility for the banking system is in the Fed's "own courtyard" while the responsibility for high unemployment is naturally shared by other policymaking institutions like the fiscal authority. Brimmer (1989) makes a persuasive case that on various occasions the Fed's policy was geared to safeguard the stability of the financial system.

The second presumption relies on the traditional function of banks which is to transform short-term liabilities into longer-term loan assets. Although some variable rate loans have recently developed, a large fraction of loans in the United States specifies a fixed loan rate and volume in advance for the period of the loan.[2] Many deposits, on the other hand (like demand deposits, short-term money market accounts, and large certificates of deposits—CDs) have more flexible terms both with respect to maturity and return.[3] This asymmetry is probably due to the fact that the fundamental service provided by banks on both sides of their balance sheet is liquidity. On the side of assets (loans) liquidity is provided by giving the borrower an advance unconditional assurance for the loan terms. On the side of liabilities (deposits) liquidity is provided by letting customers use their funds on demand. Another possible reason is that loan markets are more influenced by customer specific considerations than deposit markets.[4]

Be that as it may, this article takes the asymmetry in the contract provisions of loans and of deposits as given, and explores the implications of its existence for the behavior of the central bank.

The advance commitment of banks to loan terms makes them vulnerable to changes in the conditions of financial markets after they have committed their funds. For example, if after loan contracts have been made, there is an unexpected decrease in the aggregate supply of deposits, banks lose reserves and incur higher marginal costs of illiquidity.[5] In order to correct this situation, each individual bank tries to regain deposits by raising its deposit rate. Since all banks do that, there is a general increase in the total cost of funds to banks and a decrease in the profits of the banking industry. The squeeze in profits is amplified by the fact that rates rise on the entire stock of deposits after loan rates and quantities have been preset. This increases, in turn, the likelihood that some relatively weak banks will fail. Since the Fed is concerned about the stability of the banking system, it has interest in counteracting the increase in the likelihood of banking failures. Provided the price level is temporarily fixed, the Fed can temporarily offset the decrease in banks' profits by stepping up the rate of increase in reserves. This action decreases banks' demand for deposits and dampens some of the increase in the rate of interest paid on deposits, thus offsetting at least some of the increase in the risk of banking failures. However, the higher rate of reserve expansion is also costly from the point of view of the Fed, since after a while it leads to a larger rate of inflation. Hence when the cost of funds to banks unexpectedly goes down, increasing banks' profits and decreasing the likelihood of failures, the Fed puts more emphasis on the stability of the general price level and decreases the rate of growth of base money. This action dampens, in the short run, the initial decrease in the cost of funds to the banking industry.

Thus interest rate smoothing by the central bank arises as a byproduct of the bank's attempt to minimize some combination of the risks of financial instability and of the costs of inflation. The central bank directs policy mostly to increase the soundness of the banking system when the risks of financial instability are relatively high. It focuses mostly on maintainance of price stability when profits in the banking industry are high and the risks of failure are, therefore, relatively low. Since, because of the asymmetry in the structure of their contracts, banks' profits are negatively related to the level of interest rates in the short run, the central bank's actions result in interest rate smoothing. The theory implies that the Fed is concerned with the predictability of interest rates rather than with their level.[6] This article develops this intuitive mechanism more precisely and characterizes the conditions under which it operates in the presence of various shocks. In particular, shocks to the deposit market, the short-term bond market, and the loan market are considered. It shows that smoothing by the central bank arises also in the case in which, due to the existence of credit lines, the volume of loans adjusts passively to shocks to loan demand. As a matter of fact, the existence of credit lines provides another reason for the Fed to engage in interest rate smoothing.[7]

Additional implications of the article's framework are:

1. The rate of high-powered money growth behaves procyclically. More precisely, when unanticipated increases in economic activity raise the supply of bonds and the bond rate, the Fed responds by stepping up the rate of increase in base money. Rasche (1988) presents evidence suggesting that base money growth is procyclical. Similar evidence concerning M1 growth appears in Meltzer (1990).

2. The time series pattern of nominal interest rates that emerges in the presence of central bank intervention is nearer to being a random walk than their pattern in the absence of intervention. This is consistent with the findings of Miron (1986) and of Mankiw, Miron, and Weil (1987) who report that, after the foundation of the Fed, short-term rates were much closer to a random walk than prior to that.

3. The concern of the central bank for the stability of the banking system creates an inflationary bias even in the absence of employment considerations of the type discussed by Kydland and Prescott (1977), Barro and Gordon (1983), and many others. This bias makes expected rates on deposits, federal funds, and short-term bonds lower than in the absence of intervention, inducing the banking system to take higher risks by lending more.

4. Arrival of new information indicating a substantial cumulation of losses within the financial system induces the central bank to step up the rate of reserves created in the short run. This result may have some power for explaining monetary accelerations prior to the thrift industry bailout.

In order to analyze the interaction between the central bank and the banking industry precisely, it is necessary to specify the structure and type of equilibrium that characterize the banking industry. Banks are modeled as having some degree of local monopoly power (not necessarily the same) in both the loan and deposit markets.[8] Each bank picks its loan rate, the volume of loans, and its deposit rate so as to maximize profits, taking the loan and deposit rates of other banks as given. We focus on the resulting Cournot-Nash symmetric equilibrium of the banking industry. The structure of the ex post equilibrium in which the deposit rate and the demand for short-term bonds by banks is determined (for predetermined loan contracts) is discussed in section 2. Section 3 characterizes the short-term bond market equilibrium and demonstrates that, with sufficient competition in the banking sector, there is a short-run negative relationship between profits in this sector and the bond rate. The ex ante (prior to realizations of shocks) determination of loan contracts is presented in section 4. Ex ante each bank picks the loan rate and the volume of loans so as to maximize expected profits over the loans' period. In doing so, each bank takes the loan rates of other banks and the policy rule of the Fed as given. Again we focus on the Cournot-Nash symmetric ex ante equilibrium of the banking system. Section 4 also characterizes the ex ante determination of the price level which, once set, remains fixed for one period. The price level is determined at the level that clears the market for bank reserves in an ex ante sense. This way of modeling general price level determination is meant to capture the fact that prices of goods normally do not adjust instantaneously to changes in nominal shocks.[9] This temporary stickiness makes it possible for the Fed to influence interest rates in the short run.

The objectives of the central bank and the characterization of its policy appear in section 5. This section also demonstrates the existence of an inflationary bias that is induced by the central bank's concern for financial stability. The basic result of the article concerning smoothing of interest rates in the face of shocks to the deposit and the short-term bond markets is developed and discussed in section 6. For a given ex post equilibrium of the banking industry, the central bank picks the rate of expansion of the monetary base so as to minimize the combined risks of financial instability and inflation. This behavior is shown to result in interest rate smoothing. The procyclical behavior of base money growth and the tendency of short-term rates to behave more nearly as random walks in the presence of intervention is developed in section 7. The discussion is extended, and the basic smoothing result shown to carry over, to the case of credit lines in section 8. This is followed by concluding remarks.

2. Structure of the Banking Industry and the Ex Post Equilibrium

The central element of banking activity is the transformation of relatively short-term liabilities like demand deposits, certificates of deposit, and other short-term money market instruments into longer-term loans to bank customers. An important consequence of this activity is that banks have to commit to loan terms before they know with certainty the quantity and cost of their sources of funds.[10] In order to capture this fundamental asymmetry in a simple way, we postulate that each bank determines the quantity of one-period loans and their price at the beginning of each period for the period. In particular this commitment is made before various shocks that affect the economy and the banking system during the period are realized. But the volume and cost of deposits are determined within the period after the realization of those shocks. The banking industry is composed of N banks that compete for sources of funds as well as for borrowers.[11] The demand function for (real) loans facing bank i is

$$\ell(r_{\ell i}, \mathbf{r}_{\ell i}, \varepsilon_\ell) = \frac{1}{N}(A_\ell + \varepsilon_\ell - \ell_0 r_{\ell i}) - \ell \sum_{\substack{j=1\\ j\neq i}}^{N} (r_{\ell i} - r_{\ell j}) \qquad (1)$$

where $r_{\ell i}$ is the (real) loan rate charged by bank i, $\mathbf{r}_{\ell i}$ is the vector of loan rates charged by all other banks, ε_ℓ is a stochastic shock (with zero expected value) to aggregate demand for credit, and A_ℓ, ℓ_0, and ℓ are positive parameters. Note that when all loan rates are equal this demand function reduces to $(1/N)(A_\ell + \varepsilon_\ell - \ell_0 r_\ell)$ and correspondingly the aggregate demand for loans facing the industry is $A_\ell + \varepsilon_\ell - \ell_0 r_\ell$. Hence ℓ_0 is a measure of the sensitivity of *total* demand for credit to an increase in the loan rate. The parameter ℓ measures the degree of local monopoly power of each bank. The higher it is, the more customers are lost by the individual bank when it raises its rate and all other banks maintain their rates at fixed levels. Hence, given N, a higher ℓ implies a smaller degree of local monopoly power. Equation (1) represents the demand for loans facing a bank after the realization of intra-period shocks. The demand facing it at the beginning of the period is the same expression with $\varepsilon_\ell = 0$. If during the period ε_ℓ is (say) positive, there is an incrememtal demand of ε_ℓ/N which is not satisfied by the bank since all loan contracts have been concluded at the beginning of the period.[12]

The (real) supply of deposits function facing bank i is

$$d(r_{di}, \mathbf{r}_{di}, \varepsilon_d) = \frac{1}{N}(A_d + \varepsilon_d + d_0 r_{di}) + d \sum_{\substack{j=1\\ j\neq i}}^{N} (r_{di} - r_{dj}) \qquad (2)$$

where r_{di} is the (real) rate paid on deposits by bank i, $\mathbf{r}_{di}$ is the vector of rates paid on deposits by all other banks, ε_d is a stochastic shock (with zero expected value) to aggregate deposit supply, and A_d, d_0, and d are positive parameters. The parameter d_0 measures the sensitivity of aggregate deposit supply to a change in the average deposit rate. The parameter d measures the degree of local monopoly power in the deposit market for a given number of banks. The lower d, the less competitive is the banking industry in the deposit market.

The required reserve ratio against deposits is τ. Hence the (real) required reserves of bank i are

$$r\rho_i = \tau d(r_{di}, \mathbf{r}_{di}, \varepsilon_d). \qquad (3)$$

There is an economywide short-term bond market. The (real) bond rate, r_b, is determined on the stock exchange. It is, therefore, influenced by the within-period realizations of the various shocks that affect the economy. The non-bank real demand for bonds is

$$\varepsilon_b^d + s_0 r_b \qquad (4)$$

where ε_b^d is a stochastic shock to the real demand for bonds with zero mean, and s_0 is a positive parameter. Banks choose their bond portfolios after the realization of stochastic shocks within the period. In order to maintain the complexity of the model at a manageable level, it is assumed that bonds are traded only once within a period after the realization of shocks. Furthermore, only one-period bonds that mature just prior to trade-in bonds in the next period are considered. This specification abstracts from the function of bonds as secondary liquidity. But it does account for the tendency of banks to reduce their bond portfolios when they lose reserves, thus bringing out part of the function of bonds as secondary reserves as well as the effect of reserve losses on bond market equilibrium.[13]

In addition to the interest it pays on deposits, the individual bank incurs various costs that are associated with illiquidity. Those costs increase at an increasing rate with the degree of the bank's illiquidity which is measured, in turn, as the difference between the required reserves of the bank and its actual (real) level of reserves. More precisely, the costs of illiquidity are:

$$c(\rho_i - r\rho_i) = \begin{Bmatrix} \frac{c}{2}[\alpha - (\rho_i - r\rho_i)]^2 & \text{for } \alpha - (\rho_i - r\rho_i) \geq 0 \\ 0 & \text{otherwise} \end{Bmatrix}. \qquad (5)$$

Here ρ_i are the actual (real) reserves of the bank, α is a non-negative parameter, and c is a positive parameter. The costs of illiquidity are zero whenever actual reserves exceed required reserves by more than the threshold α. But once the difference between actual and required reserves drops below the threshold, the costs of illiquidity become positive and increase at an increasing rate with further increases in illiquidity. Two presumptions underlie this specification. One is that as the difference between actual and required reserves decreases, the individual bank dips more heavily into the discount window and incurs higher implicit penalties from the Fed. The other is that the lower this difference, the higher the amount of managerial and other resources devoted by the bank to execute trades in the federal funds market. Obviously each of those presumptions alone is sufficient to generate increasing marginal costs of illiquidity as specified in equation (5).

Abstracting from inessential items, the balance sheet of an individual bank implies that total assets, which are composed of reserves, bonds, and loans, are equal to total deposits. Letting R_i,B_i,L_i, and D_i denote, respectively, the nominal quantities of reserves, bonds, loans, and deposits of bank i, its balance sheet identity can be written

$$R_i + B_i + L_i = D_i. \tag{6}$$

Dividing by the price level and rearranging

$$\rho_i = d(r_{di}, r_{di}, \varepsilon_d) - \ell(r_{\ell i}, r_{\ell i}, \varepsilon_\ell) - b_i \tag{6a}$$

where b_i is the real stock of bonds held by the bank. The general price level, P, for each period is determined at the beginning of the period so as to clear the market for the monetary base in an ex ante sense.

It is useful to summarize the timing of events. Loan contracts covering both the price and the quantity of loans and the general price level are determined at the beginning of each period. Within the period the timing of events is as follows. First, the short-term bonds carried over from the previous period mature, then the intra-period shocks realize, and finally decisions about new bond portfolios and the interest rate on deposits are made.

The ex ante determination of the price level, the loan rate, and the volume of loans are discussed in section 4. Here we focus on the ex post, within period, equilibrium of the financial system for previously predetermined values of the price level, the loan rate, and the amount of outstanding loans.

Taking those variables, the bond rate, and the deposit rates of all other banks as given, the individual bank chooses its own deposit rate and the amount of bonds so as to maximize real profits. Those profits are equal to revenues from loans minus interest paid on deposits and the costs of illiquidity. Using equations (3) and (6a) in (5), and noting that revenues from loans as well as their quantity are predetermined, the maximization problem of bank i can be written:

$$\begin{aligned}\max_{\{r_{di},b_i\}}\ & r^p_{\ell i}\,\ell^p_i + r_b b_i - r_{di} d(r_{di}, r_{di}, \varepsilon_d) \\ & - \tfrac{c}{2}[\alpha + \ell^p_i + b_i - (1-\tau)d(r_{di}, r_{di}, \varepsilon_d)]^2 + u_i\end{aligned} \tag{7}$$

where u_i is an idiosyncratic stochastic shock to bank i's profits that realizes concurrently with ε_d and ε_b. The sum of the u shocks over banks satisfies $\Sigma_{i=1}^{N} u_i = 0$. The superscript "p" designates variables that have been predetermined at the beginning of the period. For simplicity, and without much loss of generality, we set $\alpha = 0$. The formulation in equation (7) is based on the presumption that the single bank operates in the range for which the costs of illiquidity are positive. As explained in note 14, this always is the case when the real return on bonds is positive. Substituting the particular form of the deposit demand function from equation (2) into (7) and differentiating with respect to r_{di} and b_i, the first order conditions for bank i's optimization are:[14]

$$\begin{aligned}&-\frac{1}{N}(A_d + \varepsilon_d) - \left(\frac{2d_0}{N} + (N-1)d\right)r_{di} - d\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{di} - r_{dj}) \\ &+c(1-\tau)\left(\frac{d_0}{N} + (N-1)d\right)\Bigg(\ell^p_i + b_i - (1-\tau) \\ &\cdot\left\{\frac{A_d + \varepsilon_d + d_0 r_{di}}{N} + d\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{di} - r_{dj})\right\}\Bigg) = 0\end{aligned} \tag{8a}$$

$$r_b - c\left(\ell^p_i + b_i - (1-\tau)\left\{\frac{A_d + \varepsilon_d + d_0 r_{di}}{N} + d\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{di} - r_{dj})\right\}\right) = 0. \tag{8b}$$

As in any oligopolistic market, the decisions of bank i depend on the decisions of other banks in the industry. In particular, as can be seen from the first order conditions in (8), the choice of r_{di} and of b_i by bank i depends on the deposit rate of all other banks in the industry. In a Nash equilibrium the choice made by each bank has to be such that, given the optimal choices of all other banks, the individual bank is also at an optimum. We focus here on a symmetric Nash equilibrium of the banking industry in which

$$r_{di} = r_d, \quad b_i = b \text{ for all } i. \tag{9}$$

Substituting equation (9) into (8) and solving for r_d and b, the equilibrium values of the deposit rate and of the individual bank demand for bonds are[15]

$$r_d = -\frac{1}{D}(A_d + \varepsilon_d) + (1-\tau)\left(1 - \frac{d_0}{D}\right)r_b \tag{10a}$$

$$b = -\ell^p + (1-\tau)\left(1 - \frac{d_0}{D}\right)\frac{\varepsilon_d}{N} + \left(\frac{1}{c} + (1-\tau)^2\frac{d_0}{N}\left(1 - \frac{d_0}{N}\right)\right)r_b \quad (10b)$$

where

$$D \equiv 2d_0 + N(N-1)d. \quad (11)$$

The features of those solutions are plausible. The deposit rate offered by banks is higher the higher the return on bonds and is lower the higher the ex post demand for deposits. In a wider model with an explicit federal funds market r_d and the federal funds rate will normally move in tandem. Hence, within the present model, r_d can also be thought of as a proxy for the federal funds rate. The demand for bonds by the individual bank is an increasing function of the bond rate and is smaller, ceteris paribus, the larger the amount of loan commitments that have been made at the beginning of the period.

Substituting equations (10) into the profit function of the individual bank in (7) and rearranging, the profits of an individual bank are:[16]

$$\pi_i = (r_\ell^p - r_b)\ell^p + \frac{1}{DN}\left(1 - \frac{d_0}{D}\right) \cdot \left((1-\tau)d_0 r_b + A_d + \varepsilon_d\right)^2 + \frac{r_b^2}{2c} + u_i. \quad (12)$$

Depending on whether the ex post value of the bond rate is smaller or larger than the precommited loan rate, a larger volume of loans is beneficial or detrimental to profits ex post. Since $\Sigma_{i=1}^N u_i = 0$ the (ex post) profits of the entire banking industry are:

$$\pi = N\pi_i = (r_\ell^p - r_b)N\ell^p + \frac{1}{D}\left(1 - \frac{d_0}{D}\right) \cdot [(1-\tau)d_0 r_b + A_d + \varepsilon_d]^2 + \frac{N}{2c}r_b^2. \quad (13)$$

3. The Short-Run Negative Relationship Between the Bond Rate and the Profits of the Banking Industry

The effect of an increase in the real rate on bonds on the profits of the banking system after the conclusion of loan contracts can be obtained by differentiating equation (13) with respect to r_b. The resulting expression is

$$\frac{\partial \pi}{\partial r_b} = N\left(\frac{r_b}{c} + 2(1-\tau)\frac{d_0}{D}\left\{1 - \frac{d_0}{D}\right\}\frac{(1-\tau)d_0 r_b + A_d + \varepsilon_d}{N} - \ell^p\right). \quad (14)$$

The term $(1/N)[(1-\tau)d_0 r_b + A_d + \varepsilon_d]$ is somewhat smaller than the ex post equilibrium volume of deposits at a representative bank. ℓ^p is the volume of loans at a representative bank. The expression $2(1-\tau)(d_0/D)(1 - d_0/D)$ which multiplies the deposit-related term is substantially smaller than 1 already for a moderately large N since $(1-\tau)(1 - d_0/D) < 1$ and d_0/D tends to zero as N gets larger.[17] Since r_b is a fraction r_b/c is also smaller than 1 if $c > r_b$ which seems a relatively mild restriction. The upshot is that if the marginal cost of illiquidity is not too small and the number of banks moderately large, the last negative term in equation (14) dominates the sign of $\partial\pi/\partial r_b$ and an increase in the bond rate decreases the profits of the banking industry. Either condition alone may be sufficient to induce this negative effect. The remainder of the discussion is based on the presumption that a within-period increase in the bond rate squeezes the profits of the banking system.

The intuition underlying this total negative effect is as follows: An increase in the bond rate induces two opposing effects on the profits of the banking industry. On one hand, there is an increase in the return on the bond portfolio and a related upward adjustment in the quantity of bonds held by each bank (see equation (10b)), both of which tend to increase the profits of banks. On the other hand, the more lucrative bond rate causes an intensification of the banks' competition for funds and results in an increase in the deposit rate (see equation (10a)) on the *entire* stock of deposits. This market effect reduces the profits of the banking industry. If banks had not previously committed a large part of their funds to loans, they would have increased their investment in the bond market also by decreasing the amount of loans offered to customers as well as by increasing the loan rate. However, the previously made commitment to a certain level of loans limits the banks' ability to take advantage of the better bond market opportunities. The larger this commitment, the more limited is the ability of banks to increase their bond portfolio because of increasing costs of illiquidity. This limitation is reflected in equation (10b) which implies that the total amount of earning assets of a bank (loans + bonds) is limited by a constant which depends on r_b and on the shock to the demand for deposits. Thus the ability of banks to take advantage of the more lucrative bond rate is limited by past commitments of funds. However, the increase in the deposit rate increases the cost of all funds, including those that are needed to fulfill the obligation to previously contracted loans. As a consequence the negative market-induced effect of an increase in r_b on profits dominates the direct positive effect.

We turn next to a characterization of the (ex post) bond market equilibrium. Let ε_b^s be a (zero mean) shock to the real supply of bonds during the period. Let EB be the nominal supply of bonds as anticipated at the beginning of period t.[18] All unindexed variables refer to period t. Since ε_b^s is that part of the nominal supply of bonds which was not anticipated (as of the beginning of the period), the actual real supply of bonds during the period is:

$$\frac{EB}{P^p} + \varepsilon_b^s.$$

The superscript "p" attached to the price level, P, denotes the fact that the price level has been predetermined by the ex ante equilibrium at the beginning of the period. Details concerning price level determination appear in section 4 below. The real rate on bonds during the period is determined by clearing of the bond market. The public's demand for bonds is given by equation (4) and the demand of the banking system is given by (10b) multiplied by the number of banks. Summing up these two components of demand for bonds, equating to the supply of bonds, and solving for r_b, we obtain:

$$r_b = K\left(\frac{EB}{P^p} + N\ell^p - \varepsilon_b - (1-\tau)\left(1-\frac{d_0}{D}\right)\varepsilon_d\right) + R(\varepsilon_b, \varepsilon_d) \quad (15)$$

where

$$\varepsilon_b \equiv \varepsilon_b^d - \varepsilon_b^s \quad (16a)$$

$$K \equiv \frac{1}{\dfrac{N}{c} + (1-\tau)^2 d_0\left(1-\dfrac{d_0}{D}\right) + s_0} \quad (16b)$$

and the term $R(\cdot)$ represents the reaction function of the Fed. The determination of this function is discussed toward the end of section 6. Equation (15) states that, in the absence of intervention, the equilibrium real rate on bonds is lower the higher are the intra-period shocks to the excess demand for bonds (ε_b) and to the demand for deposits (ε_d). It is higher when the volume of loans to which the banking system precommited at the beginning of the period is higher and the higher is the expected supply of bonds at that time. The intuition underlying the effects of EB and of ε_b is obvious. The positive relationship between ℓ^p and r_b is due

to the fact, mentioned earlier, that the larger the volume of loan precommitments, the smaller the increase in the demand of the banking system for bonds when r_b goes up. As a result, its attenuating effect on the rise in r_b is weaker the larger ℓ^p. Finally, the depressing effect of ε_d on the bond rate is due to the fact that a positive shock to the demand for deposits induces a decrease in the equilibrium deposit rate (see equation (10a)) and increases the demand of banks for bonds. This increased demand decreases the real rate on bonds. The discussion of the term $R(\cdot)$ is left to section 6.

We turn next to the intra-period effects of the shocks ε_b and ε_d on the profits of the banking industry. Since, from equation (13), ε_b affects π only through r_b and since $\partial\pi/\partial r_b < 0$ it follows that

$$\frac{\partial\pi}{\partial\varepsilon_b} = \frac{\partial\pi}{\partial r_b}\frac{\partial r_b}{\partial\varepsilon_b} > 0. \quad (17)$$

An increase in the excess demand for bonds increases the profits of the banking system in the short run. A change in ε_d affects profits directly, as well as through the change it induces in the bond rate. Hence

$$\frac{d\pi}{d\varepsilon_d} = \frac{\partial\pi}{\partial\varepsilon_d} + \frac{\partial\pi}{\partial r_b}\frac{\partial r_b}{\partial\varepsilon_d}. \quad (18)$$

But from (13)

$$\frac{\partial\pi}{\partial\varepsilon_d} = \frac{2}{D}\left(1-\frac{d_0}{D}\right)[(1-\tau)d_0 r_b + A_d + \varepsilon_d] \quad (18a)$$

which is positive as long as the demand for deposits is positive. Since $\partial\pi/\partial r_b < 0$ and since, from (15), $\partial r_b/\partial\varepsilon_d < 0$, the total effect of an increase in ε_d on the profits of the banking industry is positive.

The upshot is that the existence of unanticipated shocks to the excess demand for bonds or to the demand for deposits *after* the conclusion of loan contracts creates a negative correlation between the bond rate and the profits of the banking industry. It is easy to establish, by using (10a), that a similar negative correlation exists between profits and the deposit rate r_d.

4. Determination of the Loan Rate, the Volume of Loans, and the Price Level

Each individual bank is aware of the fact that after the realization of shocks, during the period, the equilibrium values of b and of r_d will depend on ε_d and on r_b in a way that is given by equations (10). However, as of the beginning of the period, the bank does not know the intra-period realizations of ε_d and of r_b. It therefore picks the loan rate $r_{\ell i}$ and the volume of loans ℓ_i so as to maximize the expected value of profits taking the relations in (10) into consideration. Hence the ex ante maximation problem of the individual bank is obtained by substituting equations (10) and (1) into the profit function of the individual bank in (7) and by taking the expected value of this expression. The resulting ex ante optimization problem of the individual bank is:

$$\begin{aligned}\underset{r_{\ell i}}{\text{Max}}\ E\Bigg[& r_{\ell i}\left(\frac{A_\ell+\varepsilon_\ell-\ell_0 r_{\ell_i}}{N}-\ell\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{\ell i}-r_{\ell j})\right)\\ &-\frac{1}{N}\left\{(1-\tau)\left(1-\frac{d_0}{D}\right)r_b-\frac{A_d+\varepsilon_d}{D}\right\}\left\{A_d+\varepsilon_d+d_0\left((1-\tau)\left(1-\frac{d_0}{D}\right)r_b-\frac{A_d+\varepsilon_d}{D}\right)\right\}\\ &+r_b\Bigg\{(1-\tau)\left(1-\frac{d_0}{D}\right)\frac{\varepsilon_d}{N}-\frac{A_\ell+\varepsilon_\ell-\ell_0 r_{\ell i}}{N}-\ell\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{\ell i}-r_{\ell j})\\ &+\left[\frac{1}{c}+(1-\tau)^2\frac{d_0}{N}\left(1-\frac{d_0}{D}\right)\right]r_b\Bigg\}-\frac{r_b^2}{2c}\Bigg].\end{aligned} \tag{19}$$

The first order condition for an internal maximum of this problem is

$$\frac{A_\ell-\ell_0 r_{\ell i}}{N}-\ell\sum_{\substack{j=1\\ j\neq i}}^{N}(r_{\ell i}-r_{\ell j})-\left(\frac{\ell_0}{N}+(N-1)\ell\right)\left(r_{\ell i}-Er_b\right)=0. \tag{20}$$

Again we focus on a symmetric (ex ante) Nash equilibrium in which

$$r_{\ell i}=r_\ell \quad \text{for all } i. \tag{21}$$

Using equation (21) in (20) and rearranging, the loan rate is predetermined at

$$r_\ell^p=\frac{A_\ell}{D_L}+\left(1-\frac{\ell_0}{D_L}\right)Er_b \tag{22}$$

where

$$D_L\equiv 2\ell_0+N(N-1)\ell. \tag{23}$$

The corresponding volume of loans contracted by a single bank at the beginning of the period is (from equation (22) and the expected demand for loans in a symmetric equilibrium):

$$\ell^p=\left(1-\frac{\ell_0}{D_L}\right)\frac{A_\ell-\ell_0 Er_b}{N}. \tag{24}$$

In order to find Er_b we substitute equation (24) into (15), take expected values of the resulting expressions, and solve for Er_b. The resulting expression is:

$$Er_b=\frac{K\left[\frac{EB}{P^p}+\left(1-\frac{\ell_0}{D_L}\right)\right]A_\ell}{1+K\ell_0\left(1-\frac{\ell_0}{D_L}\right)}. \tag{24a}$$

In order to fully characterize Er_b it is still necessary to specify how P^p and EB are determined. The remainder of this section is devoted to the first issue. The expected value, EB, of the supply of bonds depends, inter alia, on what banks know about the open market policy of the central bank. Since this policy is specified only in the next section, the precise characterization of EB is presented there.

We turn next to the price level which is determined by the condition that the market for nominal bank reserves clears in an ex ante sense. The advance determination of the price level for the period is meant to capture the well-accepted fact that prices of many goods and services on real markets do not respond to shocks immediately.

From equations (6) and (6a) the demand of an individual bank for reserves after the realization of shocks is

$$R_i^D(\cdot)=P[d(\cdot)-\ell^p-b] \tag{25}$$

where ℓ^p and b are given in equations (24) and (10b), respectively, and the explicit form of $d(\cdot)$ can be obtained by substituting equations (9) and (10a) into equation (2). Since in equilibrium $d(\cdot)$, ℓ^p and b are identical across all banks, the intra-period total demand for reserves is N times the single bank demand in (25):

$$R^D(\cdot)\equiv\sum_{i=1}^{N}R_i^D(\cdot)=PN[d(\cdot)-\ell^p-b]\equiv Px. \tag{25a}$$

Since $R^D(\cdot)$ depends on the intra-period realization of shocks and of the bond rate, it is not known with certainty at the beginning of the period when the price level is determined. Let R be the total nominal quantity of reserves made available to the banking system during the period. Since reserves respond, through the policy of the central bank, to intra-period shocks, their supply is also not known with certainty at the beginning of the period. We postulate that the price level is determined so as to equate the expected value of the natural logarithm of the demand for reserves with the expected value of the natural logarithm of reserves' supply.[19]

$$ElnR^D(\cdot) = ElnR \tag{26}$$

Using equation (25a) in (26) and rearranging

$$lnP = ElnR - Elnx \equiv lnR_{-1} + E\mu - Elnx \tag{26a}$$

where

$$\mu \equiv ln\frac{R}{R_{-1}} \text{ or } R = R_{-1}e^{\mu}. \tag{27}$$

Here use has been made of the fact that the nominal reserves, R_{-1}, of the previous period are known with certainty at the beginning of the current period. Note that $ln\ P$ is directly proportional to the ln of the last period's reserves plus the expected rate of growth of reserves and is inversely related to $Elnx$. The analogy to the traditional money market clearing condition used to determine the price level is evident: the price level is higher the higher the expected supply of nominal reserves for the period and the lower the expected real demand for reserves as measured by $E\ ln\ x$.

5. Central Bank Objectives and Behavior

A main, self-acknowledged goal of the Federal Reserve both by law and custom is the preservation of the stability of the financial system in general, and that of the banking system in particular (*Federal Reserve Bulletin*, July 1984, p. 548).

This objective of the Fed is more likely to be attained the higher the profits are of the banking system, particularly if the Fed does not know the realizations of the idiosyncratic shocks, u_i, across individual banks (equation (7)). This statement can be elaborated by noting that the profits of a single bank in equation (7) are composed of a common component that includes all the terms except the last one which is idiosyncratic to the individual bank. If the common component of profits is large, even banks with particularly adverse realizations of u_i will be solvent, but if the common component of profits is small even banks with moderately adverse u_i's may run into difficulties.[20] Thus the higher the profits of the banking system, the smaller the probability of a serious financial crisis. Therefore, if the Fed values financial stability, it should, ceteris paribus, prefer a state of nature with higher profits in the banking industry to a state with lower profits. However, as total profits increase further, the incremental contribution to financial stability most probably diminishes. We shall model those features by postulating that one component of the objective function

of the central bank is a function, $f(\pi)$, which increases in π but at a decreasing rate. In addition, as in Barro and Gordon (1983), the central bank dislikes inflation. Thus the entire objective function of the central bank may be written[21]

$$-\tfrac{1}{2}(ln P_{t+1} - ln\ P_t)^2 + gf(\pi_t),\ f'(\cdot) > 0,\ f''(\cdot) < 0. \tag{28}$$

Here $ln\ P_{t+1} - ln P_t$ is the rate of inflation between period t and period $t+1$, π_t are the profits of the banking industry in period t and g is a positive parameter that measures the relative concern of the central bank for financial stability versus price stability. This formulation reflects a basic externality that is internalized by the Fed. Each bank cares only about its own profits, but the Fed cares about the profits of the entire industry because of the connection between this aggregate and financial stability.

The profits of the banking system after the realization of intra-period shocks are given by equation (13). The discussion in section 3 implies that an intra-period decrease in the bond rate can increase the profits of the banking system in the short run. Since the price level is fixed, the central bank can temporarily decrease the bond rate by performing open market purchases of bonds, thus injecting additional reserves into the banking industry. Provided every dollar of bonds purchased generates a full additional dollar of reserves[22]

$$dR_t = -dB_t. \tag{29}$$

Combining equations (15) and (29),

$$dr_{bt} = \frac{K}{P^p}dB_t = -\frac{K}{P^p}dR_t \text{ or } \frac{dr_{bt}}{dR_t} = -\frac{K}{P^p} < 0 \tag{30}$$

where

$$B_t \equiv E_{t-1}B_t + \varepsilon^s_{bt}. \tag{31}$$

Equation (30) confirms the ability of the central bank to decrease the interest rate on bonds for a predetermined price level. But

$$\frac{dr_{bt}}{d\mu_t} = \frac{dr_{bt}}{dR_t}\frac{\partial R_t}{\partial \mu_t} = -\frac{K}{P^p_t}R_{t-1}e^{\mu} \tag{32}$$

where the extreme right-hand equality follows from equations (27) and (30). Equation (32) may be restated as:[23]

$$\frac{dr_{bt}}{d_{\mu_t}} = -K\bar{x}e^{\mu_t - E\mu_t} < 0,\ \bar{x} \equiv Elnx. \tag{32a}$$

The time index has been deleted from the term $Elnx$ since this expected value is time invariant due to the fact that all shocks are transitory. For the same reason $E\mu_t$ turns out to be time invariant as well.[24] This invariance in conjunction with equation (26a) implies:

$$lnP_{t+1} - lnP_t = lnR_t + E\mu - \bar{x} - (lnR_{t-1} + E\mu - \bar{x}) = \mu_t. \quad (33)$$

Substituting equation (33) into (28) and recognizing explicitly the dependence of banks' profits on ε_{dt} and on ε_{bt} and μ_t through their effects on r_{bt}, the objective function of the central bank may be restated as

$$\underset{\mu_t}{\text{Max}} - \tfrac{1}{2}\mu_t^2 + gf[\pi_t(\varepsilon_{dt}, r_{bt}(\varepsilon_{bt}, \mu_t))]. \quad (28a)$$

This restatement emphasizes the basic intra-period tradeoff confronting the central bank. It may, if it wishes, increase the profits of the banking system by stepping up the rate of nominal reserve creation, μ_t. Such a policy increases the profits of banks by decreasing the bond rate and decreases the probability of financial instability. This is a benefit for central bank objectives. But an increase in the rate of reserve creation also increases the rate of inflation between the current and the next period, and that is a cost. The choice of μ_t involves weighing the benefits of increased financial stability against the costs of higher inflation. The first and second order conditions for an internal maximum of equation (28a) are, respectively:

$$F_\mu \equiv -\mu_t + gf'(\pi_t)\frac{\partial \pi_t}{\partial r_{bt}}\frac{dr_{bt}}{d\mu_t} = 0 \quad (34a)$$

$$F_{\mu\mu} \equiv -\left[1 - g(K\bar{x})^2\left\{f''(\pi_t)\left(\frac{\partial \pi_t}{\partial r_{bt}}\right)^2 + f'(\pi_t)\left[\frac{N}{c} + 2(1-\tau)^2\frac{d_0}{D}\left(1 - \frac{d_0}{D}\right)\right]\right\} + gK\bar{x}f'(\pi_t)\frac{\partial \pi_t}{\partial r_{bt}}\right] < 0. \quad (34b)$$

Since (from the discussion in section 3) $\partial\pi_t/\partial r_{bt}$ is negative and (from equation (32a)) $dr_{bt}/d\mu_t$ is also negative, the first order condition in equation (34a) implies that the rate of reserve creation by the central bank is positive for *every* possible realization of the intra-period shocks. Thus central bank concern for the stability of the banking system creates an inflationary bias similar to the one produced by the Kydland-Prescott (1977) and Barro-Gordon (1983) employment motive. But there is an important difference. In the case of the employment motive perfect foresight with respect to central bank policies by the public neutralizes any

potential effect of nominal policies on real variables. As explained in the remainder of this section, this is not the case here. The realization by banks of the central bank's policy induces them to charge lower real loan rates and to supply a larger real quantity of credit.

In order to determine the effect of the central bank's policy on the loan market it is necessary to complete the characterization of EB. This is needed to obtain a fully specified solution for Er_b in equation (24a). Banks are aware of the inflationary bias of the Fed and take that into consideration when forecasting the bond rate at the beginning of the period. In particular, they know from equation (29) that

$$B = B_{-1} + dB_F = B_{-1} - dR$$

where dB_F is the amount of bonds purchased by the Fed through open market operations during the period. Using equation (27) and the approximation $e^\mu \cong \mu$, we obtain

$$dR = R_{-1}\mu.$$

Substituting this equation into the previous one and taking expected values,

$$EB = B_{-1} - R_{-1}E\mu = B_{-1} - R_{-1}gEf'(\pi)\frac{\partial \pi}{\partial r_b}\frac{\partial r_b}{\partial \mu} < B_{-1}. \quad (24b)$$

The last equality follows by rearranging the first order condition in equation (34a) and by taking expected values.[25] The inequality follows from the inflationary bias of the central bank. Equation (24b) implies that in the absence of expected changes in the supply of bonds from non-central bank sources, private banks expect the Fed to purchase some of the existing debt because of the Fed's concern for the stability of the banking system. Note that the *higher* this concern relative to the concern for price stability, the larger g and the lower EB. But a lower expected stock of bonds leads (through equation (24a)) to a lower expected real bond rate and (through equation (22)) to a lower loan rate and to a higher volume of commercial loans. The upshot is that the inflationary bias of the central bank produces a permanent downward effect on loan rates and that this effect is stronger the higher g. This effect is permanent in spite of the fact that the Fed's ability to affect real rates is limited only to the time interval over which the price level is fixed. The reason is that the central bank has this bias in every period and is known by banks to have it when they set their loan rates at the beginning of each period.

Thus, in contrast to the employment motive that only gives rise to an inflation bias but does not affect real variables, the financial stability motive induces *both* an inflationary bias and an expansion in the real quantity of loans.

6. An Explanation for the Fed's Tendency To Smooth Interest Rates

We saw in section 2 that an unexpected intra-period decrease in the demand for deposits or an increase in the bond rate due to an upward shock to the supply of bonds or a downward shock to the demand for bonds decreases the profits of the banking industry. When profits are lower the likelihood of bank failures is larger and the marginal value to the Fed of an incremental increase in the profits of the banking industry is larger. The Fed is, therefore, more willing to tolerate larger increases in bank reserves, even if they increase the rate of inflation provided the decrease in profits is thereby attenuated.

But, as explained in section 4, the Fed can dampen the short-run decrease in banks' profits by stepping up the rate of reserve creation, thereby decreasing the bond rate and the deposit rate (see equations (32a) and (10a)). The Fed's tendency to follow such a policy is stronger when unanticipated shocks to financial markets raise the bond rate and the deposit rate and concurrently decrease profits. On this view the Fed has no long-term concern about the level of interest rates per se. However, due to the short-run negative correlation between the bond rate and the profits of the banking industry, the Fed at least partially offsets unanticipated increases in interest rates in order to dampen the adverse effect that such increases have on the profits and the stability of the banking system. This is consistent with the minutes from the February 1963 report of the Federal Advisory Council (FAC) to the Board. The FAC advised the board that "the principal thesis of the Council's thinking was that bankers would accommodate to almost any policy of restraint when it was applied gradually, but that sudden twists caused serious dislocations" (Woolley, 1984, p. 118, footnote 9).

Conversely, when unanticipated shocks decrease interest rates and increase the profits of banks, the value to the Fed of further increases in profits is diminished. It therefore puts more emphasis on reducing the rate of inflation by reducing the rate of reserve creation below its mean value. As a result, the decrease in interest rates is not as large as it would have been without an active policy on the part of the Fed.

The upshot is that the central bank smoothes short-run fluctuations in real rates. When shocks push rates unexpectedly above their mean level, the bank steps up the rate of reserve creation and dampens the increase in rates. When shocks decrease rates below their mean level, the bank slows down the rate of reserve creation and dampens the decrease in rates.

We turn now to a more precise demonstration of those intuitive results. In order to gain a better understanding of the processes involved, it is convenient to examine first the response of the Fed to each shock in isolation. Consider the Fed's response to an unanticipated shock to the excess demand for bonds, ε_b. Performing a comparative statics experiment with respect to ε_b on the central bank's first order condition in equation (34a) and evaluating the resulting change in the rate of growth of reserves at the no-shocks equilibrium, we obtain[26]

$$\frac{d\mu}{d\varepsilon_b} = \frac{NgK^2\bar{x}}{-F_{\mu\mu}}\Bigg[f''(\pi)N\Bigg\{\frac{r_b}{c} + 2(1-\tau) \cdot \left(1-\frac{d_0}{D}\right)\frac{d_0}{DN}\Big((1-\tau)d_0 r_b + A_d\Big) - \ell^p\Bigg\} + f'(\pi)\left\{\frac{1}{c} + \frac{2}{N}(1-\tau)^2\frac{d_0^2}{DN}\left(1-\frac{d_0}{D}\right)\right\}\Bigg]. \tag{35}$$

Since $-F_{\mu\mu}$ is positive by the second order condition in equation (34b), the sign of this expression depends on the sign of the bracketed expression which is negative if and only if

$$\theta \equiv \left|\frac{f''(\pi)}{f'(\pi)}\right| > \frac{\frac{1}{c} + \frac{2}{N}(1-\tau)^2\frac{d_0}{D}\left(1-\frac{d_0}{D}\right)}{N\left[\frac{r_b}{c} + 2(1-\tau)\left(1-\frac{d_0}{D}\right)\frac{d_0}{D}\frac{(1-\tau)d_0 r_b + A_d}{N} - \ell^p\right]^2}. \tag{36}$$

The right-hand side of equation (36) tends to zero as N becomes large and is likely to be small already for a moderately large number of banks. The left-hand side is formally analogous to a coefficient of absolute risk aversion. In the present context it measures how quickly the marginal contribution of additional profits to banks' stability diminishes with the level of profits of the banking industry. It may also be interpreted as reflecting how quickly the marginal "utility" of the Fed from further increases in banks' stability decreases with additional increases in stability. It obviously may reflect a mixture of both elements. The first element is determined by the structure of the economy while the second depends on the preferences of the central bank. We refer to θ as the index of aversion to instability remembering that, in general, it is affected by both the structure of the economy and the preferences of the central bank. The higher θ the quicker the decrease in the marginal utility of profits because of the combined effects of further profits on stability and of more stability on the objectives of the central bank. The condition in equation (36) is satisfied if the index of aversion to instability is sufficiently large. The following proposition summarizes the main qualitative result.

Proposition 1: For a sufficiently large number of banks and/or a sufficiently large index of aversion to instability, the central bank decreases the rate of growth of reserves when the intra-period excess demand for bonds increases. The precise condition appears in equation (36).

Since the condition in (36) is likely to be satisfied even for moderately large values of N and of θ, the rest of the discussion is based on the presumption that it is satisfied and that, therefore,

$$\frac{d\mu}{d\varepsilon_b} < 0. \tag{35a}$$

An immediate consequence of equation (35a) is that the central bank smoothes fluctuations in the bond rate. This can be seen by noting, from equation (15), that a decrease in ε_b raises the bond rate. Equation (35a) implies that the central bank reacts to this increase by stepping up the rate of reserves creation, which from (32a), pushes the bond rate in the opposite direction.

We turn now to the response of the central bank to an unanticipated shock to the demand for deposits. Performing a comparative statics experiment with respect to a change in ε_d on the first order condition in equation (34a), it can be shown that the central bank responds to an increase in ε_d by decreasing μ provided conditions similar to those in proposition 1 are satisifed. The derivation and the precise condition are in part 1 of the Appendix. The main qualitative result is summarized in the following proposition.

Proposition 2: For a sufficiently large number of banks and/or a sufficiently large index of aversion to instability, the central bank responds to an unanticipated increase in the demand for deposits by slowing down the rate of reserves expansion.

Proposition 2 implies that the central bank attenuates fluctuations in the bond rate which are due to unanticipated shocks to the demand for deposits. The argument is similar to that used when the origin of shocks is in the bond market. A decrease in the demand for deposits raises interest rates. The central bank responds, according to proposition 2, by stepping

up the rate of reserve creation thus at least partially offsetting the short-run increase in rates.

In summary, if either of the following holds: (1) The number of banks is large, (2) The index of aversion to instability is sufficiently large,[27]

$$\frac{d\mu}{d\varepsilon_b} < 0, \quad \frac{d\mu}{d\varepsilon_d} < 0 \tag{37}$$

and the central bank smoothes interest rates in the face of short-run shocks to both the bond and deposit markets.

In general, shocks to both the bond and the deposit market may occur simultaneously and not always in the same direction. It is, therefore, not possible to rule out *particular* configurations of shocks for which one of r_b or r_d increases and profits still increase because the other rate decreases by a sufficient amount. However, such cases will not be typical if the correlation between profits and interest rates is negative in the short run. Provided the shocks ε_d and ε_b have symmetric distributions and are independent, the covariance between the profits of the banking industry and the bond rate is[28]

$$\operatorname{cov}(\pi, r_b) = -N\left[\ell^p + \frac{r_b^*}{c}\right]\operatorname{Var}(r_b) \tag{38}$$

where Var (r_b) is the intra-period variance of the bond rate around its no-shocks value, r_b^*. Since the real bond rate is usually positive, the expression in equation (38) is negative, confirming that, in the absence of intervention, the profits of the banking industry are negatively correlated with the bond rate.[29]

In general, the Fed responds to a combination of the shocks ε_b and ε_d. If the realization of shocks changes profits in a given direction, the Fed responds by altering the rate of change of reserves so as to move the bond rate in the same direction. Since, in the absence of intervention, profits and the bond rate are negatively correlated, this implies that, on average, the Fed acts so as to dampen fluctuations in r_b. Equations (37) and (32a) imply that the Fed responds to an increase in either of ε_b or ε_d by moving the short-term bond rate in a direction that is opposite to the effect of these shocks on the bond rate in the absence of intervention. This is formalized by the Fed's response function,

$$R(\varepsilon_b, \varepsilon_d),$$

that appears as one of the determinants of the equilibrium short-term bond rate in equation (15). Since, in the absence of intervention, the effect of increases in ε_b and in ε_d on r_b is negative, the partial derivative of $R(\cdot)$ with respect to either argument is positive. Hence the main result of the article, stated in terms of equation (15), is that the effects of ε_b and ε_d on r_b through the Fed's response function are opposite in sign to the direct effects of those shocks on r_b.

Note that the existence of a non-zero correlation between ε_b and ε_d does not alter the fact that the central bank needs to intervene. But the sign and magnitude of the correlation affects the extent of intervention. A positive contemporaneous correlation between ε_b and ε_d is likely to increase the necessity for the Fed's intervention while a negative one is likely to reduce it. However, except for the extreme case in which movements in ε_b and in ε_d, in the absence of intervention, exactly offset each other, leaving the profits of the banking system unaltered, some intervention is necessary. A sufficiently high degree of negative correlation between the shocks may alter the sign of the partial derivatives of $R(\cdot)$. On the other hand, positive serial correlation between ε_b and ε_d reinforces the likelihood that the partial derivatives of $R(\cdot)$ are positive. Provided the shocks ε_d and ε_b are mostly affected by common disturbances to the supply of funds, the second case seems more likely.

As noted above, the hypothesis about the Fed's behavior embedded in equation (28) reflects a basic externality. Each financial institution cares only about its own profits, but the Fed is concerned about the profitability of the entire system. Hence when there is an unexpected cumulation of losses across a number of financial institutions, the Fed's reaction can be expected to be more vigorous. In order to see this effect in isolation, suppose that the profits of the entire banking system in equation (13) are unexpectedly reduced by an exogenous amount L. To determine the central bank's reaction to this event, we perform a comparative statics experiment with respect to L on the first order condition in equation (34a). The resulting expression is:

$$\frac{d\mu}{dL} = \frac{g}{F_{\mu\mu}} f''(\pi) \frac{\partial \pi}{\partial r_b} \frac{dr_b}{d\mu}.$$

Since $\partial\pi/\partial r_b < 0$ and $F_{\mu\mu} < 0$ by the second order condition in equation (34b), this expression is positive. Hence an accumulation of unexpected losses across wide segments of the financial system induces the central bank to expand high-powered money at a higher rate. This result may have some power in explaining recent monetary accelerations as being partially due to the arrival of new information about the magnitude of losses in the thrift industry.

7. Implications for the Procyclical Behavior of Money Growth and the Time Series Characteristics of Nominal Rates

The shock ε_b to the excess demand for bonds may be taken as a proxy for the cyclical position of the economy. When it is negative, there is an excess supply of bonds due to high cyclical activity. Conversely, a positive value of ε_b is associated with low cyclical activity. Since, from equation (37), the central bank steps up the rate of reserve creation, μ, when ε_b is negative and reduces it when ε_b is positive, the behavior of μ is procyclical. There is evidence that base money growth in the United States behaves procyclically (Rasche, 1988). ε_b can also be interpreted as a seasonal shock to the demand for liquidity of the type that induced financial panics in the pre-Fed era (Donaldson, 1989b).

Miron (1986) and Mankiw, Miron, and Weil (1987) find that after the creation of the Fed, short-term nominal rates became nearer to random walks than prior to that time. Friedman and Schwartz (1963, p. 293) report a similar phenomenon. To examine whether this change could have been caused by the Fed's concern for the profits and the stability of the financial system, I compare the behavior of the nominal bond rate in the presence of central bank intervention with its behavior in the absence of intervention. From equation (15) the short-term nominal bond rate in the presence of intervention is[30]

$$n_b^I = r_b^I + E^I\mu = K\left[\frac{E^I B}{P^{pI}} + N\ell^{pI} - \left(\varepsilon_b + (1-\tau)\left(1 - \frac{d_0}{D}\right)\varepsilon_d\right)\right] + R(\varepsilon_b, \varepsilon_d) + E^I\mu \tag{39a}$$

where the superscript "I" designates equilibrium values in the presence of interest rate smoothing by the central bank. In the absence of intervention the reaction function $R(\cdot)$ vanishes and there is no systematic expectation of inflation—the expected value of μ is zero. Hence without a central bank the equilibrium value of the nominal bond rate is

$$n_b = r_b = K\left[\frac{EB}{P^p} + N\ell^p - \left(\varepsilon_b + (1-\tau)\left(1 - \frac{d_0}{D}\right)\varepsilon_d\right)\right] \tag{39b}$$

where, only in this section, variables that do not carry the index I denote the equilibrium values of these variables in the absence of any intervention by the central bank.

Since the shocks ε_b and ε_d are transitory, the expected values of n_b^I and of n_b conditional on the realizations of those shocks are, respectively,

$$K\left[\frac{E^I B}{P^{pI}} + N\ell^{pI}\right] + E^I\mu \tag{40a}$$

$$K\left[\frac{EB}{P^p} + N\ell^p\right]. \tag{40b}$$

In order to judge whether one time series is more nearly a random walk than another, it is necessary to specify an index of nearness to a random walk. I use as a measure of the nearness of a time series to a random walk the absolute value of the difference between the current state of the series and its predicted value given the current state. For a random walk this index is zero, and it increases monotonically as the series departs more from a random walk. From equations (39) and (40) this measure, with and without intervention, respectively, is:

$$\left|-K\left[\varepsilon_b + (1-\tau)\left(1-\frac{d_0}{D}\right)\varepsilon_d\right] + R(\varepsilon_b, \varepsilon_d)\right| \tag{41a}$$

$$\left|K\left[\varepsilon_b + (1-\tau)\left(1-\frac{d_0}{D}\right)\varepsilon_d\right]\right|. \tag{41b}$$

Since the partial derivatives of $R(\cdot)$ are both positive, the index of nearness to a random walk is always smaller in the presence of interest rate smoothing than in its absence.[31] The upshot is that the theory presented in this article is consistent with the change that occured in the time series properties of short-term interest rates after the creation of the Fed as reported in Miron (1986) and Mankiw, Miron, and Weil (1987).

Strictly speaking, this result has been demonstrated only for the case in which exogenous shocks are white noises. However, I believe that, as long as the Fed smoothes only purely transitory movements in interest rates, the same argument extends to a wide variety of specifications for the exogenous shocks. When the shocks have some predictable persistence, the forecasts in equations (40) incorporate this persistence. Since the Fed smoothes out only purely transitory shocks, its reaction function still depends only on terms like ε_b and ε_d which now have to be interpreted as the transitory parts of the exogenous shocks. Subject to this reinterpretation equations (41) remain the same and the previous argument extends to the more general specification.[32]

8. Extension to the Case of Credit Lines

To this point the analysis was based on the assumption that the entire volume of loans is predetermined before the realization of shocks during the period of the loan. In practice part of banking credit takes the form of credit lines in which borrowers are free to determine the actual amount borrowed, up to a predetermined ceiling, after the realization of shocks (Brady, 1985).

This section examines the robustness of the main result of the article to this alternative form of loan contract. Specifically it is assumed now that banks passively accommodate any intra-period changes in the demand for loans at the loan rate which was set at the beginning of the period.

The main difference between this framework and the previous one is that now shocks to the demand for loans affect the ex post profitability of the banking industry in addition to shocks to the bond and deposit markets. The loan rate is still determined by solving the problem in equation (19). Before shocks realize $E\varepsilon_\ell = 0$. Hence the ex ante maximization problem with lines of credit is formally equivalent to the same problem when loan volume is determined ex ante and the equilibrium loan rate for both problems is given by equation (22). The difference is that now the volume of intra-period loans is determined by the ex post demand for loans instead of being equal to ℓ^p from equation (24) as was previously the case. Equation (10a) still represents the ex post equilibrium level of r_d.

The ex post equilibrium demand for bonds by the individual bank is given by equation (10b) with ℓ^p replaced by

$$\ell(r_\ell^p, r_\ell^p, 2_\ell) = \frac{A_\ell + \varepsilon_\ell - \ell_0 r_\ell^p}{N}. \tag{42}$$

Similarly the expression for total profits of banks in equation (13) remains the same except that ℓ^p is replaced by the expression in (42). As a consequence, profits become dependent on the shock, ε_ℓ, to the demand for loans. Since the intra-period demand for bonds by banks depends now on ε_ℓ, the bond rate becomes a function of ε_ℓ, too. The precise relation between r_b and ε_ℓ is obtained by substituting equation (42) instead of ℓ^p in equation (15). An intra-period increase in the demand for loans increases the bond rate. The reason is that banks have to supply a larger demand for credit. This reduces their liquidity. They partially restore liquidity by reducing their bond portfolios. This pushes the bond rate up.

If the loan rate is larger than the bond rate, an unexpected increase in the demand for loans generally has an ambiguous effect on the profits of the banking system. On one hand, profits are squeezed, as in the previous case, because of the increase in the bond rate brought about by the larger demand for loans. On the other hand, since $r_\ell^p > r_b$, a substitution of loans for bonds increases profits. However, for a sufficiently large number of banks the negative effect on profits is likely to dominate. Details appear in part 3 of the Appendix. We shall therefore proceed under the presumption that

$$\frac{d\pi}{d\varepsilon_\ell} = \frac{\partial\pi}{\partial\varepsilon_\ell} + \frac{\partial\pi}{\partial r_b}\frac{\partial r_b}{\partial\varepsilon_\ell} < 0. \tag{43}$$

The maximization problem of the central bank and the corresponding first and second order conditions remain as in equations (28a) and (34) except that banks' profits now also depend on the realization of the shock ε_ℓ. Totally differentiating the first order condition of the central bank in (34a) with respect to ε_ℓ, evaluating at the no-shocks equilibrium, and rearranging

$$\frac{d\mu}{d\varepsilon_\ell} = \frac{gK\bar{x}}{F_{\mu\mu}}\left[f''(\pi)\frac{\partial\pi}{\partial r_b}\frac{d\pi}{d\varepsilon_\ell} + f'(\pi)\left(\frac{\dfrac{N}{c} + (1-\tau)^2 d_0\left(1 - \dfrac{d_0}{D}\right)\dfrac{2d_0}{D}}{\dfrac{N}{c} + (1-\tau)^2 d_0\left(1 - \dfrac{d_0}{D}\right) + s_0} - 1\right)\right]. \tag{44}$$

$F_{\mu\mu} < 0$ by the second order condition. Equation (43) implies that the first term in brackets on the right-hand side of (44) is negative. Since $2d_0/D < 1$ and $s_0 > 0$, the second term is negative, too. Hence

$$\frac{d\mu}{d\varepsilon_\ell} > 0. \tag{45}$$

The central bank responds to the increased demand for credit by increasing the rate of reserves creation. It thereby, at least partially, offsets the upward effect of this increased demand on the bond rate. The bank's attempt to preserve the profits of the banking industry within a "reasonable range" induces it to accommodate changes in credit demand.

The upshot is that the major result of the article—that the central bank smoothes fluctuations in interest rates—extends to the case in which credit is allocated to customers via credit lines. As a matter of fact, in the presence of credit lines, the bank smoothes fluctuations in interest rates that are due to shocks to the loan market as well as to shocks to the bond and deposit markets. Since shocks to the demand for credit are positively correlated with the cycle, the procyclical response of reserves growth is amplified by the existence of credit lines.

8. Concluding Remarks

The explanation for the Fed's tendency to dampen fluctuations in interest rates relies on the presumption that the interest rate on all loan contracts is

determined prior to the determination of the cost of funds to banks. The assumption that this contractual arrangement applies to *all* loans is made for simplicity and is not essential. Even if the interest rate on *part* of bank loans is adjusted simultaneously with changes in the cost of funds, the Fed will have an incentive to smooth interest rates provided the fraction of loans with predetermined rates is sufficiently large. This observation implies that the incentive of the Fed to engage in interest rate smoothing depends on the degree of inflexibility in the terms of banks' loans. In particular when, other things the same, a larger fraction of credit is marketed via variable rates loans, the central bank's tendency to smooth interest rates diminishes. But since the correlation between the rate to which variable rate loans are indexed and the cost of funds to banks is not perfect, the incentive to smooth rates does not disappear.[33]

A basic implication of this article is that financial instability is more likely when interest rates rise. This is consistent with the evidence in table 1 of Donaldson (1989a) who finds that in the pre-Fed era interest rates rose to very high levels during financial panics.[34]

Some concern of the central bank for banks' profits can always be justified on the ground that sufficiently high profits are necessary for the stability of the banking system. But the intensity of this concern (measured by g in equation (28)) may also be due to "captive regulator" elements in the motives of the central bank. Such motives tend to strengthen the tendency toward interest rate smoothing. In any case this article has no implications for the extent to which the policy of interest rate smoothing followed by the Fed is due only to its concern for the public interest or also to "captive regulator" elements. Woolley (1984) attributes some weight to such elements, particularly during the early seventies.

The analysis in this article abstracted from the required reserve ratio as an instrument of short-run policy first because it is seldom used as such by the Fed. This raises an interesting question concerning the reason for such allocation of instruments. A probable answer is that the impact of open market operations on interest rates and banks profits is more immediate and clearcut than that of changes in reserve requirements that affect the financial system with a lag. In addition, reserve requirements are not as flexible as open market operations since their span is limited to the positive range ($\tau \geq 0$).

In order to maintain the analytic framework within managable proportions we have abstracted from possible dependencies between the demand for loans and deposits at the individual bank (Cukierman, 1978). We have also abstracted from the difference between borrowed and unborrowed reserves. This distinction, following the useful analysis in Goodfriend (1982), could probably be incorporated in the framework of this article.

However, it is unlikely that such extensions will alter the basic result of the article.

Note that the controversy about whether the business cycle is largely due to monetary factors (Friedman and Schwartz, 1963) or to real factors (Plosser, 1990) does not affect the arguments in this article. The reason is that interest rate smoothing and an inflationary bias of policy arise as a consequence of the interaction between the Fed and the banking system even in the absence of a short-run Phillips curve.

In closing, note the following interesting implication of the article's framework: an unexpected increase in the supply of bonds by the federal government to finance an increase in the budget deficit triggers (by raising the bond rate) increased monetization by the monetary authority in the short run. Again, this is due to the concern this authority has for the stability of the banking system.

Notes

1. See, for example, *Federal Reserve Bulletin* (July 1984, p. 548). Bernanke (1983) argues persuasively that financial crises retard capital formation, thereby inducing a real output cost.

2. The fraction of credit marketed through such contracts was even larger prior to the acceleration of inflation in the seventies.

3. The maturity of demand deposits and of money market accounts is obviously at the continuous discretion of depositors.

4. A bank normally has to invest some resources in gathering information about a borrower before granting a loan. No similar investment is necessary in order to accept a deposit.

5. The rise in costs partially reflects the increasing difficulties of borrowing successively larger amounts at the discount window.

6. This is consistent with Woolley's (1984, p. 72) observation that bankers care little about the ease or tightness of monetary policy as long as they are not caught by surprise.

7. See Brady (1985).

8. Due to locational and other idiosyncratic characteristics.

9. A similar device has been used in Brunner, Cukierman, and Meltzer (1983). A totally different view of the origin of the Fed's ability to affect interest rates is presented by Goodfriend (1987). In Goodfriend's model the price level adjusts instantaneously to always clear the money market. In his model the central bank affects the nominal interest rate by changing the expected rate of inflation. This is done by altering the current price level for a given expected future price level. By contrast here the short-run fixity of the price level enables the central bank to temporarily affect both the real and the nominal short-term rates in the short run. Shiller (1980) presents evidence that supports the view that the Fed has some temporary influence on short-term real rates.

10. This asymmetry is due to the fact that borrowers need to know the period for which funds are available with certainty in advance while depositors prefer to retain as much flexibility as possible.

11. The banking industry model is a variant of the model in Cukierman and Sokoler (1988).

12. The case in which, due to the existence of credit lines, banks passively accommodate fluctuations in the demand for credit after the realization of shocks is discussed in section 8.

13. Treasury bills and other good quality short-term paper are the most frequently used real-life counterparts of the "bonds" in the model (Tobin, 1982).

14. Equation (8b) confirms that if $r_b > 0$ the costs of illiquidity are positive in the individual bank's equilibrium.

15. The solution for b incorporates the assumption that the ex ante Nash equilibrium which determines the amount of loans given out at the beginning of the period is also symmetric. It also incorporates the assumption that this solution occurs in the non-negative range of b. Details appear in section 4.

16. Again, use has been made of the fact that the ex ante equilibrium is also symmetric. See also previous note. Note, however, that in spite of the symmetry of both the ex ante and the ex post equilibria, profits may differ across banks due to different realizations of the idiosyncratic default shocks u_i.

17. For $N = 1{,}000$ and $d_0 = 100$, d_0/D is equal to 0.0001.

18. Letting the time index t refer to within-period realizations of shocks, a more explicit form for this expectation is $E_{t-1}B_t$ since at the beginning of period t only the realization of period's $t - 1$ shocks are known. The more explicit notation is utilized in section 5.

19. This specification abstracts from the existence of cash.

20. Incomplete information by the central bank about the realizations of the $u_i - s$ and of profits across individual banks makes it difficult to apply bank specific measures and increases the reliance of the central bank on industrywide measures to preserve profits. Even if the realizations of the $u_i - s$ were known to the central bank, the latter may find it preferable and more in the spirit of free markets to use industrywide instruments rather than bank-specific interventions. Brimmer (1989) argues that except under extraordinary circumstances, the Fed prefers generalized to specific measures.

21. To focus on the consequences of the interaction between the central bank and the private banking system in isolation, we abstract from other possible motives for inflation like the employment and the revenue motives.

22. In a model with cash this will be the case if the real demand for cash is constant. A more general formulation could incorporate leakages into cash, but it is unlikely that this would alter the main qualitative result of the article.

23. The demonstration follows: from (26a) $P_t^p = \exp[\ln R_{t-1} + E\mu_t - \bar{x}]$. By definition $R_{t-1} = \exp[\ln R_{t-1}]$. Substituting those two terms into (32) and rearranging, we obtain (32a).

24. An elaboration of this statement appears later.

25. Note from equation (26a) and (27) that $\ln P_{t+1} - \ln P_t = \ln \dfrac{R_t}{R_{t-1}} = \mu_t$.

Hence the expected rate of inflation is also equal to $E\mu$ and the nominal loan rate is equal to $r_\ell^p + E\mu$.

26. Since there is no danger of confusion, the time index t is omitted. Evaluation of the derivative in (35) at the no-shock equilibrium is strictly correct for small shocks. For large shocks the expression in (35) also depends on ε_d, ε_b and on the actual rate of growth of reserves, but the general qualitative results are similar.

27. Note that either condition alone may be sufficient for the result in (37) and interest rate smoothing.

28. The covariance is evaluated around the no-shocks value of π and r_b in the absence of central bank intervention. Details appear in part 2 of the Appendix.

29. When ε_b and ε_d are positively correlated, the following additional expression appears on the right-hand side of (38):

$$\frac{\frac{2d_0}{D}\left(1 - \frac{d_0}{D}\right)(1 - \tau)}{\left[\frac{N}{c} + (2 - \tau)^2 d_0\left(1 - \frac{d_0}{D}\right) + s_0\right]^2}\left[\frac{E\varepsilon_d\varepsilon_b^2}{(P^p)^2} + \frac{2(1 - \tau)}{P^p}\left(1 - \frac{d_0}{D}\right)E\varepsilon_b\varepsilon_d^2\right].$$

But for a sufficiently large number of banks it is dominated by the negative terms in (38).

30. The first order condition in (34a) implies that (omitting the time index)

$$E'\mu = gEf'(\cdot)\frac{\partial \pi}{\partial r_b}\frac{dr_b}{d\mu}.$$

Since $f'(\cdot) > 0$, $\partial\pi/\partial r_b < 0$, and $dr_b/d\mu < 0$ this expression is positive.

31. In this context "always" means of all possible realizations of ε_b and ε_d except the case for $\varepsilon_b = \varepsilon_d = 0$ for which the indices for the two regimes trivially coincide.

32. If, for example, the typical shock is specified as a first order Markoff process, $v_{t+1} = \rho v_t + \eta_t$, the predictable persistent part as of period t is ρv_t and the purely transitory part is $(1 - \rho)v_t$.

33. Financial institutions can also partially hedge their net maturity position through the use of future markets. However, some residual risk usually remains since available standardized future contracts are not fully tailored to meet the idiosyncratic hedging needs of individual banks.

34. See also Donaldson (1989b).

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APPENDIX

1. Comparative statics with respect to ε_d and precise characterization of the conditions underlying proposition 2.

Totally differentiating the first order condition in (34a) with respect to ε_d, evaluating at the no-shocks equilibrium, and rearranging

$$\frac{d\mu}{d\varepsilon_d} = \frac{gK\bar{x}}{F_{\mu\mu}}(1-\tau)\left(1-\frac{d_0}{D}\right)\left[f''(\pi)\frac{\partial\pi}{\partial r_b}Z_1 + f'(\pi)Z_2\right] \qquad \text{(A1a)}$$

$$Z_1 \equiv \frac{2}{D}\left(d_0 r_b + \frac{A_d}{1-\tau}\right) - K\frac{\partial\pi}{\partial r_b} \qquad \text{(A1b)}$$

$$Z_2 \equiv \frac{2d_0}{D} - \frac{\dfrac{N}{c} + \dfrac{2d_0^2}{D}(1-\tau)^2\left(1-\dfrac{d_0}{D}\right)}{\dfrac{N}{c} + d_0(1-\tau)^2\left(1-\dfrac{d_0}{D}\right) + s_0}\, r. \qquad \text{(A1c)}$$

Since $F_{\mu\mu} < 0$, $d\mu/d\varepsilon_d < 0$ if and only if the expression in brackets on the right-hand side of ($A1a$) is positive. Provided $r_b > 0$ and the demand for deposits at a zero deposit rate is positive $Z_1 > 0$ since $\partial\pi/\partial r_b < 0$. Hence a necessary and sufficient condition for $d\mu/d\varepsilon_d < 0$ is

$$\theta \equiv \left|\frac{f''(\pi)}{f'(\pi)}\right| > \frac{Z_2}{Z_1 \dfrac{\partial \pi}{\partial r_b}}. \tag{A2}$$

The denominator of this expression is negative. By using the definition of D and rearranging, it can be shown that

$$Z_2 \gtreqless 0 \text{ as } N^2(N-1) \lesseqgtr 2\frac{d_0}{d}\frac{s_0}{c}. \tag{A3}$$

If $N^2(N-1) \leq 2\dfrac{d_0 s_0}{d\, c}$ the condition in (A2) is always satisfied since in this case the right-hand side of (A2) is either negative or zero. If N is large enough to make $N^2(N-1) > 2d_0s_0/dc$, the right-hand side of (A2) is positive. However, for a sufficiently large N the right-hand side of (A2) tends to zero from above so that even if θ is moderately large the condition in (A2) is satisfied. This can be seen by using equation (14) and (16b) to rewrite the right-hand side of (A2) as

$$\frac{Z_2}{Z_1 \dfrac{\partial \pi}{\partial r_b}} = \frac{1}{N} \cdot \frac{\dfrac{2d_0}{D} - \dfrac{\dfrac{1}{c} + \dfrac{2(1-\tau)d_0}{D}g(N)}{\dfrac{1}{c} + (1-\tau)g(N) + \dfrac{s_0}{N}}}{\left(\dfrac{1}{c} + \dfrac{2(1-\tau)d_0}{D}g(N)\right)r_b + 2\dfrac{A_d}{D}g(N) - \ell^p}$$

$$\cdot \frac{1}{\dfrac{2T}{D} - \dfrac{\left\{\dfrac{1}{c} + \dfrac{2(1-\tau)d_0}{D}g(N)\right\}r_b + 2\dfrac{A_d}{D}g(N) - \ell^p}{\dfrac{1}{c} + (1-\tau)g(N) + \dfrac{s_0}{N}}} \tag{A4}$$

where

$$g(N) \equiv \frac{d_0}{N}(1-\tau)\left(1 - \frac{d_0}{D}\right); \quad T \equiv d_0 r_b + \frac{A_d}{1-\tau}.$$

When N becomes large, $g(N)$ tends to zero and the last two terms on the right-hand side of (A4) tend to

$$\frac{1}{\left(\dfrac{r_b}{c} - \ell^p\right)^2}$$

while $1/N$ tends to zero. Hence for N sufficiently large (A4) tends to zero from above so that condition (A4) is satisfied even for small values of θ.

2. Derivation of the covariance in equation (38)

Let π^*, r_b^* be the values of π and r_b at the no-shocks equilibrium. From (13) and (15)

$$\pi^* = (r_\ell^p - r_b^*)\,N\ell^p + \frac{1}{D}\left(1 - \frac{d_0}{D}\right)[(1-\tau)d_0 r_b^* + A_d]^2 + \frac{N}{2c}(r_b^*)^2. \tag{A6}$$

By definition

$$\operatorname{cov}(\pi, r_b) \equiv E(\pi - \pi^*)(r_b - r_b^*). \tag{A7}$$

Equation (38) is derived by using (13) and (A6) in (A7), rearranging and using the statistical independence of ε_b and ε_d and the fact that $E\varepsilon_b^3 = E\varepsilon_d^3 = 0$ by symmetry of the distributions of ε_d and of ε_b.

3. Demonstration that an increase in ε_ℓ reduces banks' profits if the number of banks is sufficiently large

Replacing ℓ^p in equation (13) with the expression from equation (42) and differentiating totally with respect to ε_ℓ

$$\frac{d\pi}{d\varepsilon_\ell} = \frac{\partial \pi}{\partial \varepsilon_\ell} + \frac{\partial \pi}{\partial r_b}\frac{\partial \pi_b}{\partial \varepsilon_\ell}$$

$$= r_\ell^p - r_b + \frac{\left(\dfrac{1}{c} + \dfrac{2(1-\tau)d_0}{D}g(N)\right)r_b + \dfrac{2}{D}g(N)(A_d + \varepsilon_d) - \ell(r_\ell^p, r_\ell^p, \varepsilon_\ell)}{\dfrac{1}{c} + (1-\tau)^2\dfrac{d_0}{N}\left(1 - \dfrac{d_0}{D}\right) + \dfrac{s_0}{N}} \tag{A8}$$

For N sufficiently large this expression tends to

$$\lim_{N\to\infty} \frac{d\pi}{d\varepsilon_\ell} = r_\ell^p - r_b - c\,\ell(r_\ell^p, r_\ell^p, \varepsilon_\ell). \tag{A9}$$

Obviously if $r_\ell^p \leq r_b$ this expression is unambiguously negative. However, even when $r_\ell^p > r_b$ it is likely to be negative if the costs of illiquidity as measured by c are not negligible. For $c = 1$, for example, the expression in (A9) is negative provided:

$$\ell(r_\ell^p, r_\ell^p, \varepsilon_\ell) > r_\ell^p - r_b.$$