Should Banks Create Money?*

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Abstract

How costly are proposals like 100% reserves narrow banking or a system with a central bank digital currency, which constrain private banks' ability to issue deposits in excess of their reserve holdings? The paper shows that in contrast to widespread concerns, 100% reserve banking or a central bank digital currency must not increase loan rates and thus crowd out private intermediation if banks have viable financing alternatives to deposits. Instead, the welfare costs of such proposals mainly arise from lower interest payments on deposits, which protect deposit holders less well against inflation. The model calibrated to the US economy suggests however, that these costs are relatively small.

Keywords: *Fractional reserve banking, money supply, narrow banking, CBDC*

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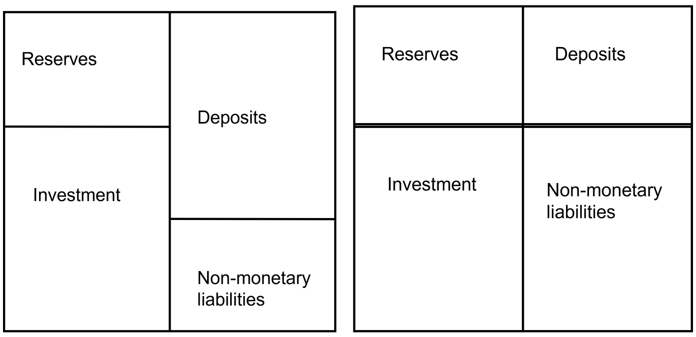
1 Introduction

Current monetary systems are characterized by a mixture of public and private provision of means of payment. Households and firms primarily pay using digital liabilities of private financial intermediaries, mainly demandable bank deposits. Banks themselves settle these transactions with digital reserves issued by the central bank, to which non-banks don't have access. Typically banks "create money", i.e. they issue deposits in excess of their reserve holdings and operate under fractional reserve banking (FB). This traditional division of labor has been increasingly debated in recent years. The Swiss "Vollgeld" referendum in June 2018 for instance, wanted to prohibit private money creation by forcing banks to fully back their deposits with reserves, i.e. to introduce a 100% reserves banking system. Less drastic central bank digital currency (CBDC) proposals want the central bank to offer digital money also to non-banks. This indirectly constrains the issuance of bank deposits as banks face competition from a CBDC. Both proposals belong to a broader debate on narrow banking (NB), i.e. the idea that financial intermediaries fully backing their demandable or very short term debt with very safe and liquid assets should play a greater role in the financial system.[1]

Figure 1: Fractional and 100% reserves banking



(a) Fractional reserve banking (b) 100% reserves banking

To better understand the implications of such proposals, the paper compares FB to the benchmark case of a 100% reserves NB system, as illustrated in figure 1. The focus is on the question how costly it is to constrain FB or private money creation, abstracting from financial stability issues.[2]

[1] Pennacchi (2012) provides a good overview on NB and Auer et al. (2021) on CBDC proposals. 76 central banks currently explore CBDCs and more than 50 are running concrete experiments (Kosse and Mattei, 2022). The central bank might issue CBDC indirectly over specially regulated narrow banks as in Williamson (2022), or directly as digital official fiat currency. How "narrow" the financial system becomes with a CBDC, depends on how much non-banks substitute deposits for CBDC. In the extreme, i.e. if they completely switch from deposits to CBDC, a system with a CBDC is equivalent to a full NB system like 100% reserves.

[2] That the FB financing arrangement creates the possibility of self fulfilling bank runs and financial instability, has been well understood and extensively studied since the seminal paper by Diamond and Dybvig (1983). By eliminating interest rate and liquidity risk 100% reserve banking prevents these runs at least for the payment system. The efficiency benefits of FB on the other hand are less clear. While Brunnermeier and Niepelt (2019) or

A widespread concern, e.g. studied by Keister and Sanches (2022), Chiu et al. (2023) or Williamson (2022) in the CBDC context, is that constraining FB leads to disintermediation, i.e. a crowding out of private investment and lending. Figure 1 illustrates this idea with the stylized financial sector balance sheets in the two monetary systems. FB essentially means that monetary liabilities or deposits also finance investment or lending. This is not possible with 100% reserves banking, so banks need to replace deposit financed investment with non-monetary liabilities. Since deposits are typically cheaper due to their liquidity premium, this increase in funding costs might increase loan rates and decrease investment.

The paper studies the potential benefits of FB using a monetary general equilibrium model building on Lagos and Wright (2005), calibrated to the US economy. Concretely, the model adds FB and bank market power in the deposit market following Chiu et al. (2023) to the framework of Berentsen et al. (2007), which, as the paper shows, can be interpreted as a NB economy.[3] Money demand comes from households, who work and acquire money to buy consumption goods. Each period they face liquidity shocks, which divide them into savers, who don't need money, and borrowers, who need more. Financial intermediaries or banks intermediate between these needs. They lend to borrowers, issue liquid deposits subject to a reserve requirement and illiquid bonds. While deposits can circulate as means of payment, bonds – by assumption – cannot. They thus play the role of the non-monetary liabilities in figure 1 and can be interpreted as longer-term saving deposits or wholesale funding. Usually banks want to issue as many deposits as they can, so the reserve requirement binds and also determines the monetary system. If the reserve requirement is fractional, banks issue more deposits than reserves and we have a FB system. If the reserve requirement is full, we have a 100% reserves NB system. Finally, a central bank issues potentially interest bearing reserves, which can also circulate as money, controls inflation and the nominal interest rate. Households and banks have both access to reserves, so they can also be interpreted as a CBDC, in particular if they are interest bearing. The central bank sets an inflation rate above the Friedman rule, i.e. holding money is costly, which is the basic inefficiency in the model.

The model provides 3 main insights. The first is to provide a different explanation for the benefits of FB, which does not rely on the usual disintermediation argument. The basic idea is that sufficiently competitive FB provides a means of payment with a higher return than a NB system.

Pennacchi (2012) argue FB has no benefits that could not be obtained within a carefully designed NB system, others like Ceccetti and Schoenholtz (2014) believe FB is essential to banking and increases investment and intermediation. The fact that FB dominates monetary history also suggests a socially useful function. However, Chari and Phelan (2014) show an inefficient FB system can also persist over time due to pecuniary externalities.

[3]Other New Monetarist models with FB include He et al. (2008), Sanches (2016) and Lee (2021). The purpose of imperfect competition is mainly to generate a realistic spread between the deposit rate and the nominal interest rate in the quantitative part. The basic qualitative results also hold in a perfectly competitive model.

As highlighted above, under FB banks fund loans with deposits while under NB they fund them with bonds. Since loans have a higher return than reserves, banks have a higher income on their asset side under FB than under NB. With sufficient competition they pass on this higher income to their liability side in the form of higher interest payments on deposits. This is beneficial because it compensates the deposit holders against inflation.

The second insight is that a NB system like 100% reserves or a system with a CBDC does not necessarily lead to disintermediation in the sense of higher loan rates and lower bank lending. As highlighted in figure 1 the introduction of 100% reserves NB implies a shift from cheap deposit financed lending to more expensive bond financed lending. However, despite this shift the loan rate does not increase in the model, i.e. the disintermediation channel explained above is not at work. The same holds if the central bank issues an interest bearing CBDC. Crucial for this result is that bonds have an essential role in the economy, which is to insure households against the liquidity shocks.[4] In equilibrium the bond rate equals the nominal interest rate, thus savers holding bonds are fully compensated for the inflation tax and bonds provide perfect liquidity insurance. Since bonds are essential banks already use them to finance loans under FB and the loan rate equals marginal costs, i.e. is equal to the nominal interest rate. The full switch to bond financed lending under NB does not change this. The model thus formalizes the idea that NB or a system with a CBDC doesn't affect loan rates too much because financial intermediaries can finance lending and investment with other, less liquid liabilities than deposits. This confirms similar results from partial equilibrium banking models like Whited et al. (2022) from a general equilibrium perspective.

The third insight is that the benefits of FB or the costs of proposals like 100% reserves NB are relatively small. The calibration to the pre-crisis, positive nominal interest period economy of the US 1984–2008 estimates them at around 0.03% of annual GDP. These estimates become more sizeable for higher inflation rates – up to 0.38% of GDP for an inflation rate of 10% and a real interest rate of 4% – but they remain low if the central bank complements the NB system with paying interest on reserves. In fact, if the interest rate on reserves is high enough, the benefits of FB disappear, confirming the equivalence argument of Brunnermeier and Niepelt (2019). This suggests that – to the extent that NB systems mitigate the inherent fragility of FB – increasing financial stability with a NB system might not be so costly.[5]

[4] This is in contrast Chiu et al. (2023) or Keister and Sanches (2022) where higher deposit rates can increase the loan rate and lead to disintermediation. In both papers other means of financing are not essential. In Keister and Sanches (2022) banks can only issue deposits. In Chiu et al. (2023) issuing other liabilities is possible but they are not used in equilibrium.

[5] Current FB systems exhibit various regulations to mitigate the financial instability of FB, most notably deposit insurance. Jackson and Pennacchi (2021) provide an interesting comparison between NB and FB with deposit insurance.

The rest of the paper is organized as follows: Section 2 introduces the basic environment. Section 3 then presents the model under perfect competition and section 4 under imperfect competition. I calibrate the model in section 5 and conclude in section 6.

2 Environment

The environment builds on Lagos and Wright (2005) and in particular on Berentsen et al. (2007). Time is discrete and continues forever. There are three types of agents: a continuum of households with measure 1, a continuum of banks with measure 1,[6] and a central bank. Every period is divided into two sequential competitive markets called first market (FM) and second market (SM).[7] In each market there is a perishable consumption good, q in the FM and x in the SM.

Households are infinitely lived, discount future periods with β and are anonymous. At the beginning of every period they face a preference shock which divides them into two groups. With probability $s \in (0, 1)$ a household becomes a seller in the FM and produces with weakly convex disutility $c(q_s)$. With the inverse probability a household is a buyer in the FM and consumes with strictly concave utility $u(q_b)$, satisfying the Inada-conditions. In the SM all households consume x and produce h with quasi-linear utility $U(x) - h$, where $U(x)$ is strictly concave and also satisfies the Inada-conditions.

As a benchmark we first derive the first-best allocation. With perishable consumption goods a social planner chooses non-negative consumption and production to maximize the expected period welfare of a household subject to feasibility,

$$\max_{q_b, x_b, h_b, q_s, x_s, h_s} \quad (1-s)\left[u(q_b) + U(x_b) - h_b\right] + s\left[-c(q_s) + U(x_b) - h_b\right]$$

$$s.t. \quad (1-s)q_b = sq_s \tag{1}$$

$$(1-s)x_b + sx_s = (1-s)h_b + sh_s \tag{2}$$

where (1) says buyers consume what sellers produce in the FM and (2) equalizes aggregate consumption to aggregate production in the SM. The efficient quantities q_b^*, q_s^*, and $x_b^* = x_s^* = x^*$, then equalize marginal utility of consumption and marginal disutility of production in both markets:

[6] In section 4 with imperfect competition there will be a finite number N of banks.

[7] Since both markets are competitive I follow Berentsen et al. (2007) and call these markets first and second market instead of the more common notations decentralized market (DM) and centralized market (CM) in the New Monetarist literature.

$$\frac{u'(q_b^*)}{c'(\frac{1-s}{s}q_b^*)} = 1, \quad q_s^* = \frac{1-s}{s}q_b^*, \quad U'(x^*) = 1. \tag{3}$$

However, in a decentralized economy households cannot trade in the FM due to anonymity. In particular, anonymity precludes buyers to issue debt to buy goods from sellers in the FM. Households thus find it useful to hold a means of payment or money.

The first source of the money supply is the central bank, who issues fiat money M or reserves. Reserves are potentially interest bearing with interest rate i_m and growth rate $\gamma = M/M_{-1}$.[8] The central bank manages the supply of reserves by lump-sum transfers τ to agents in the SM. Thus the central bank seignorage revenue in period t, $M - M_{-1}$, which is negative if the central bank reduces the money supply, is used for transfers τ and interest payments $i_m M_{-1}$. The nominal budget constraint of the central bank reads:

$$M - M_{-1} = (\gamma - 1)M_{-1} = \tau + i_m M_{-1}. \tag{4}$$

An economy with $i_m = 0$ resembles the monetary system before the financial crisis, where banks hold non-interest bearing reserves and households hold currency. An economy with $i_m > 0$ resembles a monetary system with an interest bearing CBDC, to which both, households and banks, have access.[9]

Let $1/\phi$ be the price of x in terms of reserves in the SM and let p be the price of q in terms of reserves in the following SM. Also define inflation as the ratio of prices between two consecutive SM, ϕ_{-1}/ϕ. Under stationarity the real value of money is constant, $\phi M = \phi_{-1}M_{-1}$, and the money growth rate γ equals the inflation rate. So the central bank perfectly controls long-run inflation and the nominal interest rate, defined as $1 + i = \gamma/\beta$, the product of inflation γ and the real interest rate $1/\beta$.

I assume the central bank sets a positive nominal interest rate above the Friedman rule where $\gamma = \beta$ and above the interest rate on reserves:

$$i > 0 \quad , \quad i > i_m. \tag{5}$$

[8]In the whole paper I denote variables in a representative period t without subscript, the period before t with subscript -1 and the period after with $+1$.

[9]The FED started to pay interest on reserves in October 2008 only. One could also consider a CBDC implementation where only households have access to interest bearing reserves (CBDC) and banks are restricted to hold non-interest bearing reserves like in the baseline of Chiu et al. (2023). This would not affect the main results, except that it adds an equilibrium where households hold CBDC instead of deposits and banks only finance loans with bonds.

This implies holding money is costly and gives rise to the basic inefficiency of the environment in the form of an "inflation tax" on real FM activity. If holding money is costly, households hold too little and FM consumption and production are below the first best allocation.

The second source of the money supply are profit-maximizing risk-neutral banks, owned by households. Banks can commit and monitor households at no cost. This enables them to issue debt and to make loans. Banks acquire two types of assets: loans l at interest rate i_l and and reserves m. To finance these assets they issue deposits d at interest rate i_d and bonds at interest rate i_b. Deposits are the other means of payment besides reserves, while bonds are illiquid.[10] Deposits are subject to a reserve requirement. A bank issuing d deposits must back them at least with a fraction α of reserves, so $\alpha d \leq m$.[11] Usually banks want to issue as many deposits as they can, so the reserve requirement binds. The reserve requirement then also determines the monetary system. If $\alpha < 1$ banks issue more deposits than reserves and we have a FB system and if $\alpha = 1$ banks fully back deposits with reserves and we have a NB system.

Financial contracts are nominal, formed after the preference shock in the FM, and fully redeemed in the following SM.[12] The paper considers two different market structures: In section 3 the banking sector is fully competitive. In section 4 there is imperfect competition with a fixed number N of banks and Cournot competition in the deposit market.

3 The Model

3.1 Banks

Banks acquire reserves m and loans l by issuing deposits d and bonds b. They maximize their profits π, subject to the reserve constraint and a balance sheet constraint:

$$\max_{l,m,d,b\ \forall \geq 0} \pi = m(1+i_m) + l(1+i_l) - d(1+i_d) - b(1+i_b) \tag{6}$$

$$s.t. \quad \alpha d \leq m \quad , \quad l + m = d + b$$

We focus on the case with positive loans. Using the balance sheet constraint with $l = d + b - m$

[10]Deposits and bonds might also be interpreted as two more or less liquid forms of deposits, like checking and time deposits.

[11]The reserve requirement might be interpreted either as a regulatory or a technological constraint. Even if the regulatory reserve requirement is 0 banks hold reserves to settle the transactions made with deposits.

[12]With quasi-linear utility in the SM there is no gain from spreading the redemption of debt or the repayment of loans over multiple periods. Thus assuming this kind of contracts is not constraining in this environment.

the problem rewrites as:

$$\max_{m,d,b} m(i_m - i_l) - d(i_l - i_d) - b(i_l - i_d)$$
$$s.t. \quad \alpha d \leq m$$

Suppose $i_l \geq i_b, i_d > i_m$, i.e. financing loans with deposits or bonds is profitable, loans have a higher return than reserves and financing reserves with deposits or bonds is not profitable. Then the reserve constraint binds and we can rewrite the objective function as:

$$\max_{d,b} d\left(\alpha i_m + (1-\alpha)i_l - i_d\right) + b\left(i_l - i_b\right).$$

Any equilibrium with positive demand for deposits and bonds from households thus involves

$$i_d = \alpha i_m + (1-\alpha)i_l \tag{7}$$
$$i_b = i_l \tag{8}$$

and banks making zero profits. From (7) the deposit rate is a weighted average of the return on reserves and the return on loans. With a binding reserve requirement α is the ratio of reserves to deposits, and $1-\alpha$ is the ratio of loans financed by deposits to deposits. In equilibrium the loan rate exceeds the reserve rate, so the deposit rate lies between the loan rate and the reserve rate. Under NB the deposit rate just equals the reserve rate, since deposits are only backed by reserves. From (8) the bond rate equals the loan rate since banks also finance loans with bonds. We thus get the following relations between the interest rates, consistent with the assumptions above:

$$i_l = i_b > i_d \geq i_m \tag{9}$$

By issuing bonds banks can lend more because they don't need to hold reserves when issuing bonds, but bonds are more expensive. This is the basic tradeoff between deposits and bonds for the bank. As already explained in the environment the binding reserve requirement also determines whether banks operate under a FB system with $\alpha \in (0,1)$ or a NB system with $\alpha = 1$.

3.2 Buyers

Let $V_b(m)$ denote the value of a household entering period t with m reserves, who just learned he is a buyer. Also let $V(m_{b+1})$ denote the expected value of a buyer entering period $t+1$ with m_{b+1} reserves. The problem of a buyer reads:

$$V_b(m) = \max_{q_b,x_b,h_b,m_{b+1},l_b,d_b,m'_b,b_b} \quad u(q_b) - h_b + U(x_b) + \beta V(m_{b+1})$$

$$s.t. \quad m + l_b \leq b_b + m'_b + d_b \tag{10}$$

$$pq_b \leq m'_b(1+i_m) + d_b(1+i_d) \tag{11}$$

$$h_b + \phi\left(m'_b(1+i_m) + d_b(1+i_d) - pq_b\right) + \phi(\tau+\pi) + b_b\phi(1+i_b) \tag{12}$$

$$= x_b + \phi m_{b+1} + l_b\phi(1+i_l)$$

After the preference shock buyers first acquire financial assets and borrow from banks. They use their reserves m and borrow l_b to acquire bonds b_b, reserves m'_b and deposits d_b as shown in (10). In the FM buyers either use reserves or deposits to buy goods from sellers, see (11).[13] When buyers enter the SM they get resources from working h_b, from monetary wealth left over after the FM, $m'_b(1+i_m) + d_b(1+i_d) - pq_b$, from transfers of the central bank and profits from banks, $\phi(\tau+\pi)$, and from their bond holdings $b_b\phi(1+i_b)$. They use these resources to acquire consumption goods x_b, new money holdings ϕm_{b+1} and repay loans $l_b\phi(1+i_l)$ as shown in (12).

In the following δ denotes the Lagrange multiplier for (10) and λ the Lagrange multiplier for (11). Substituting (12) into the objective function, the problem yields the following first-order conditions, assuming interior solutions for q_b, x_b, m_{b+1} and l_b:

[13]Note that p is the price of q in terms of reserves in the *next* SM. This is why the interest rates i_m and i_d show up in the budget constraint. One might think of $m'_b(1+i_m) + d_b(1+i_d)$ as the "monetary wealth" of a buyer in the following SM.

$$
\begin{aligned}
&q_b: && u'(q_b) = p\,(\phi + \lambda) && (13)\\
&x_b: && U'(x_b) = 1 && (14)\\
&m_{b+1}: && \beta V'(m_{b+1}) = \phi && (15)\\
&l_b: && \delta = \phi(1 + i_l) && (16)\\
&d_b: && (1 + i_d)(\phi + \lambda) \le \delta && (17)\\
&m_b': && (1 + i_m)(\phi + \lambda) \le \delta && (18)\\
&b_b: && \phi(1 + i_b) \le \delta && (19)
\end{aligned}
$$

Clearly, to consume in the FM, buyers want to hold either reserves or deposits. From the bank problem (9) we know that the deposit rate is weakly above the interest on reserves. Thus the marginal benefit of deposits, the left-hand side of (17), is weakly higher than the marginal benefit of reserves, the left-hand side of (18). Buyers weakly prefer holding deposits, so (17) binds and (18) is slack. Combining (17) and (16) the multiplier of the liquidity constraint reads:

$$
\lambda = \phi \left(\frac{1 + i_l}{1 + i_d} - 1 \right)
$$

The expression says that as long as there is a spread between the loan rate and the deposit rate, buyers use all their deposits in the FM, i.e. they are liquidity constrained. From the bank problem we know the loan rate is above the deposit rate so this holds. We also know the bond rate equals the loan rate. This means buyers could increase their borrowing and acquire bonds with these additional funds. This does not affect the real allocation so we assume buyers do not hold bonds. Finally from (14) buyers consume the efficient quantity in the SM, and from (15) the expected marginal value of new reserve holdings equals marginal costs. Summarizing, the solution to the buyer problem reads:

$$u'(q_b) = p\phi \frac{1+i_l}{1+i_d} \tag{20}$$

$$x_b = x^* \tag{21}$$

$$\beta V'(m_{b+1}) = \phi \tag{22}$$

$$d_b = \frac{pq_b}{1+i_d} \tag{23}$$

$$l_b = d_b - m \tag{24}$$

$$m'_b = 0 \quad , \quad b_b = 0 \tag{25}$$

This also yields the envelope condition to the buyer problem:

$$V'_b(m) = \delta = \phi(1+i_l) \tag{26}$$

3.3 Sellers

The problem for sellers is analogue to the buyers' problem, except for the liquidity constraint because sellers don't consume in the FM:

$$\begin{aligned} V_s(m) = & \max_{q_s,x_s,h_s,m_{s+1},l_s,d_s,m'_s,b_s} \quad -c(q_s) - h_s + U(x_s) + \beta V(m_{s+1}) \\ s.t. \quad & m + l_s \leq b_s + m'_s + d_s \\ & h_s + \phi\left(m'_s(1+i_m) + d_s(1+i_d) + pq_s\right) + \phi(\tau+\pi) + b_s\phi(1+i_b) \\ & = x_s + \phi m_{s+1} + l_s\phi(1+i_l) \end{aligned}$$

Again I replace h_s in the objective function with the budget constraint.[14] Assuming interior solutions for q_s, x_s and m_{s+1} we get the following first-order conditions:

[14]This assumes $h_s > 0$ which requires a scaling condition on $U(.)$. As we will see sellers also consume the efficient quantity in the SM $x_s = x^*$. So $h_s > 0$ holds if x^* is sufficiently big.

$$
\begin{aligned}
q_s &: & p\phi &= c'(q_s) & \\
x_s &: & U'(x_s) &= 1 & (27)\\
m_{s+1} &: & \beta V'(m_{s+1}) &= \phi & (28)\\
l_s &: & \delta &\leq \phi(1+i) & \\
d_s &: & (1+i_d)\phi &\leq \delta & \\
m'_s &: & (1+i_m)\phi &\leq \delta & \\
b_s &: & \phi(1+i_b) &\leq \delta & (29)
\end{aligned}
$$

Since sellers don't need liquidity in the FM, their choice of financial assets is only driven by return considerations. From the banking problem and (9) we know the bond rate is higher than the deposit rate and the reserve rate. Therefore sellers prefer holding bonds over deposits and reserves and (29) holds with equality. Because the bond rate equals the loan rate, sellers are indifferent to borrow more funds and acquire additional bonds. As with buyers this type of borrowing does not affect the real allocation and we assume sellers don't borrow. From (27) also sellers consume the efficient amount in the SM, and the first-order condition for new reserve holdings, (28), is identical to the condition for buyers, (15). In particular the condition does not depend on the household's type or their wealth in the SM. So buyers and sellers choose the same reserve holdings in the SM: $m_{b+1} = m_{s+1} = m_{+1}$. This is an implication of quasi-linear utility introduced by Lagos and Wright (2005). We can summarize the solution to the seller problem as:

$$c'(q_s) = p\phi \tag{30}$$

$$x_s = x^* \tag{31}$$

$$\beta V'(m_{+1}) = \phi \tag{32}$$

$$d_s = l_s = m'_s = 0 \tag{33}$$

$$b_s = m \tag{34}$$

Sellers produce in the FM to equalize marginal disutility and utility of production, they consume the efficient quantity x^* in the SM and they acquire the same money holdings as buyers in the SM. They only hold bonds because these have the highest return and they don't borrow. The envelope condition is:

$$V_s'(m) = \delta = \phi(1 + i_b) \tag{35}$$

Iterating (35) and the envelope condition of buyers (26) one period forward, the optimality condition for optimal reserve holdings in the SM rewrites as:

$$\begin{aligned} \phi = \beta V'(m_{+1}) &= \beta s V_s'(m_{+1}) + \beta(1-s)V_b'(m_{+1}) \\ &= \beta s \phi_{+1}(1 + i_{b+1}) + \beta(1-s)\phi_{+1}(1 + i_{l+1}) \end{aligned} \tag{36}$$

The marginal cost of reserves, ϕ, equals the marginal expected benefits for sellers and buyers. For sellers the marginal benefit is the real bond rate because they deposit reserves to acquire bonds. For buyers the marginal benefit is the real loan rate because if they bring more reserves they can borrow less and they save on the loan interest payments. Market clearing for reserves in the SM then reads:

$$(1-s)m_{b+1} + sm_{s+1} = m_{+1} = M \tag{37}$$

Since buyers and sellers acquire the same reserve holdings and they together have mass one, individual reserve holdings equal aggregate reserve supply.

Suppose the banks in total supply D deposits, B bonds, and hold L loans and R reserves. Market clearing for reserves, bonds, deposits and loans in the banking period then reads:

$$R + (1-s)m_b' + sm_s' = R = M_{-1} \tag{38}$$

$$(1-s)b_b + sb_s = sM_{-1} = B \tag{39}$$

$$(1-s)d_b = D = \frac{R}{\alpha} = \frac{M_{-1}}{\alpha} \tag{40}$$

$$(1-s)l_b = L = D + B - R = \left(\frac{1-\alpha}{\alpha} + s\right) M_{-1} \tag{41}$$

From (38), the reserve holdings of banks, R, and the reserve holdings of households after interacting with the banks, must equal the total amount of reserves brought into the period by households, M_{-1}. Since $m_b' = m_s' = 0$, banks hold all reserves after the banking period. In the bond market (39) only sellers hold bonds, which must equal total supply B from banks. In the deposit market (40) only buyers hold deposits. The total supply must equal R/α due to the binding reserve

requirement and since banks hold all the reserves from (38) this is M_{-1}/α. In the loan market (41) demand from buyers equals $D+B-R$ by the balance sheet of the banking sector which using the expressions for D, B and R is also a function of total reserves.
Ultimately, the FM and the SM clear according to (1) and (2).

3.4 Equilibrium

To solve for equilibrium interest rates we combine the expression for optimal reserve holdings, (36), with the relations for interest rates from the bank problem, (7) and (8), and apply stationarity where $\gamma = \phi/\phi_{+1}$. This yields:

$$i_l = i_b = i \tag{42}$$

$$i_d = (1-\alpha)i + \alpha i_m \tag{43}$$

The equilibrium loan rate and the bond rate equal the nominal interest, while the equilibrium deposit rate is lower because holding money is costly and $i > i_m$. The deposit rate decreases in the reserve requirement, thus it is higher under FB where $\alpha \in (0,1)$ and deposits also finance loans, than under NB where $\alpha = 1$ and deposits only finance reserves.
To get equilibrium FM consumption combine optimal consumption (20) with optimal production (30) and use the equilibrium expressions for the interest rates and market clearing (1):

$$\frac{u'(q_b)}{c'(\frac{1-s}{s}q_b)} = \frac{1+i}{1+i_d} \tag{44}$$

The rest of the equilibrium allocation is given by:

$$q_s = \frac{1-s}{s}q_b$$

$$\phi D = (1-s)q_b\frac{c'(q_s)}{1+i_d} \quad , \quad \phi M_{-1} = \alpha\phi D \quad , \quad \phi L = \left(\frac{1-\alpha}{\alpha} + s\right)\phi M_{-1}$$

$$x_b = x_s = x^*$$

$$h_s = x^* + \phi M_{-1}(1+i_m) - \frac{\phi D(1+i_d)}{s} - \phi M_{-1}(1+i) \tag{45}$$

$$h_b = x^* + \phi M_{-1}(1+i_m) + \frac{\phi L(1+i)}{1-s} \tag{46}$$

From (45) sellers work in the SM to consume and acquire new, interest-paying real balances and get resources from redeeming deposits and bonds. From (46) buyers work in the SM to consume and repay their loans. Since SM consumption is always efficient at x^*, we can focus on the FM allocation (44) for welfare analysis. FM consumption decreases in the spread between the nominal interest rate and the deposit rate.[15] Without spread, the allocation achieves the efficient allocation (3). Therefore the welfare comparison between FB and NB depends on which system provides a higher deposit rate. Proposition 1 summarizes the main welfare implications:

Proposition 1. *Suppose holding money is costly, the banking system is fully competitive and either operates under FB with $\alpha \in (0, 1)$ or under NB with $\alpha = 1$. Then there is a stationary equilibrium in which:*

i) The deposit rate i_d and welfare decrease in α, thus $W_{FB} > W_{NB}$.

ii) The loan rate $i_l = i$ is independent of α.

iii) An interest-bearing CBDC with $i_m > 0$ increases welfare.

From *i*) FB is beneficial. If banks issue more deposits – induced by a lower reserve requirement α – i_d and welfare increase. In contrast to the quantity theory the composition and the quantity of money matter here.[16] The reasoning is as follows: Since $i_l = i > i_m$, i.e. the return on loans is higher than the return on reserves in equilibrium, and under FB deposits also fund loans while under NB deposits only finance reserves, banks have a higher income on their asset side under FB than under NB. With perfect competition they will pass on this higher income to the deposit holders in form of higher i_d.[17] This is beneficial because it compensates the deposit holders against inflation or the money holding costs, the basic inefficiency in the model.

Interestingly this result does not rely on the usual disintermediation argument. Going from FB to NB banks substitute deposit financed with bond financed lending. Disintermediation means the loan rate should increase and lending should go down as bank funding shifts to more costly liabilities. However, as *ii*) shows this does not happen here. The reason is that banks' financing alternatives to deposits – bonds – serve an essential economic role for households, which is to provide insurance against preference or liquidity shocks. After the preference shock, sellers have idle money holdings they don't need in the FM. For them, illiquid bonds with a higher return are a useful savings vehicle and since in equilibrium $i_b = i$, sellers who acquire bonds, are perfectly compensated for the money holding costs i. The risk of becoming a seller with idle, money holdings is irrelevant if bonds paying i are available. Thus bonds provide perfect insurance in both banking

[15] The left-hand side of (44) decreases in q_b, so a higher spread must imply a lower q_b.

[16] Note however that an increase in deposits induced by a one time change in the level of M is neutral. Note also we can restore neutrality with an appropriate tax/transfer system as Brunnermeier and Niepelt (2019) suggest. Suppose the central bank accompanies the introduction of a NB system with interest on reserves equal to the deposit rate under FB, i.e. she pays $i'_m = i_d = (1-\alpha)i + \alpha i_m$. Trivially the allocations under FB and NB must be identical.

[17] The next section discusses this conclusion under imperfect competition.

systems and q_b in (44) is independent of s.[18] Since bonds are essential banks already use them under FB to finance loans. The shift to NB just shifts the composition of loan financing fully to bonds but this does not affect the loan rate.

The same mechanism prevents disintermediation after the introduction of an interest bearing CBDC. Introducing a CBDC with $i_m > 0$ only increases i_d through a higher remuneration of reserves and does not affect i_l. i_l and i_b are both pinned down by i, independent from changes in i_m. As above this is welfare improving because it better compensates the deposit holders against the welfare costs of inflation. This contrasts with CBDC-models like Chiu et al. (2023) or Keister and Sanches (2022) where under certain conditions higher i_m also increases i_d but this also translates into higher i_l and thus funding costs for borrowers, which reduces lending and intermediation and seems detrimental for welfare.[19] The difference is that financing alternatives to deposits are not essential in these models. In Chiu et al. (2023) financing lending over bonds – although it is possible – is not used in equilibrium and in Keister and Sanches (2022) banks cannot issue other liabilities than deposits. Thus the paper shows the transmission of higher i_d to loan rates and disintermediation also depends on the role of other bank liabilities. Introducing a NB system or an interest bearing CBDC might not affect loan rates too much because financial intermediaries can finance lending and investment with other, less liquid liabilities than deposits.

4 Imperfect Competition

A perfect competition model cannot explain the observed spread between the nominal interest rate and the deposit rate, as the quantitative analysis below demonstrates. For the calibration I thus use an imperfect competition model, introduced in this section. In particular, following Chiu et al. (2023), I assume Cournot competition with N banks in the deposit market, while the bond and loan market are still perfectly competitive. This means an individual bank j anticipates the effects of her own deposit supply on the deposit rate over market clearing, taking the deposit issuance of other banks $i \neq j$ as given, but ignores similar effects on the loan and the bond rate. From the perspective of bank j the total real supply of deposits is given as

$$\phi D = \phi \left(\sum_{i \neq j}^{N} d_i + d_j \right) \tag{47}$$

[18] Appendix A.2 shows, the NB allocation is identical to an economy without preference shock and banks.

[19] A decrease in lending or disintermediation must not mean a decrease in welfare. In fact, it can be welfare increasing if there was over-investment initially, a point also made by Williamson (2022).

where d_j is the own supply of deposits and $\sum_{i\neq j}^{N} d_i$ is the supply of all other banks. The bank anticipates total real demand for deposits from buyers from (20), (23) and (30) as:

$$\phi D = \begin{cases} (1-s)\frac{q_b u'(q_b)}{1+i} & \text{if} \quad i_d \geq i_m \\ 0 & \text{if} \quad i_d < i_m \end{cases} \tag{48}$$

The real demand for deposits is only positive for deposit rates weakly higher than the reserve rate. If $i_d < i_m$, buyers switch from holding deposits to holding reserves and the demand for deposits is zero.

Equalizing (47) and (48) yields a connection between the deposits issued by bank j and the deposit rate, which I denote as $i_d(\phi D)$, where ϕD is given by (47). The interesting case is when the real demand for deposits (48) increases with the deposit rate, i.e. when $\partial\phi D/\partial i_d > 0$ and $\partial i_d/\partial\phi D > 0$. This means if the bank issues more deposits, buyers must be compensated with a higher return for holding these additional deposits. Only in this case the bank faces a tradeoff when issuing deposits.[20] From (44) buyers consume more at higher deposit rates. Whether they finance this higher consumption by holding more, less or the same level of real deposits depends on preferences however. From (48) the real demand for deposits increases in the deposit rate if the coefficient of relative risk aversion is below 1:

$$-\frac{q_b u''(q_b)}{u'(q_b)} < 1. \tag{49}$$

In the following I assume this condition holds.[21]

The problem of representative bank j is very similar to the problem under perfect competition (6). Again, if $i_l \geq i_b, i_d > i_m$ the reserve constraint binds and the banking problem reads

$$\max_{d_j, b_j} \quad d_j\left((\alpha i_m + (1-\alpha)i - i_d(\phi D)\right) + b_j\left(i - i_b\right),$$

where the first order condition for deposits becomes:

$$(1-\alpha)i + \alpha i_m - i_d = i_d^{PC} - i_d = \phi d_j \frac{\partial i_d(\phi D)}{\partial \phi D}. \tag{50}$$

The bank now takes into account that the deposit rate depends on how many deposits she issues. This introduces a spread between the deposit rate under perfect and under imperfect competition,

[20] In the opposite case, i.e. if a bank issues more deposits and buyers are willing to hold these deposits at a lower deposit rate, the bank would always issue as many deposits as she could, such that i_d is as low as possible, i.e. $i_d = i_m$.

[21] Using CRRA-utility, the calibration yields $\sigma = 0.16$. So the data supports this assumption.

$i_d^{PC} - i_d$.[22]

In a symmetric equilibrium all banks issue the same amount of deposits, i.e. $d_j = d_i = d = D/N$. (50) then becomes the familiar equality between a type of Lerner index and the inverse interest-elasticity of real deposits multiplied by the number of banks N (Freixas and Rochet, 2008, p. 78–80).

$$\frac{i_d^{PC} - i_d}{i_d} = \frac{1}{\varepsilon_D(i_d)} \frac{1}{N} \quad \text{where} \quad \varepsilon_D(i_d) = \frac{i_d}{\phi D} \frac{\partial \phi D}{\partial i_d} \tag{51}$$

The spread between i_d^{PC} and i_d decreases with competition and the elasticity of deposit demand. It goes to zero if the banking sector becomes perfectly competitive, i.e. if $N \to \infty$, or if deposit demand is perfectly elastic, i.e. if $\varepsilon_D \to \infty$. Denoting the solution of (51) with i_d^*, the equilibrium deposit rate under imperfect competition solves:

$$i_d = \max\{i_d^*, i_m\} \leq i_d^{PC} \tag{52}$$

(52) reflects the characteristics of deposit demand. If competition or the elasticity are very low, banks want to set $i_d^* < i_m$. But then buyers prefer to hold reserves and banks loose the cheap funding over deposits. Therefore they set the deposit rate to the lowest possible value such that buyers are indifferent, i_m. Under NB $i_d^{PC} = i_m$ so $i_d^* < i_m$ always holds and banks set $i_d = i_m$. Thus with imperfect competition a higher i_m not only increases i_d through higher bank reserve remunerations, but also by disciplining banks' market power. Households' outside option of holding reserves or an interest bearing CBDC forces banks to increase deposit rates, similar to Chiu et al. (2023). Proposition 2 summarizes the welfare implications of the two banking systems under imperfect competition:

Proposition 2. *Suppose holding money is costly, there is Cournot competition with N banks in the deposit market and the banking system either operates under FB with $\alpha \in (0, 1)$ or under NB with $\alpha = 1$. Then there is a stationary equilibrium in which:*

i) welfare under FB is higher than under NB if banking is sufficiently competitive, i.e. if $N > \bar{N}$

where

$$\bar{N} = \frac{i_m}{(1-\alpha)(i - i_m)\varepsilon_D(i_m)} \tag{53}$$

With imperfect competition FB does not always dominate NB in terms of welfare. Although banks

[22] The spread implies banks make positive profits in equilibrium, distributed to households in the SM. This does not affect the equilibrium allocation as long as sellers still work in the SM, see also footnote 14.

still generate higher income on the asset side under FB they only pass on this higher income to deposit holders if competition is sufficiently high. This is more likely, i.e. $\bar{N}$ is low, if a) the elasticity is high and it does not make sense for banks to substantially reduce the deposit rate, b) the nominal interest rate is high and banks get a higher income on their assets independent of competition, and c) the reserve requirement is low. Note that as the economy becomes a NB economy the threshold $\bar{N}$ goes to infinity and $N > \bar{N}$ can never hold. In this case, as we already saw, banks will always set the deposit rate to the reserve rate, independent of competition.[23]

5 Calibration

In this section I quantify the efficiency benefits of FB because of higher interest payments on deposits for the US economy 1984–2008, using the imperfect competition model from section 4. Following the literature I parametrize $u(q) = q^{1-\sigma}/(1-\sigma)$, $c(q) = q$ and $U(x) = B\log(x)$. This implies the stationary allocation is given by:

$$x^* = B \tag{54}$$

$$q_b = \left(\frac{1+i_d}{1+i}\right)^{1/\sigma} \tag{55}$$

$$\phi D = (1-s)\frac{(1+i_d)^{\frac{1-\sigma}{\sigma}}}{(1+i)^{\frac{1}{\sigma}}} \tag{56}$$

$$i_d = \max\left\{i_m, \frac{1+i_d^{PC}}{1+\frac{\sigma}{1-\sigma}\frac{1}{N}} - 1\right\} \tag{57}$$

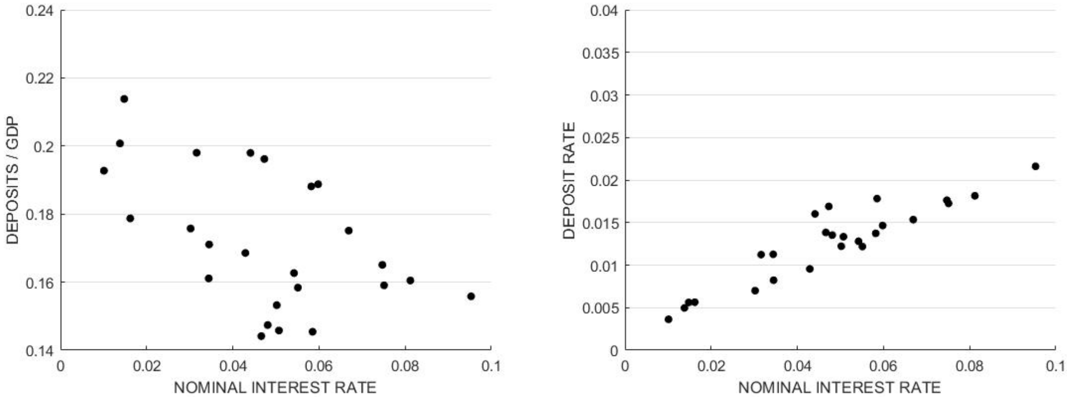
Note that $\partial\phi D/\partial i_d > 0$, i.e. real deposits increase in the deposit rate and assumption (49) holds, if $\sigma < 1$.

Figure 2 plots the yearly ratios of deposits to nominal GDP, i.e. aggregate real money demand or inverse velocity, and the deposit rate against the 3-month T-Bill rate as a measure of the nominal interest rate i . In the following I interpret every combination of real money demand and i, and the deposit rate and i as a temporary steady state of the model, generated in particular by unexpected changes in i by the central bank.[24]

[23]Note that $\bar{N}$ does not go to zero if $i_m \to 0$ as one might think from (53). Since the elasticity has i_m in the numerator this cancels with the i_m in the numerator of (53).

[24]For similar approaches in the New Monetarist literature see in particular Lagos and Wright (2005), Craig and Rocheteau (2008) and Berentsen et al. (2015). Lucas (2000), Lucas (2013) and Lucas and Nicolini (2015) make similar arguments with a cash-in-advance model.

Figure 2: Money demand and deposit rates US 1984–2008



In the model, real money demand z is given by:[25]

$$z = \frac{D}{D + x^*/\phi} = \frac{1}{1 + \frac{B}{\phi D}} \tag{58}$$

Thus (58) and (57) are the model equivalents thought to generate the data from figure 2.Note that z decreases in i since $\partial(\phi D)/\partial i < 0$, which is plausible from the data. The deposit rate on the other hand increases in i but much less than one-to-one, due to an imperfect transmission.

The calibration uses yearly, averaged data from 1984 to 2008.[26] Before the 1980s the Glass-Steagall Act prohibited banks to pay interest on deposits and only in 1982 they were allowed to issue interest-bearing money market deposit accounts (MMDA). Following Lucas and Nicolini (2015) I assume it took the banks two years to adjust to this new type of account and from 1984 the model mechanism was operative. I stop after 2008 because nominal interest rates were close to zero afterwards.

Table 1: Model variables and data

Model	**Data**
deposits D	M1 − currency + MMDA
reserves M	M0 − currency
nominal interest rate i	3-Month T-Bill rate
reserve rate i_m	interest on reserves
deposit rate i_d	weighted interest of deposit components

Data sources: FRED, Lucas and Nicolini (2015).

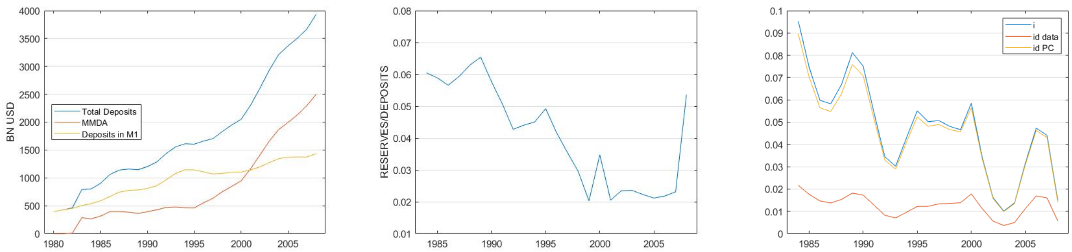
Table 1 shows how the model variables are measured. Deposits include MMDA because they

[25]Total money balances held are total deposits D which also equal nominal output in the FM. Nominal output in the SM is given by x^*/ϕ so nominal GDP is given by $D + x^*/\phi$.

[26]Using HP-filtered data with with $\lambda = 100$ yields practically identical parameter estimates.

perform a similar economic function and money demand is not stable without this correction (Lucas and Nicolini, 2015). Subfigure 3a shows MMDA strongly increase to over 280bn USD in 1983, accounting for over 36% of total deposits and after 1995 they dominate the evolution of total deposits.[27] Reserves are M0 minus currency, thus bank reserve holdings are $\alpha = M/D$. Subfigure 3b shows that bank reserve holdings α are very low over the whole period, with a mean of 0.04. The nominal interest rate is the 3-month T-bill rate and since the FED didn't pay interest on reserves until October 2008 I directly set $i_m = 0$. The deposit rate is calculated based on data from Lucas and Nicolini (2015) on the average deposit rate of M1 deposits and MMDA accounts, weighted by the shares of the two aggregates.[28] As α is close to 0 the deposit rate under perfect competition, which is $(1-\alpha)i$ with $i_m = 0$, should be very close to i. However, as subfigure 3c shows, the deposit rate in the data is much lower. To account for this spread it is crucial to use the imperfect competition model from section 4.

Figure 3: The Data



(a) Deposit components (b) Reserve ratio (c) Interest rates

For the calibration i, i_m and α are taken directly from the data. Thus the parameters left to calibrate are s, σ, B and N. They are chosen to minimize the sum of squared relative residuals between money demand and the deposit rate from the model given by (54) to (58) and the data counterparts z_t and i_{d_t}:[29]

$$\min_{s,\sigma,B,N} \quad SSR = \sum_{1984}^{2008} \left(\frac{z}{z_t} - 1 \right)^2 + \sum_{1984}^{2008} \left(\frac{i_d}{i_{d_t}} - 1 \right)^2 \tag{59}$$

To take into account changing degrees of competition over the sample period of 25 years I further split the data in two subperiods, with a degree of competition N_1 for the first and N_2 for the

[27] The strong increase of MMDA after the mid-90s is related to the introduction of so called "sweep"-deposit accounts in 1994. This was another response to a relaxation of Regulation Q. Sweep-accounts essentially allowed banks to automatically move funds from traditional deposit accounts to MMDA. See Lucas and Nicolini (2015) and Berentsen et al. (2015).

[28] For the few years where there is no interest rate data for both series, I use a linear extrapolation.

[29] Calibrating the model to match data moments yields similar results.

second subperiod. It turns out that splitting the data between 1984–1990 and 1991–2008 provides the best fit. It also turns out that (59) only identifies a constant $k = B/(1-s)$ in the denominator of z, which different combinations of s and B can satisfy.[30]

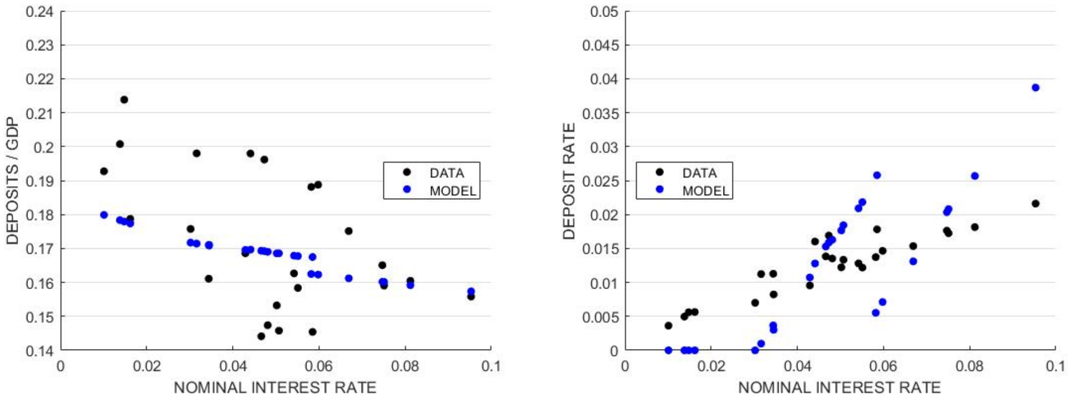
Table 2: Calibrated parameters

$B/(1-s)$	σ	N_1 1984–1990	N_2 1991–2008	SSR
4.43	0.35	11	18	10.1432

The parameters from table 2, which will serve as our baseline calibration, are broadly in line with similar calibrations.[31] $N_2 > N_1$ indicates increasing competition in the sample period. This seems plausible given the deregulation of the financial sector at that time.

Figure 4: Model fit

(a) Money demand (b) Deposit rate



To measure the welfare gains from FB, (60) calculates the fraction Δ_{FB} of expected steady state consumption or GDP households would give up under FB to be at the welfare level of a NB economy with $q_{b_{NB}}$ given by (55) with $\alpha = 1$ and $i_m = 0$. The welfare gains of FB, or the welfare costs of NB, are then $1 - \Delta_{FB}$.[32]

$$
\begin{aligned}
W_{FB}(\Delta_{FB}) &= (1-s)\frac{(q_b \cdot \Delta_{FB})}{1-\sigma}^{1-\sigma} - sq_s + B(\ln(B \cdot \Delta_{FB}) - 1) \qquad (60)\\
&= (1-s)\frac{(q_{b_{NB}})}{1-\sigma}^{1-\sigma} - sq_{s_{NB}} + B(\ln(B) - 1) = W_{NB}
\end{aligned}
$$

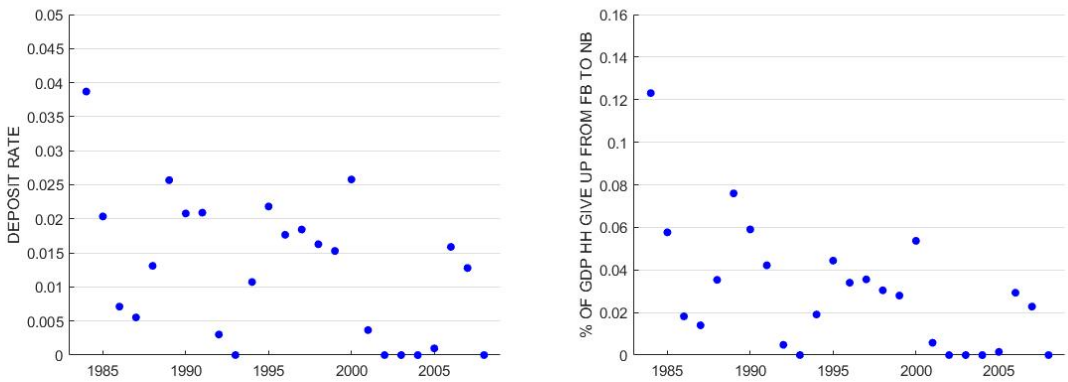
[30] As explained below, $B/(1-s)$ is sufficient to calculate welfare effects and we don't need explicit values for s and B.

[31] Lagos and Wright (2005) find $\sigma = 0.16, k = 3.94$, Craig and Rocheteau (2008) find $\sigma = 0.14, k = 3.64$, and Berentsen et al. (2015) find $\sigma = 0.31$ and $k = 4.48$ for a similar specification. Chiu et al. (2023) find $\sigma = 1.31, k = 3.73$ and $N = 26$.

[32] As mentioned above the single values of B and s do not matter for this welfare calculation, only the constant $B/(1-s)$ does. This is due to the natural log specification of SM utility which implies $\ln(B \cdot \Delta_{FB}) - \ln(B) = \ln(\Delta_{FB})$.

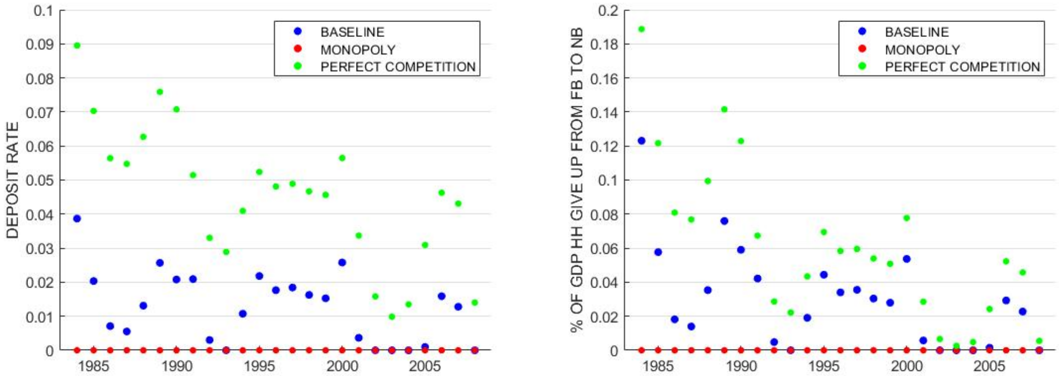
We first use the baseline calibration to analyse households' valuation of the FB system in place 1984–2008 against the alternative of a NB system with 0 interest on reserves. As figure 5 shows in years with low nominal interest rates like 2002 or 2008 the two systems were equivalent. The deposit rates generated by the FB system were 0 in these years, like under NB, and thus the welfare gains are also 0. In years with high nominal interest rates like 1984, FB provides higher deposit rates than 0 which households value at around 0.12% of GDP. Table 3 shows banks under FB on average created deposit rates $\bar{i_d}$ of 1.3% in this period (at an average nominal interest rate $\bar{i}$ of 4.8%), which on average was worth 0.03% of GDP to households.

Figure 5: Welfare gains from FB



Next we compare the welfare gains of FB in this baseline economy to counterfactual economies with different degrees of competition. From the model we know higher competition increases welfare. Would the welfare results have been significantly different in a more or less competitive banking system compared to the baseline calibration? The answer, broadly, is no. Figure 6 shows the results for the extreme cases of a monopolistic ($N = 1$) and a perfectly competitive banking sector ($N = \infty$), while table 3 below also includes intermediate cases. In a monopoly the bank sets $i_d = 0$ and there is no welfare benefit from FB. Conversely, under perfect competition i_d closely follows the nominal interest rate. Table 3 shows this increases the average deposit rate $\bar{i_d}$ by more than 2% compared to the baseline calibration, but this increases households' valuation of the FB system to only 0.06% of GDP, compared to 0.03% before.

Figure 6: Welfare gains and competition



Next we compare the welfare gains of FB in the baseline economy to economies with higher nominal interest or inflation rates. From the model we know a higher i increases i_d and thus makes FB more valuable compared to NB. The average nominal interest rate in the data $\bar{i}$ is 4.8%. We consider two counterfactuals: one where the average nominal interest rate $\bar{i}$ is twice as high, i.e. around 10%, and one where $\bar{i}$ is three times as high, i.e. around 15%. The latter is close to the often considered benchmark of 10% inflation and a real interest rate of 4%. Figure 7 shows two distributions every i_t in the data has been doubled (+100%) or tripled (+200%).[33]

Figure 7: Welfare gains and inflation

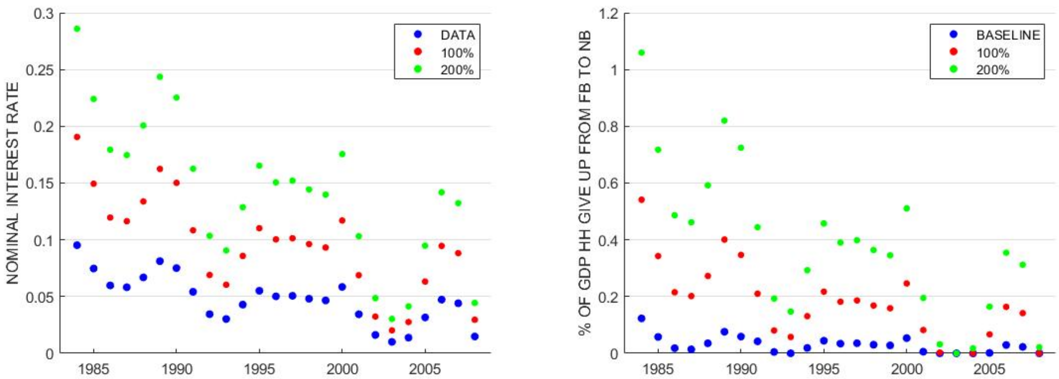


Table 3 shows the results. The increase in $\bar{i}$ of 5 pp to 9.6% increases average deposit rates by roughly 4 pp to 5.5%. At such a nominal interest rate households value a FB system with 0.18% of GDP on average. The increase in $\bar{i}$ of roughly 10 pp to 14.3% increases average deposit rates by roughly 8.5 pp to 9.8%. At these nominal interest rates households value a FB system at 0.38% of GDP. Thus the welfare gains of a FB system (or the costs of a NB system with 0 interest on

[33]Other data transformations to double or triple $\bar{i}$ yield very similar results.

reserves) seem only sizeable for very high nominal interest or inflation rates.

Table 3: Welfare gains from FB

	Baseline	Different N				Different $\bar{i}$		
		Monopoly	-50%	+50%	Perf. comp.	+50%	+100%	+200%
N_1, N_2	11,18	1,1	5.5,9	16.5,27	∞, ∞	11,18	11,18	11,18
$\bar{i}$	0.048	0.048	0.048	0.048	0.048	0.072	0.096	0.143
$\bar{i_d}$	0.013	0	0	0.023	0.046	0.034	0.055	0.098
$1 - \bar{\Delta}_{FB}$	0.03%	0%	0%	0.05%	0.06%	0.09%	0.18%	0.38%

Notes: $\sigma = 0.35$, $B/(1-s) = 4.43$ for all scenarios, $i_m = 0$ under NB.

Thus far the welfare gains of a FB system (or the costs of a NB system) were only sizeable, say above 0.1% of GDP, for high nominal interest or inflation rates. But the central bank could complement the introduction of a NB system with positive interest on reserves. Suppose the central bank pays $i_m = \lambda i_d$ under NB (and $i_m = 0$ under FB) with $\lambda \in (0, 1)$. $\lambda = 0$ captures the zero interest rate case considered so far and $\lambda = 1$ the case, where the central bank pays i_m equal to the deposit rate prevailing under FB and the two allocations are equivalent.

Table 4: Interest on reserves under NB

	$\bar{i} = 0.096$		$\bar{i} = 0.143$	
	$\lambda = 0$	$\lambda = 0.34$	$\lambda = 0$	$\lambda = 0.62$
N_1, N_2	11,18	11,18	11,18	11,18
$\bar{i_d}$	0.055	0.055	0.098	0.098
$\bar{i_m}$	0	0.019	0	0.061
$1 - \bar{\Delta}_{FB}$	0.18%	0.10%	0.38%	0.10%

Notes: $\sigma = 0.35$, $B/(1-s) = 4.43$ for all scenarios

Table 4 shows how high average i_m needs to be to bring the welfare losses of NB at 0.1% of GDP, for the two high interest rate scenarios where $\bar{i}$ is 9.6% or 14.3% respectively. The result is that in the first case the central bank needs to pay $\bar{i_m}$ of 1.9%, around 1/3 of average deposit rates $\bar{i_d}$ of 5.5%, in the second case $\bar{i_m}$ is 6.1%, around 2/3 of the average deposit rate. Thus complementing a NB system with interest on reserves significantly reduces the welfare costs of NB.

6 Conclusion

The paper aimed to come up with a qualitative and a quantitative answer to the question, what is at stake if we move from the current FB system, with its characteristic combination of financing investments or lending with monetary liabilities like deposits, to 100% reserves NB or a system with a CBDC which constrain or prohibit private money creation. The paper argues that, indeed the unique feature of FB provides a socially useful function, especially if the banking system is competitive and inflation is high. In this case FB provides a means of payment with higher return that compensates money holders against inflation. The calibration suggests however, that the quantitative importance of these benefits is relatively small and gets even smaller if the central bank pays interest on reserves. Thus to the extent that NB systems are able to resolve the instability issues associated to the unique financing structure of FB, the social costs of financial safety seem relatively small.

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Appendix A

A.1 Economy with reserves and preference shock

In this economy there are no banks and the only source of money is the central bank issuing outside money or reserves. This is the basic model of Lagos and Wright (2005) with perfect competition and interest on outside money. Without banks the optimality condition for reserve holdings, (36), looks different. Since sellers cannot deposit their reserves in banks, their marginal value of reserves next period is just $\phi_{+1}(1+i_{m+1})$, the real value of reserves next period. Buyers on the other hand can consume a little bit more if they bring more reserves. Since they are liquidity constrained if holding money is costly, their FM consumption is $q_b = m(1+i_m)/p$. Thus the marginal value of bringing more reserves into next period for a buyer is $u'(q_{b+1})(1+i_{m+1})/p_{+1}$ and (36) becomes:

$$\phi = \beta(1-s)\frac{u'(q_{b+1})(1+i_{m+1})}{p_{+1}} + \beta s \phi_{+1}(1+i_{m+1}).$$

Optimal production still equals $c'(q_s) = p\phi$. Thus the stationarity equilibrium consumption in the FM without banks solves:

$$\frac{u'(q_b)}{c'(\frac{1-s}{s}q_b)} = \left(\frac{1+i}{1+i_m} - s\right)\frac{1}{1-s} \tag{61}$$

The right-hand side of (61) is strictly higher than the right-hand side of (44). So the allocation without banks is strictly worse than the allocation with banks. Also note that the right-hand side of (61) increases with s. So the higher the risk to become a seller with costly idle money holdings, the worse the allocation. Banks are especially valuable if the risk of becoming a seller is high.

A.2 Economy with reserves and no preference shock

In this economy there are no banks and there is a fixed measure s of sellers and $1-s$ of buyers. Again money is only provided by the central bank in the form of reserves. This is a basic version of Rocheteau and Nosal (2017) with interest on outside money. In such an environment only buyers will acquire reserves if holding money is costly. Thus their optimal reserve holdings read analogue to (36):

$$\phi = \beta(1-s)\frac{u'(q_{b+1})(1+i_{m+1})}{p_{+1}}$$

Under stationarity this becomes:

$$\frac{u'(q_b)}{c'(\frac{1-s}{s}q_b)} = \frac{1+i}{1+i_m} \tag{62}$$

This is exactly the same allocation as in the perfect competition model under NB, i.e. in (44) with $\alpha = 1$.

Appendix B

B.1 proof of proposition 2

Proof. Apart from the determination of the deposit rate, (52), the equilibrium conditions under imperfect competition are the same as under perfect competition. In particular, the deposit rate and the bond rate still equal the nominal interest rate, $i_l = i_b = i$, and optimal FM consumption still solves (44). This implies total real deposits, ϕD are independent of N and $i_d^{PC} = \alpha i_m + (1-\alpha)i$. Threshold $\bar{N}$ then solves (51) at $i_d = i_m$. If N increases from $\bar{N}$ the right-hand side of (51) decreases. Thus the equation can only hold if the left-hand side decreases too which implies i_d must increase. Therefore $i_d > i_m$ if $N > \bar{N}$. The opposite logic holds for $N < \bar{N}$. ■