# Credit lines, bank deposits or CBDC? Competition & efficiency in modern payment systems*


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June 2022


**Abstract**

This paper studies the welfare effects of introducing a Central Bank Digital Currency (CBDC). Its premise is that CBDC is a new product in the market for liquidity where it competes with both commercial bank deposits and credit lines used for payments. If the central bank offers CBDC but not credit lines, then it interferes with the complementarity between credit lines and deposits built into modern payment systems. This effect dilutes benefits from new technologies that allow for cheaper provision of deposits, to the point where introducing CBDC may reduce welfare. A similar argument applies to stablecoins and other "deposits-only" forms of liquidity provision.



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An earlier version of this paper was prepared for the June 2019 Annual Macroprudential Conference in Eltville, under the title "Central bank-issued digital currency: The future of money and banking?" We thank Andy Atkeson, Michael Choi, Laura Gati, Nobuhiro Kiyotaki, Narayana Kocherlakota, Arvind Krishnamurthy, Guido Lorenzoni, Dirk Niepelt, Lorenzo Rigon, Marcelo Sena, Carolyn Wilkins and conference participants for helpful comments.

# 1 Introduction

Should central banks provide reserve accounts to everyone? A number of concrete proposals for central bank digital currency (CBDC) are now being discussed by policy makers as well as the general public. For example, the governor of the Swedish Riskbank has put the probability of issuing an "e-krona" within the next decade at greater than 50%.[1] Moreover, in the June 2018 Vollgeld referendum, Swiss voters assessed (and, for now, turned down), a proposal to introduce non-interest paying CBDC. Along with this general interest, an emerging literature is weighing the pros and cons of CBDC.

This paper is a theoretical study of the welfare effects of CBDC. Our approach is to view CBDC as a new product in the market for liquidity, broadly defined: CBDC competes not only with deposits, but also with credit lines offered by commercial banks for liquidity purposes. To illustrate the importance of credit lines for payments, Figure 1 plots deposits at all US commercial banks together with those banks' outstanding credit-card limits. Since credit-card limits provide only a lower bound on credit lines used for payments—for example, the figure leaves out credit lines provided to asset-management firms by their custodian banks—the message is that credit lines matter.

Our focus on the broad market for liquidity leads to a skeptical assessment of CBDC. In particular, introducing CBDC would interfere with current payments technology that exploits complementarities between deposit taking and credit lines. Many CBDC proposals imply the emergence of a system with two types of banks: commercial banks that offer both deposits and credit lines, and a central bank that offers only the former. Our model shows that such hybrid systems entail costs that are not present in the current system when banks jointly provide credit lines and deposits. As a result, even if the central bank can offer deposits at lower cost than commercial banks, welfare increases by less than in a system with deposits alone and could even decline.

Our argument applies beyond CBDC to any hybrid system with competition between commercial banks and a "deposit-only" intermediary. A familiar example is money-market mutual funds, which emerged in the United States in the 1970s when Regulation Q prevented banks to compensate depositors for inflation. A more recent case is that of stablecoins—electronic currency offered by the private sector that is backed by a portfolio of assets. Our results say that restricting such intermediaries to providing deposits is not beneficial. Even if they are competitive and have a technological advantage in offering deposits, they impact the provision of credit lines in a way that lowers or even reverses welfare benefits.

[1] https://news.bitcoin.com/central-bank-digital-currencies-take-center-stage-at-imf-spring-meetings/

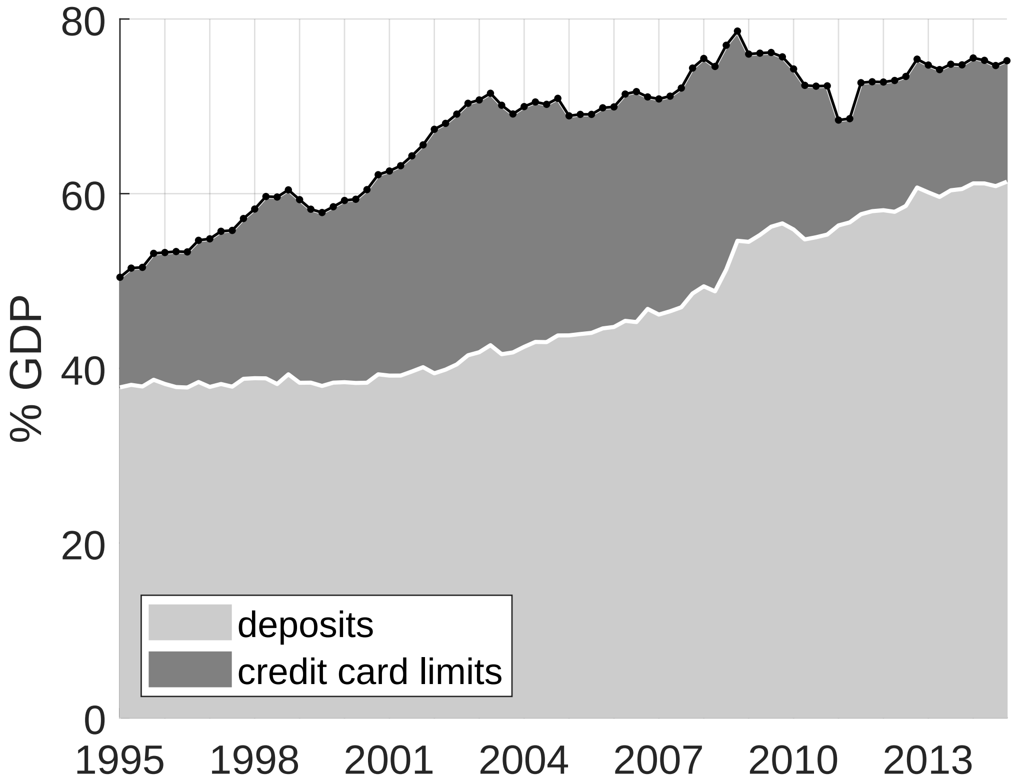


Figure 1: Deposits and credit card limits at US commercial banks

Our conclusions are derived from four assumptions. First, banks face leverage constraints: to be credible as payment instruments, deposits require backing by bank assets. Second, holding assets inside banks is costly: delegation of asset holdings gives rise to asset-management costs. Third, a transaction typically generates a double need for liquidity by both the buyer and the seller, who may rely on different liquidity providers. Finally, deposit contracts are option contracts: they offer the right to buy or sell a bond on demand in order to make or receive a payment. Their cost therefore depends on banks' expectations of how deposit inflows covary with the availability of collateral to back deposits.

A good payment system minimizes costly asset holdings that are required as collateral to back promises. A banking system that jointly offers credit lines and deposits economize on collateral by exploiting the double need for liquidity from buyers and sellers: when a buyer makes a payment by drawing down a credit line, the banking system creates a matching deposit account. The loan serves as collateral for these new deposits. If instead deposits and credit lines are provided by separate types of intermediaries, then more assets are needed to facilitate payments: loans have to be funded and deposits have to be backed. Moreover, once credit line providers do not expect deposit inflows to coincide with the arrival of loans, their cost of providing liquidity increases. The magnitude of this counterforce is larger the more business in the economy is conducted via credit lines, and the better short term loans drawn from lines work as collateral.

Our model builds on the standard neoclassical growth model. We add frictions that require payment instruments supplied by banks as well as collateral constraints and balance-sheet costs. We show that a model with those frictions is equivalent to a model with a less efficient production technology. A switch to the wrong payment system thus works like a negative technology shock: it has real effects on consumption, investment, and the allocation of labor that lower welfare. We also add idiosyncratic shocks to preferences and production that make the liquidity needs of an individual agent not perfectly predictable.

We then compare three types of payment systems. We first show that a system in which banks jointly provide credit lines and deposits is superior to one where they only offer deposits. The gain from credit lines is especially large if many agents have liquidity needs that are difficult to predict. The advantage of credit lines is that assets on bank-balance sheets and the associated costs only reflect actual transactions. Deposits held by agents with unpredictable liquidity needs instead have a precautionary component that requires more assets and hence costs. The gain from credit lines is also larger the more agents have access to credit. Put differently, the loss of switching to a deposits-only system that relies on large buffer stocks for liquidity is particularly high in developed economies where a large share of transactions is currently paid for via credit lines.

To assess CBDC and other deposits-only technologies, we consider a hybrid system where a new low-cost bank offers deposits more cheaply than commercial banks. We show that such a system is unambiguously superior only if the cost advantage of the deposits-only banks is sufficiently large. As commercial banks compete with the central bank for funding, they reduce their supply of deposits. As a result, credit lines become more expensive. They nevertheless continue to be used since they are still cheaper than deposits for some bank customers. Their pricing depends on banks' expectations of how future deposit flows are synchronized with loan volume. Banks' interaction gives rise to multiple equilibria with different welfare costs. If the benefit from cheaper deposits is small, it is mitigated, and possibly even outweighed, by the higher cost of credit lines. This force is stronger if liquidity needs are harder to predict.

Our model is motivated by a liquidity-centric view of banking. In fact, the only way in which banks add value in our model is by providing liquidity. In particular, they do not have a special ability to lend, except by extending on-demand loans when credit lines are drawn.

The role of other bank assets in the model is only to provide backing for deposits. A liquidity-centric view fits well with evidence on bank portfolio composition. In most countries banks hold not only loans, for which they might have a special ability to lend, but also securities. Moreover, a sizeable share of loans tends to be mortgages that are easily securitized. In our model, it makes sense for banks to hold securities even though they are worse at holding them than households, because securities help back deposits and thus deliver payment services.

We restrict technology and preferences so that banks' required collateral is small relative to the capital stock of the economy. In other words, it is never important to accumulate capital in order to provide enough collateral to back payment instruments. Instead, society determines what share of capital is optimally held inside banks and holds the rest outside. This approach also fits well with data on sectoral wealth in modern economies. Indeed, banks typically hold only a share of fixed income securities outstanding in the economy, with another sizeable share of both government and private debt held either directly by households or indirectly through investment intermediaries such as pension funds. Moreover, in most countries, business and housing equity are held almost entirely outside banks.

We emphasize that our assumption that bank lending is small relative to capital does not mean that banking is irrelevant for investment. In our model, capital accumulation depends on the cost of payments because capital-goods producers require liquidity in order to produce. Our assumption on balance-sheet costs imply that capital-goods producing firms also find it burdensome to hold deposits and prefer credit lines.

A premise of our analysis is that it is beneficial for society to minimize the amount of assets held inside banks. Here we build on a large literature that has discussed the costs of delegated portfolio management. At the same time, delegated asset management may also have benefits, for example cheaper diversification or savings of transactions costs. Our approach assumes that such benefits can be achieved more easily through investment intermediaries such as mutual funds that are funded with equity. They do not require asset holdings inside banks that also issue debt. Moreover, the delegated monitoring problems that arise in leveraged banks—which are arguably more complicated than those of investment intermediaries—induce costs that outweigh any benefits that can be realized through investment intermediaries. It is thus optimal to minimize assets inside banks and firms, and to think of the household sector as consolidated with investment intermediaries.

To zero in on the key interaction of credit lines and deposits, our model abstracts from a number of other interesting considerations on CBDC. First, we define CBDC narrowly as a deposit contract and do not consider the option of anonymity that would make CBDC closer to physical currency. In terms of the "money flower" taxonomy of monies introduces by Bech and Garratt (2017), we study CBDC that is widely accessible (as opposed to restricted) as well as account-based (as opposed to token-based). In fact, we abstract from physical currency altogether and require that all payments are made with deposits or credit lines. As a result, we do not engage in the discussion of how CBDC might alter a potential lower bound on interest rates.

Second, we study an entirely real model and do not consider the determination of the price level or how the transmission of monetary policy might change if a CBDC is introduced.[2] This approach is guided by our focus on long-run welfare from the design of the payment system. We thus formulate policy as the elastic supply of real balances at a certain spread between the interest rate on CBDC and a safe claim that is not liquid. In practice, one would expect the central bank to fix both the price and quantity of *nominal* CBDC. In the long run, the price level would then adjust to deliver the quantity of real balances desired by the economy.

Third, we work with frictionless capital and insurance markets. In particular, households have access to a complete set of contingent claims to insure against preference shocks and banks can issue equity at no cost at all times. In addition to making the model analytically tractable, these assumptions also clarify that our mechanism does not rely on net-worth constraints in banks. Moreover, banks in our model are not needed to facilitate consumption smoothing when assets are illiquid, as in the literature that studies banks as a mechanism for liquidity insurance. Their purpose instead is to provide immediacy of payments in goods-market transactions that financial markets cannot provide. Future work might explore the interaction of our mechanism with other financial frictions.

Finally, we do not explicitly model credit risk and aggregate shocks. All lending is deterministic and there is no default. While this simplification precludes us from talking about some interesting features of the data such as risk premia or credit spreads, the loss for our study of balance-sheet positions is smaller. In particular, one interpretation of balance-sheet costs incurred by banks is bankruptcy costs in lending. Suppose for example, that banks hold claims to capital not by owning capital directly, but by making loans that carry idiosyncratic risk and deadweight costs of default. On average, banks then expect to lose a certain share of the return on capital. Households who hold capital directly or through investment intermediaries do not incur the same costs since they hold equity claims.

Our approach builds on the theoretical and empirical literature on liquidity provision.

[2]Piazzesi, Rogers and Schneider (2019) study the transmission of CBDC in a New Keynesian model. They argue that the transmission of interest-rate policy works is similar in a floor system as currently implemented by many central banks, but different from traditional corridor systems because of a lower elasticity of broad money supply. Barrdear and Kumhof (2016) also study CBDC in a New Keynesian setup and derive welfare gains from a reduction in transaction costs.

Strahan (2010) provides an overview and discusses the trend towards greater use of credit lines. Berger and Sedunov (2017) argue that including off-balance sheet measures such as loan commitments is important to measure the role of banks in an economy and provide cross-country evidence. Sufi (2007) shows that credit lines help firms avoid costs of holding cash. Consistent with this idea, our model builds in the assumption that firms can have a preference for credit lines over deposits.

Holmström and Tirole (1998) show how credit lines can help allocate liquidity when individual agents' needs for liquidity are not perfectly predictable, an important theme in our analysis. Kashyap, Rajan and Stein (2002) provide theory and evidence on complementarity between credit lines and bank deposits. They show that, at the level of the individual bank, liquidity management is cheaper when liquidity needs—that is, outflows of funds—implied by the two products are imperfectly correlated. They provide supporting cross-sectional evidence on banks' selection of products to offer (see also Gatev, Schuermann and Strahan (2009)).

In our model, complementarity is due exclusively to collateral constraints; liquidity management plays no role. In fact, we assume that bank-level shocks due to customer-payment instructions net out across banks so they can be managed with a negligible amount of reserves. As a result, banks incur no liquidity-management costs regardless of whether they offer deposits or credit lines. Complementarity is nevertheless present because loans due to drawn down credit lines serve as collateral for deposits created when payments occur. This is why fewer collateral assets are needed when banks offer both products.

In emphasizing multiple means of payments, our model also relates to the large literature on models with cash and credit goods that followed the seminal paper of Lucas and Stokey (1983). Like we do, that literature also introduces demand for liquidity via constraints: in particular, there is a demand for money because of cash-in-advance constraints for the buyers of a subset of goods, and the share of cash versus credit goods matters for welfare results. There is a critical difference to our model, however. In the literature, a credit-good transaction does not require payment instruments issued by intermediaries: it is implemented by trade credit directly from the seller to the buyer. In our model, in contrast, a credit-good transaction still requires deposits: when the buyer takes out a loan to pay, the seller accepts a transfer to a deposit account. Providing liquidity to both buyer and seller in every transaction, is costly to banks—the structure of these costs is at the heart of our mechanism.

A growing literature discusses various forms that CBDC might take, assesses their pros and cons and compares them to other forms of electronic money. Bech and Garratt (2017) provide a taxonomy of monies together with historical examples. Chapman and Wilkins (2019) point out the joint trends of innovation in cryptoassets and decline of cash and discuss challenges for central banks once banks coexist with (public or private) providers of digital currencies. Engert and Fung (2017) survey motivations for CBDC that have been brought up in the literature.

The theoretical literature on CBDC has focused on competition with bank deposits as opposed to credit lines. Andolfatto (2018) studies a model of monopoly banking where the introduction of CBDC reduces rents in the deposit market and increases financial inclusion. He also emphasizes that there need not be a detrimental effect on investment. Niepelt (2020) considers a setup with CBDC and imperfectly competitive banks that manage liquidity with reserves and characterizes optimal policy that involves setting the CBDC interest rate as well as deposit subsidies that address externalities from liquidity management. While our model abstracts from market power and liquidity management by banks, we agree that assessing their role for current bank spreads may matter for judging the impact of CBDC. In our context, it would be interesting to explore the role of concentration in both the credit line and deposit markets, as well as possible bundling of goods by noncompetitive financial institutions and its effect on payment flows.

Faure and Gersbach (2018) and Brunnermeier and Niepelt (2019) are interested in when fractional reserve banking and a system with CBDC are equivalent in terms of allocations. We share their approach of writing down environments with monetary exchange and comparing alternative payment systems. However, a key condition that is violated in our setup is that expanding balance sheets of banks (or central banks) is costless. Indeed, the equivalence results use the idea that when CBDC attracts depositors away from commercial banks, then the central bank can undo those positions by lending to commercial banks. In our model, balance-sheet costs penalize the total length of balance sheets so that the allocation would not be equivalent to one without CBDC. Our focus on balance-sheet costs also leads us to assign the government a technology for borrowing and asset management that is different from that of commercial banks.

Keister and Sanches (2019) also emphasize complementarity between deposits and lending. In their model, however, bank lending is important for funding investment and banks face net worth constraints. Offering deposits at low interest rates relaxes net worth constraints and increases investment, a benefit that is weakened by CBDC. In our model, in contrast, complementarity comes from liquidity provision; our banks are not important for funding investment and do not face net worth constraints. Our approach targets economies with large banks and highly developed securities markets.

The rest of the paper is structured as follows. Section 2 uses simple balance-sheet diagrams to illustrate the main arguments. The diagrams capture the positions taken by agents in the model, but do not get into endogenous prices and choices. Section 3 then lays out the full model. Section 4 studies the synergy between credit lines and deposits, and allows for the entry of a deposits-only intermediary that is not allowed to offer credit lines.

# 2 Transactions and payment instruments

Consider a buyer and a seller who are about to transact an amount of goods $T$. The buyer needs liquidity in order to pay the seller. One option is for the buyer to hold deposits *before* the transaction takes place, and then instruct his bank to transfer funds to the seller. We assume that both the buyer and the seller hold deposits for some period of time—perhaps short—around the date of the transaction.

We further assume that the buyer did not know for sure up front how many goods he wanted to consume. He thus holds deposits $D = T/v$ where $v \in (0, 1)$ is the probability to consume. We say that liquidity needs are more predictable if $v$ is larger. In the extreme case $v = 1$, the buyer knows exactly how much he wants to consume and holds just enough deposits to cover spending.

The banking system must provide deposits both before and after the transaction takes place. In order to do so credibly, it must hold assets worth $D/\phi$. The parameter $\phi$ works like a bound on bank leverage. Banks must further pay a proportional balance-sheet cost $\kappa$ per unit of assets held.

Table 1 illustrates balance sheets. Panel A shows that, before the transaction, the buyer holds deposits $D$ with the bank. The bank holds $A = D/\phi$ assets to back those deposits and finances the remaining assets with equity $E$. The other items in the balance sheets are not important for the argument, so we do not show them explicitly.

Panel B shows balance sheets after the transaction. The payment $vD$ has now been subtracted from deposits and instead appears in the deposit account of the seller. Total deposits at the bank $D$ have not changed. We note that handling transactions does not imply a net outflow from (or inflow into) the banking system. Banks thus do not require reserves in this example.[3]

Since banks hold $A = D/\phi = T/\phi v$ assets both before and after the transaction, we write the total cost of liquidity provision as

$$\kappa A + \kappa A = 2\kappa T/\phi v.$$

[3]We have implicitly assumed here that the transaction does not create imbalances within the banking system. For example, if all sellers had accounts at one bank and all buyers at another, then transactions would require interbank transfers. If banks are similar, we would expect transfer to net out so as to require almost no reserves.

Liquidity is cheaper if banks can lever more as well as when liquidity needs are more predictable.

In an economy where all transactions are supported by deposits, introducing CBDC is beneficial if the central bank has a lower cost of providing deposits. For example, suppose that the central bank is more efficient at managing assets and thus has a lower balance-sheet cost $\kappa^*$, or that the central bank can credibly back deposits with fewer assets to achieve a higher ratio $\phi^*$. The costs of liquidity provision with CBDC are $2\,\kappa^*\,T/\phi^* v$.

An environment in which all payments are made with deposits thus provides an argument in favor of the introduction of CBDC. The same argument applies to an environment in which buyers do not qualify for a credit line.

TABLE 1: DEPOSIT PAYMENT

Panel A: Before the transaction

| Buyer | | Seller | | Bank | |
|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |
| $D$ | | | | $A$ | $D$ |
| | | | | | $E$ |

Panel B: After the transaction

| Buyer | | Seller | | Bank | |
|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |
| $(1-v)\ D$ | | $v\ D$ | | $A$ | $D$ |
| | | | | | $E$ |

## 2.1 Deposits and Credit Lines

Suppose now the buyer arranges a credit line with his bank. The credit limit $L$ is chosen to satisfy the same overall liquidity need as before, that is, $L = T/v$. The buyer then draws down the credit line to pay $T = vL$ with his credit line to the seller, who places the funds in his deposit account.

At the time that the buyer arranges the credit line, the bank does not need to hold assets to back the credit line. After the transaction, in Panel B of Table 2, the buyer has drawn $v\,L$ from the credit line, which is a liability for the buyer and an asset for the bank. The seller receives a deposit which the bank backs with assets $\bar{A}$ that satisfy

$$v\,L = \phi\,(v\,L + \bar{A}) \Longrightarrow \bar{A} = \frac{1-\phi}{\phi} v\,L.$$

The bank finances these assets with equity $\bar{E} = \bar{A}$.

Table 2: Credit Line Payment

Panel A: Before the transaction

| Buyer | | Seller | | Bank | |
|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |
| | | | | | |

Panel B: After the transaction

| Buyer | | Seller | | Bank | |
|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |
| | $v\ L$ | $v\ L$ | | $v\ L$ | $v\ L$ |
| | | | | $\bar{A}$ | $\bar{E}$ |

The costs of liquidity provision are

$$\kappa\,v\,L + \kappa\,\bar{A} = \kappa\left(1 + \frac{(1-\phi)}{\phi}\right) v\,L = \kappa\phi\,T.$$

A credit line economizes on balance-sheet costs for two reasons. First, deposits require asset holdings both before and after transactions take place in order to provide liquidity to the buyer and the seller, respectively. When a credit line is used, in contrast, the transaction generates an asset that in turn backs deposits. This complementarity economizes on asset holdings and cuts cost by a factor of 2. Second, only a fraction $v < 1$ of the credit limit is drawn, which generates a smaller amount of deposits $v\ D$ than the deposit amount $D$ involved with a deposit payment and therefore lower asset costs. This property cuts costs by another factor of $1/v$. Credit lines thus have a greater advantage when liquidity needs are less predictable.

## 2.2 Central bank digital currency

We now introduce CBDC into an economy with deposits and credit. For simplicity, we consider a stark scenario: commercial banks withdraw from the deposit market, so all seller deposits migrate to the central bank. We also assume that the buyer continues to prefer a credit line from a bank. This will typically be the case if liquidity needs are hard to predict and CBDC is not too cheap.

The introduction of CBDC decouples credit and deposits. The seller receives funds that become digital currency, a liability of the central bank in Panel B of Table 3. The central bank backs the digital currency with assets $A^* = v\,L/\phi^*$ and needs equity $E^* = v\,(1-\phi^*)\,L/\phi^*$. Since the commercial bank loses its deposits to fund the loan to credit-line customers, it turns instead to equity $\bar{E}'$.

Table 3: CBDC and Credit Lines

Panel A: Before the transaction

| Buyer | | Seller | | Bank | |
|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |

Panel B: After the transaction

| Buyer | | Seller | | Bank | | Central Bank | |
|---|---|---|---|---|---|---|---|
| Assets | Liabilities | Assets | Liabilities | Assets | Liabilities | Assets | Liabilities |
| | $v\,L$ | $v\,L$ | | $v\,L$ | $E'$ | $A^*$ | $v\,L$ |
| | | | | | | | $E^*$ |

The costs of liquidity provision are

$$\kappa v L + \kappa^* A^* = \kappa T + \frac{\kappa^*}{\phi^*} T.$$

If the central bank has the same technology as the commercial bank, $\kappa^* = \kappa$ and $\phi^* = \phi$, these costs are lower than those with only deposit payments, $2\,\kappa\,T/\phi v$. However, they are clearly higher than with credit. The reason is that the introduction of CBDC decouples credit from deposits and thereby destroys the complementarity in liquidity production.

Our model below formalizes derives this logic in a more elaborate model. The model describes how credit lines and deposits are priced, and endogenizes customers' and banks' demand and supply decisions. It further allows some buyers to not have access to credit lines but always use deposits, and it allows loans associated with drawn credit lines to be worse collateral than other assets. These margins offer some additional insights on when gains from CBDC are present. The basic message is the same: benefits from CBDC are mitigated by weaker complementarity between credit lines and deposits.

# 3 Setup

## 3.1 Preferences and technology

Time is discrete and divided into integer dates $t = 1, 2, 3...$ and intermediate dates $t = 1.5, 2.5$ and so on. At integer dates $t$, capital is installed for production at the next intermediate date $t + .5$. At intermediate dates, an intermediate good is made from capital and labor. It can be transformed into final consumption goods or final capital goods for installation at the next integer date. The production function for the intermediate good at intermediate date $t$ is

$$Y_t = K_t^\alpha N_t^{1-\alpha}, \tag{1}$$

where $K$ is capital that depreciates at rate $\delta$ per unit of time and $N$ is labor.

There is a unit mass of households who form a large family that pools consumption. Households inelastically work at intermediate dates. Felicity from consumption and labor consumption and labor is

$$\log C_t - \theta \frac{N_t^{1+1/\varepsilon}}{1+1/\varepsilon}.$$

Preferences are time separable and households discount the future with a discount factor $\beta$ per unit of time.

Final consumption and capital goods are produced in two stages. First, the intermediate good is transformed one-for-one into component goods. There is a continuum of component goods, a share $\gamma$ of which are cash goods while the other share $1 - \gamma$ are credit goods. At an intermediate date, only a fraction $v_1$ of cash goods and a fraction $v_2$ of credit goods can be produced. Productivity shocks that select the available component goods are iid across goods and time. In the second stage, the final good is made by combining the available individual components. Here all cash goods are perfect substitutes for each other, and similarly for credit goods. However, cash and credit goods are combined via a Leontief production function.

Formally, let $C_t^1$ and $C_t^2$ denote the sum of quantities of cash and credit goods, respectively. Final consumption is then

$$C_t = \min\{\frac{C_t^1}{\gamma}, \frac{C_t^2}{1-\gamma}\}, \tag{2}$$

One way to produce $C_t$ is therefore with a production plan that makes $C_t/v_1$ of every available cash good component and $C_t/v_2$ of every available credit good component. Since $v_1\gamma$ cash good components and $v_2(1-\gamma)$ credit good components are available, this plan uses exactly $C_t$ units of the intermediate good. We focus on such symmetric plans below.

Capital is made from components using the same production function (2). Let $I_t$ denote aggregate investment. In the absence of financial frictions, the resource constraint for the intermediate good at an intermediate date $t$ and for capital at the subsequent integer date are then

$$\begin{aligned} C_t + I_t &= Y_t, \\ K_{t+1} &= I_t + (1-\delta) K_t. \end{aligned} \tag{3}$$

Here $K_{t+1}$ is capital installed at the integer date $t+.5$ for production at the subsequent intermediate date $t+1$.

**First best allocation.** The social planner maximizes expected utility subject to the production function and the resource constraints. In terms of aggregates, the optimal allocation is exactly that of the standard neoclassical growth model. Indeed, felicity for the social planner depends only on aggregate consumption and hours. The optimal allocation is independent of $\gamma$ and the $v$s – those parameters matter only once we introduce financial frictions.

## 3.2 Financial frictions

We now define a decentralized equilibrium with banks and firms and introduce frictions that make liquidity important. The basic principles are that goods trading requires liquidity for both buyers and sellers, leverage is limited, holding assets inside banks is costly and payment instruments have option features. At the same time, we allow for financial markets that are otherwise frictionless. All firms as well as banks introduced below are owned by households. We allow easy financing of firms as well as insurance against idiosyncratic shocks.

Competitive firms produce the intermediate goods and capital goods. Intermediate-goods producers rent capital and hire labor to make goods at intermediate dates. Capital-goods producers buy those intermediate goods to make capital goods ready for installation at the next integer date. There are many capital goods producers; each makes its own component capital good. Factor markets are competitive; we write $w_t$ for the wage and $r_t$ for the rental rate of capital at an intermediate date, both in units of intermediate goods.

Production of components for consumption goods from the intermediate good is done directly by households. Here each household makes its own component. We can think of heterogeneous households shopping independently for goods, and interpret the representative household objective function as arising from an insurance contract among individual households. Productivity shocks to consumption good components thus capture the fact that shopping for consumption goods is decentralized and asynchronous, so not all household members find consumption opportunities in every period.

We introduce demand for liquidity through liquidity constraints, which generalize familiar cash-in-advance constraints. In particular, we assume that goods-market transactions at intermediate dates require payments from buyers to sellers. Buyers must make sure, at the previous integer date, to have liquidity to pay for any purchases, either by holding deposits or by arranging a credit line. Similarly, sellers must carry the payments they received from sales to the next integer date. Factor market transactions are agreed at intermediate dates, but settled only at the next integer date. While all markets are Walrasian, liquidity constraints are designed to capture the fact that goods-market trade is not perfectly synchronized and centralized.

A key assumption is that households and capital-goods producers have to arrange liquidity before they observe their productivity shocks. As a result, holding a noncontingent asset such as deposits always means that there is a state of the world where the agent has "too much" liquidity. In contrast, for intermediate-goods producers who just need to store funds, the need for liquidity is predictable and hence deposits are perfectly adequate. Liquidity is provided by banks, discussed in detail below. Banks face collateral constraints: to provide deposits they must hold assets as collateral.

We also assume that households and capital-goods producers who make cash goods must pay for the intermediate good with deposits. We refer to those agents as cash-good buyers, in contrast to credit-good buyers who can arrange liquidity via credit lines and pay by taking out a loan. We thus think of the cash good and credit good as properties of the individual household of firm, not necessarily the good itself. In particular, an economy with a large share of cash-goods components can be one where many households and firms cannot commit to repay debt and hence have to arrange liquidity via deposits.

Holding assets inside banks requires asset-management services. We assume that those services are produced by an asset-management sector that rents capital and hires workers just like consumption-goods producers. If the payments technology is more costly, it therefore requires more factor inputs, leaving fewer inputs for the production of consumption goods and capital goods. We do not require the use of liquidity in the market for asset-management services. This approach is convenient since it avoids differences in welfare due to how resource costs of liquidity provision are themselves paid for. We believe such effects represent a relatively small share of output and do not want them to drive our conclusions.

The asset structure in our model is kept simple to highlight deposits and loans drawn from credit lines as special payments-related assets. The only other assets we make explicit are capital and bank equity, which are perfect substitutes. To think about the data, capital should be interpreted broadly as "all other assets", including for example bonds and loans, and bank equity should be interpreted broadly as "other bank funding" such as wholesale funding for example from the repo market. Moreover, we have not formally introduced government debt, but a Ricardian equivalence result holds in the model as long as payments instruments are not affected – that is, government debt remains a perfect substitute for capital. While this simplification loses detail for example for asset pricing and portfolio choice predictions, it helps highlight the main new features of our model.

We define $Q_t$ as the relative price of capital at an integer date $t$ in units of consumption goods at the prior intermediate date $t - .5$, and write $Q_t/R_t$ as the relative price of capital in terms of consumption goods at the following intermediate date $t + .5$. Relative prices of consumption goods between adjacent periods are indeterminate, since consumption goods cannot be converted into capital at any given date. We adopt the convention that the gross interest rate between an intermediate date and the following integer date is equal to one, so that $R_t$ is the gross interest rate, in units of consumption goods, between an integer date $t$ and the following intermediate date $t + .5$.

### 3.3 Household problem

The representative family wants to fund consumption at an intermediate date $t$. It has to provide liquidity to individual family members before knowing their productivity shocks: it wants to make sure that every member who is selected to produce can purchase the necessary intermediate goods.

Consider first liquidity for producers of cash goods. Consumption $C_t$ requires $\gamma C_t$ intermediate goods to make cash-good components. The family must provide deposits to pay for those goods. Let $D_t^1$ denote aggregate deposits available at date $t$ to household members who produce cash goods. Since only $v_1$ cash-good producers are selected, the cash-in-advance constraint for cash goods is

$$\gamma C_t \leq v_1 D_t^1. \tag{4}$$

For credit goods, the family has the option of arranging credit lines for members, in addition to providing deposits. A credit line allows borrowing up to $L_t$ between the next intermediate date $t$ and the next integer date $t + .5$ at zero interest. Since $v_2$ credit-goods producers are selected, the liquidity constraint for credit goods is

$$(1-\gamma)C_t \leq v_2\left(D_t^2 + L_t\right). \tag{5}$$

The family starts at the integer date $t - .5$ with wealth $W_{t-.5}$ and earns an interest rate $R_{t-.5}$ on capital invested until the next integer date. It pays for deposits by giving up a spread $s_t$ for every half period that deposits are in the bank. For example, the deposits $D_t^1$ held to pay for cash goods are all the bank between dates $t - .5$ and $t$, and in addition a share $1 - v_1$ remains in the bank between dates $t$ and $t + .5$. As a result, the total spread given up is $s_t(2 - v_1)$. For a credit line, the family pays a fee $f_t$ per unit of credit limit, payable at date $t + .5$. Putting things together, we write the family budget constraint as

$$W_{t+.5} = R_{t-.5}W_{t-.5} + w_t - C_t - s_t\left((2-v_1)D_t^1 + (2-v_2)D_t^2\right) - (v_2 + f_{t-.5})\,L_t. \tag{6}$$

The constraints clarify that deposits and credit lines are functionally equivalent when paying for credit goods: the balance $D_t^2$ works like the credit limit $L_t$, and deposits $(1-v_c)\,D_{t-.5}$ carried over to the next integer period work like the undrawn credit line $(1-v_t)\,L_t$. The difference is in when funds have to be placed in the bank, and how costs are paid. With deposits, the household has to save $D_t$ inside the bank between $t - .5$ and $t$, further has to save a share $1 - v_c$ between date $t$ and $t + .5$, and costs are paid as spreads on both investments. In contrast, with a credit line there is no savings between either pair of dates and the cost is paid as a fee at the end only.

Functional equivalence of deposits and credit lines means that the family will always choose the cheaper of the two to pay for credit goods: it compares the cost of providing liquidity with deposits, $s_t(2 - v_2)$, with the cost of using the line, $f_t$. We define the cost of liquidity for cash and credit goods as

$$\begin{aligned}\omega_t^1 &= s_t(2-v_1), \\ \omega_t^2 &= \min\left\{s_t(2-v_2), f_t\right\}.\end{aligned} \tag{7}$$

Importantly, the cost of liquidity depends not only on market prices of the payment instruments, but also on the predictability of liquidity needs, captured by $v_2$. Holding fixed prices ($s_t$ and $f_t$), less predictable liquidity needs (smaller $v_2$) favor a credit line.

If liquidity is costly, that is, the spread on deposits and the fee on credit lines is positive, the liquidity constraints hold with equality. We can then substitute out payment instruments in the budget constraint. Since liquidity is a perfect complement to consumption, its cost adds to the effective price of consumption. The first-order condition for consumption is then

$$\frac{1}{C_t} = \lambda_{t+.5} \left( 1 + \gamma \frac{\omega_t^1}{v_2} + (1-\gamma) \frac{\omega_t^2}{v_1} \right), \tag{8}$$

where $\lambda_t$ is the marginal utility of wealth, or the multiplier on the budget constraint. The effective price of consumption depends on the $v$s not only through the cost of liquidity, but also through the required quantity. For example, every unit of cash goods requires $1/v_1$ units of liquidity; less predictable liquidity needs require more prrecautionary deposit holdings.

## 3.4 Goods-producing firms

There are three types of firms in the economy. Here we discuss firms that make the intermediate good and capital goods. Firms that provide asset-management services are described below in the section on banking.

**Consumption-goods producers.** Firms that produce the intermediate good sell output at intermediate dates, receive payments, and must carry revenue into the next integer period, when they pay wages and rent on capital. The only way for them to carry revenue forward across subperiods is with deposits on which they pay the spread $s_t$. Given our convention of a zero interest rate between the intermediate date and the subsequent integer date, consumption-goods producers maximize

$$Y_t^c \left(1 - \omega_t^y\right) - w_t N_t - r_t K_t, \tag{9}$$

where $\omega_t^y = s_t$ is the liquidity cost.

The first-order conditions for consumption-goods producers show how liquidity costs lowers marginal revenue:

$$\begin{aligned} \alpha \frac{Y_t^c}{K_t} \left(1 - \omega_t^y\right) &= r_t, \\ (1-\alpha) \frac{Y_t^c}{N_t} \left(1 - \omega_t^y\right) &= w_t. \end{aligned} \tag{10}$$

Complementarity between deposits and production implies that a higher cost of liquidity makes firms plan *as if* wages and rents are higher. This effect is familiar from work on the "cost channel" of monetary policy.

**Capital-goods producers.** Every firm that produces capital goods makes a single component. It must arrange liquidity at date $t - .5$ to prepare for purchasing inputs at date $t$, either through deposits $D_t$ or, for a credit good producer, through a credit line $L_t$. Let $\chi_t \in \{0, 1\}$ indicate whether an individual firm can produce its component at the intermediate date $t$ (we thus omit an index $j$ for the individual firm.) Credit goods producers face the liquidity constraint

$$0 \leq i_t\left(\chi_t\right) \leq D_t + L_t. \tag{11}$$

Investment must be covered by prearranged liquidity, much like households' purchases of consumption goods.

Let $Q_t^2$ denote the price of credit-good components in capital. Shareholder value of a credit-goods producer can be written as

$$R_{t-.5}^{-1}\left(E\left[Q_{t+.5}^2 \chi_t i_t\left(\chi_t\right) - i_t\left(\chi_t\right)\right] - s_t(2 - v_2)D_t - f_{t-.5}L_t\right).$$

Here profits are discounted at the rate of return on capital $R$. At date $t - .5$, the firm arranges the credit line and issues equity to invest in deposits. At date $t$, the firm either pays with deposits or draws down the credit line in order to pay for investment. Deposits not needed for payment cannot be paid out to shareholders right away but must be held inside the firm until the next integer date when the firm sells capital, pays back loans, and receives deposit payout.

Suppose that $Q_{t+.5}^2 > 1$ and liquidity is costly. Firms with $\chi_t = 1$ then want to invest as much as possible and exhaust their liquidity, so that their liquidity constraint binds. Moreover, deposits and credit lines are again functionally equivalent. The firm thus chooses to cheaper option. Just like for household producers of credit goods, its cost of liquidity is thus

$$\omega_t^2 = \min\left\{s_t(2 - v_2), f_t\right\}. \tag{12}$$

Since firms with $\chi_t = 0$ do not invest while the liquidity constraint binds for firms with $\chi_t = 1$, we can substitute out payment instruments and write shareholder value as

$$R_{t-.5}^{-1}\left(v_2(Q_{t+.5}^2 - 1)i_t\left(1\right) - \omega_t^2 i_t(1)\right). \tag{13}$$

Precautionary liquidity provision implies that firms pay more than one for one with the investment they actually do: they are all prepared to invest $i_t(1)$, but only $v_2$ are selected to produce.

For capital-goods producers to break even, the price of credit-goods components must equal their marginal cost, including the liquidity cost. The same is true for cash goods: shareholder value for cash-goods producers takes the same form, except that $\omega_t^1$ is constrained to be the cost of deposits and the price of cash-goods components is $Q_t^1$. Since final capital goods are made from components with Leontief technology, their price is a weighted average of the component prices. We thus arrive at

$$Q_{t+.5} = 1 + \gamma \frac{\omega_t^1}{v_1} + (1-\gamma) \frac{\omega_t^2}{v_2}. \tag{14}$$

The first order condition is thus analogous to the case of consumption in (8). The liquidity costs effectively increase the price of capital goods.

### 3.5 Banking

Banks are competitive firms that live from one integer date to the next. They have a technology to provide liquidity to households and firms at intermediate dates, when the latter cannot access asset markets. Since liquidity is valuable to households and firms, banks earn positive revenue from providing it. However, banks have to hold assets to back deposits, which is costly, to be able to provide this liquidity credibly. Banks trade assets in competitive capital, equity and deposit markets at all dates. There is free entry into banking and banks can be recapitalized at no cost at any date.

We focus throughout on equilibria in which not all capital is held inside banks. Below we will make assumptions on preferences and technology such that some part of the capital stock is always held directly by households. Since there is no aggregate risk, returns on all assets held by households are equated: in particular, the return on capital is the same as the interest rate $R_t$. Since households own banks, the return on bank equity is also equal to $R_t$. As for capital-goods producers, we compute shareholder value using discounting at the return on equity $R_t$.

Consider a bank that provides liquidity for the intermediate date $t$. When the bank provides credit lines, it offers the option to take out a loan. It must therefore conjecture a share $\nu_t$ of lines that is drawn down. Similarly, when the bank provides deposits, it gives customers the option to pay in and out of the bank on demand at the intermediate date. It conjectures a profile for usage of deposits: per unit of deposits provided at the intermediate date $t$, which must be in the bank between dates $t-.5$ and $t$, the bank expects $\sigma_t$ units of deposits to remain in the bank also between date $t$ and the subsequent integer date $t+.5$. Here $\sigma_t$ ranges between zero and infinity: the bank may expect either inflows or outflows of deposits.

At integer dates $t-.5$, the bank issues deposits that provide liquidity $D_t$ at the intermediate date $t$ and buys capital $K_{t-.5}$ to back those deposits. It also provides credit lines that promise liquidity up to $L_t$ at the intermediate date $t$. At integer dates, credit lines are off-balance-sheet, so the initial balance sheet of the bank just equates capital to the sum of deposits and equity. At date $t$, customers draw down a fraction $\nu_t$ of credit lines. Banks can trade capital and deposits to arrive at its new balance sheet

$$\nu_t L_t + K_t = \sigma_t D_t + E_t. \tag{15}$$

The bank can now back deposits with either loans due to drawn credit lines or with capital.

At all dates, banks face a leverage constraint which requires deposits to be less than a fraction of the value of assets:

$$D_t \leq \phi R_{t-.5} K_{t-.5}, \tag{16a}$$

$$\sigma_t D_t \leq \phi_l \nu_t L_t + \phi K_t. \tag{16b}$$

In both cases, the constraint relates deposits used in transactions to the value of assets at the time the transactions are made. In particular, we require that the balance of deposits promised at date $t$ for use in transactions at $t + .5$ is less than $\phi$ times the value of assets at $t + .5$. At the same time, deposits that reflect customer transactions in $t + .5$ must be backed by the value of assets at $t + .5$. We allow for $\phi_l \leq \phi$, that is, the maximal loan-to-value ratio for borrowing against loans is lower than for borrowing against capital. The idea here is to accommodate possible differences in risk between loans which represent unsecured short term debt and bank holdings that represent secured debt such as mortgages.

The key friction in our model is that banks face balance-sheet costs. In particular, for any deposits that banks provide to facilitate transactions at date $t$, banks must buy a proportional amount $\kappa$ of asset management services at a price $p_t$. For any intermediate date $t$, balance sheet costs on deposits provided to sellers (and non-buyers) are thus proportional to $\sigma_t D_t$. Balance-sheet costs on deposits provided to buyers at the prior integer date are proportional to $D_t$, the amount of funds available to buyers. Asset-management services are provided by a competitive asset-management sector which produces services from capital and labor using the same technology as consumption goods.

Our approach abstracts from liquidity shocks and precautionary holdings of interbank deposits to buffer such shocks. With many banks, one might imagine that customer transactions generate large interbank flows. Here the idea is that such flows net out according to a law of large numbers so that no precautionary holdings are necessary as long as the banking system does not face a net outflow of funds. Since interbank liquidity management is not essential to our argument we also abstract from introducing reserves at this point, and capital is the only asset.[4]

The bank chooses nonnegative capital, deposits and credit lines to maximize shareholder value. We write the current value as of date $t + .5$ as

$$(f_t - \nu_t \kappa p_t) L_t + s_t (1 + \sigma_t) D_t - \kappa p_t (K_t + R_{t-.5} K_{t-.5}).$$

On credit lines, banks earn the fee on all lines, but must pay balance-sheet costs for drawn down lines. On deposits, banks earn the spread per period that funds are in the bank. The bank must respect the collateral constraints (16) and pay balance-sheet costs on all capital used as collateral.

Since bank technology is linear, banks' optimal plans are indeterminate. Bank optimization provides conditions that equate prices of payment instruments to banks' marginal cost, that is, banks' expenditure on asset-management services. Moreover, it determines balance-sheet composition at different dates. We assume throughout that the deposits spread $s_t$ is positive and characterize the optimal solution as a function of $s_t$ and the credit line fee $f_t$. We always assume $f_t \leq \nu_t \kappa p_t$, that is, the net return from credit lines funded with equity is nonpositive. Since the balance-sheet cost also makes the net return from holding capital negative, it follows that holding assets is only valuable for the bank if those assets relax the collateral constraints (16).

Suppose the optimal solution has the bank issue a positive quantity of deposits. Since assets are not valuable except as collateral, the collateral constraints (16) both bind. It follows that the bank always holds some capital between dates $t - .5$ and $t$. Its optimal portfolio at date $t$ depends on the relative cost of using loans and capital as collateral. For a bank that issues deposits to break even, the deposit spread must equal the cost of backing deposits:

$$s_t (1 + \sigma_t) = \frac{\kappa p_t}{\phi} + \sigma_t \min \left\{ \frac{\kappa p_t}{\phi}, \frac{\kappa p_t - f_t / \nu_t}{\phi_l} \right\}. \tag{17}$$

Here the first term is the cost of backing deposits with capital between dates $t - .5$ and $t$, while the second term is the cost of backing deposits between dates $t$ and $t + .5$.

Consider the collateral cost in more detail. Holding capital in the first period between dates $t - .5$ and $t$ costs $\kappa p_t$ per unit of capital. The binding collateral constraint (16a) further says that it takes $1/\phi$ units of capital per unit of deposits. In order to back deposits in the

[4] Piazzesi and Schneider (2018) and Piazzesi, Rogers and Schneider (2019) study models in which liquidity management requires reserves and compare spreads and bank positions in a corridor system with scarce reserves as well as a floor system with ample reserves. While adding such detail has further interesting predictions, the key role of collateral in backing money is the same as in the present paper.

second period between dates $t$ and $t+.5$, the bank can rely on capital again, with the same cost per unit of deposits; this is the first term in braces. Alternatively, the bank can rely on loans: it then needs $1/\phi_l$ loans per unit of deposits, but also earns fees. Since only $\nu_t$ credit line customers draw down the line, the fee income is $1/\nu_t$ per unit of loans. If the two cost terms in braces are different, the bank chooses only the cheaper collateral option at date $t$.

The bank does not issue deposits if the spread $s_t$ is below the value that satisfies (17). For such a bank, the fee must satisfy $f_t = \nu_t \kappa p_t$, so the bank breaks even when it funds loans with equity. The second term in (17) is then zero, and the spread satisfies

$$s_t(1+\sigma_t) < \frac{\kappa p_t}{\phi}. \tag{18}$$

We note that the bank's expected deposit-use profile, captured by $\sigma_t$ matters for its choice. This is because the cost of backing deposits may differ across periods: if fees are high, then it may be cheaper to back deposits with loans in the second period than backing them with capital in the first period. For low enough expected deposit flows in the second period, the bank then withdraws from the deposit market.

To sum up, we can distinguish three different business models for the bank. If prices satisfy

$$s_t = \frac{\kappa p_t}{\phi}, \qquad\qquad f_t = \nu_t \kappa p_t \left(1 - \frac{\phi_l}{\phi}\right), \tag{19}$$

then the bank holds both loans and capital at date $t$. For lower values of $s_t$, it is not profitable to back deposits with capital. However, issuing deposits still makes sense if the spread is not too low and the fee on credit lines is high enough. Since issuing deposits always attracts some customers at date $t-.5$, the bank purchases some capital to back them. Its negative margin in the first period is outweighed by a positive margin in the second period. The required negative equilibrium relationship between $f_t$ and $s_t$ can be read off from (17) when the second term in braces is strictly below the first. Finally, if the spread is below the threshold (18), then the bank prefers to fund loans with equity rather than deposits.

**Asset management and the pricing of liquidity.** In equilibrium, bank customers' costs of liquidity $\omega$ reflect the deposit spread $s_t$ and the credit-line fee $f_t$. Bank optimality implies that both of these prices are proportional to banks' expenditure on asset-management services. This is because asset-management services are the only factor of production in banking. These services are produced by a sector that uses the same technology as intermediate goods producers. In equilibrium, both asset-management services and the intermediate good must be produced. Since production functions are identical, the relative price of asset-management services at intermediate date $t$ must be $p_t = 1 - \omega_t^y$, the effective price realized by intermediate goods producers from (9). At this price, banks and intermediate good producers break even.

In equilibrium, any unit of consumption and investment requires the same amount of extra output to make asset-management services. Indeed, consider a unit of consumption or investment. The coefficients $\omega$ capture expenditure for liquidity by both buyers and sellers. Since the shares of cash and credit goods are the same for consumption and investment, so is the expenditure on liquidity by buyers. Dividing by the price of asset-management services, we obtain the quantity of asset-management services needed per unit of output

$$\ell_t = \gamma \frac{\omega_t^1}{v_1 p_t} + (1-\gamma)\frac{\omega_t^2}{v_2 p_t} + \frac{\omega_t^y}{p_t} = \frac{1 + \gamma \frac{\omega_t^1}{v_1} + (1-\gamma)\frac{\omega_t^2}{v_2}}{1-\omega_t^y} - 1. \tag{20}$$

The statistic $\ell_t$ summarizes the real effects of the payment system in our model. We refer to it as the *welfare cost of liquidity*.

Market clearing conditions for the intermediate good, capital goods, consumption goods, and asset-management services are tightly related. Liquidity provided by payment instruments is a perfect complement to consumption and investment, which are made one for one from the intermediate good. Moreover, the cost of providing payment instruments is expenditure on asset-management services that are produced with the same technology as the intermediate good. We write $Y_t$ for total output of the intermediate good plus asset-management services. We can then write the resource constraint with financial frictions as

$$(C_t + I_t)(1 + \ell_t) = Y_t. \tag{21}$$

## 3.6 Characterizing equilibrium

A competitive equilibrium consists of (i) a real allocation $(C_t, K_t, N_t, Y_t)$, (ii) prices of goods and assets, (iii) asset and liability positions for households, firms and banks, and (iv) banks' expected paths for deposits $\sigma_t$ and credit lines $v_t$ such that all agents optimize, markets clear and banks' expected paths are consistent with equilibrium outcomes. We restrict attention to symmetric equilibria in which all banks and firms of the same type behave identically.

Capital serves two purposes in our model: it is used to produce goods and to back deposits. In principle, the economy could be such that issuance of deposits is constrained by the total amount of capital available to back them. We now make an assumption on preferences and technology to rule out this possibility in steady state. We require that, even if all payments have to be made with deposits, there is enough capital to back those deposits:

*Assumption A1. (Liquidity provision is not a motive for capital accumulation in steady state.)*

$$\rho + \delta < \frac{\alpha\phi}{\frac{\gamma}{v_1} + \frac{1-\gamma}{v_2}\left(1 + 2\frac{\kappa}{\phi}\left(\frac{\gamma}{v_1} + \frac{1-\gamma}{v_2}\right)\right)}.$$

Assumption A1 requires sufficiently low rates of time preference and depreciation relative to the probabilities of trading $v$. The two rates capture households' distaste for capital accumulation, which must be weak relative to their need for liquidity captured by $v$. The condition is also easier to satisfy when the capital share in production is higher (higher $\alpha$) so production requires more capital accumulation, as well as when banks can leverage more (higher $\phi$), so banks need fewer assets to back deposits.

Given Assumption A1, a convenient feature of our model is that choices and prices of payment instruments together with bank balance sheets can be solved in a first step independently of the real allocation. This is because the payment technology is linear, all instruments are priced at marginal cost and bank customers' choice of payment instruments is discrete. The result of this first step is then a set of costs of liquidity $\omega$ for all bank customers, and hence a welfare cost of liquidity $\ell_t$. Given a path for $\ell_t$, we characterize equilibrium by combining bank customers' optimality conditions and market clearing. In this section, we illustrate this second step. We then go through different cases for the first step to discuss the real effects of payments technology.

Consider first the intratemporal tradeoff between leisure and consumption. We combine household first-order conditions for consumption (8), intermediate good firms' first-order condition for labor (10) and the definition of the cost of liquidity $\ell_t$ in (20) to arrive at the intratemporal condition

$$\theta C_t N_t^{\frac{1}{\varepsilon}} = \frac{1}{1+\ell_t}\left(1-\alpha\right)\frac{Y_t}{N_t}. \tag{22}$$

From the perspective of an econometrician, the welfare cost of liquidity works like a "labor wedge": much like a tax on labor income, it leads to lower hours for the same marginal product of labor. The difference to the tax case is that $\ell_t$ is an actual cost that enters the resource constraint (21).

Consider next the intertemporal tradeoff between consumption and investment. From capital goods producers' first-order condition (14), the relative price of capital reflects only liquidity costs and is constant in equilibrium. Combining that condition with the definition of the return on capital $(Q_{t+.5}(1-\delta)+r_t)/Q_{t-.5}$ as well as intermediate goods firms' first order conditions for capital (10), we have

$$\beta \frac{C_t}{C_{t+1}} \left(1 - \delta + \alpha \frac{Y_{t+1}}{K_{t+1}} \frac{1}{1+\ell_t}\right) = 1. \tag{23}$$

A higher welfare cost of liquidity reduces the incentive to accumulate capital – it works like an “investment wedge", in addition to its role as a labor wedge above.

Given a path for the liquidity cost $\ell_t$, an equilibrium allocation is a path for consumption, capital, hours and output that satisfies (21)-(23) together with the production function (1). We note that such a path would also be chosen by a social planner who chooses consumption, investment, capital, and output to maximize expected utility subject to the capital accumulation equation and the resource constraint (21). Indeed, eliminating prices from firms' and household marginal conditions or eliminating multipliers from the social planner's first-order conditions both deliver the same set of equations.

To think about the dynamics of the model, we can further exploit the fact that it is isomorphic to the standard neoclassical growth model. Indeed, a higher welfare cost of liquidity works exactly like lower TFP in the growth model. In the cross section of payment systems, a more costly system thus leads to lower capital and lower output. Moreover, an unanticipated increase in the welfare cost of liquidity, say a decrease in $\phi$ that tightens banks' leverage constraint, works like a drop in TFP: it generates a recession with lower output, consumption, hours, and investment.

**Steady-state welfare.** To compare economies with different liquidity provision arrangements, we compute steady-state welfare. In steady state with constant liquidity cost $\ell$, output, labor, consumption, and investment are also constant. The capital-labor ratio $K/N$ follows from (23) and the production function as

$$\frac{K}{N} = \left(\frac{\alpha}{(\rho+\delta)(1+\ell)}\right)^{\frac{1}{1-\alpha}}.$$

A higher cost of liquidity implies a lower long-run capital stock.

Since we have assumed balanced growth preferences and changes in liquidity costs work like technology shifts, steady-state labor hours are at the first best level $\bar{N}$, say, independently of the $\ell$ . The welfare effect of liquidity derives instead from the level of consumption

$$C = \bar{C}\left(\frac{1}{1+\ell}\right)^{\frac{\alpha}{1-\alpha}}, \tag{24}$$

where $\bar{C}$ is consumption in the absence of liquidity frictions.

To verify that the capital stock is higher than assets held by banks, we observe that the capital-output ratio is $(K/N)^{1-\alpha}$. Substituting for $\ell$ using (20) and (7), Assumption A.1 says that the capital stock is larger than what would be needed when deposits were used to pay for all of output. The latter is an upper bound on assets required by banks. Indeed, banks need to hold fewer assets between an integer date and the next intermediate date, since it is enough to back deposits worth the sum of consumption and investment, not asset-management services. Between an intermediate date and the next integer date, banks hold the same amount of assets: the only accounting change is that some deposits are transferred from buyers' accounts to sellers' accounts.

# 4 Comparing payment systems

We now begin our comparison of equilibria with different payment technologies. We first illustrate the welfare benefits of credit lines and the complementarity between credit lines and deposits.

## 4.1 Equilibrium with credit lines and deposits

We first study equilibria such that all credit-good components are purchased using credit lines. In such equilibria, even though banks can use loans as collateral to back deposits, they still must hold capital in every period. Indeed, deposits must be available for sellers to store all output. Since $\phi_l < 1$, loans provided to credit-good customers do not deliver sufficient collateral even when the share of credit goods $\gamma$ is equal to one. From our discussion in Section 3.5, banks hold capital if and only if prices of liquidity are given by (19). Moreover, in this case banks' expectations about deposit flows do not matter for bank portfolios. Expectations about credit-line use are simply $\nu_t = v_2$; credit line buyers who have a liquidity need draw down their line.

We derive the welfare cost of liquidity by substituting the prices (19) into (20) using $w_t^2 = f_t$, and from problem of goods-producing firms we know $\omega_t^y = s_t = \kappa p_t/\phi$. We obtain

$$\ell = \frac{\kappa}{\phi}\left(1+\gamma\frac{2-v_1}{v_1}+(1-\gamma)\left(\phi-\phi_l\right)\right). \tag{25}$$

We can interpret the first term as the cost of supplying cash-good buyers and sellers with deposits backed by *with capital*. Here every unit of deposits requires $1/\phi$ units of capital. Liquidity for cash-good buyers requires $(2-v_1)/v_1 > 1$ units of deposits per unit of consumption because of precautionary deposit holdings. The second term is the additional cost due to provision of credit lines to credit-good buyers. It is positive only if $\phi_l < \phi$, that is, loans are worse collateral than capital. The key here is the complementarity in production between deposits and loans: providing liquidity via lines does not add to cost since collateral is already needed to back deposits.

For an equilibrium with credit lines to exist, it is necessary that credit-good buyers indeed prefer a credit line to deposits. We thus need that the price of the credit line $f_t$ is below the expenditure on deposit spreads for the same liquidity $s_t(2 - v_2)$. Using the price formulas (19), the condition is

$$\frac{2 - v_2}{v_2} - (\phi - \phi_l) > 0. \tag{26}$$

This condition is always satisfied. Since all parameters are between zero and one, the first term is bounded below by one and the second term is bounded above by one.

The two terms showcase the two reasons why credit lines are useful in our model. On the one hand, they save balance-sheet costs since they require no first period deposits and no second period deposits, due to unused precautionary holdings. Balance-sheet space needed for liquidity is exactly the quantity transacted. As a result, credit lines are preferred even if loans are useless as collateral ($\phi_l = 0$), while capital is perfect ($\phi = 1$). On the other hand, credit lines are attractive because loans can be used to back deposits that have to be provided to sellers in any case. The smaller the difference in collateral value on the left-hand side, the more beneficial credit lines are as a payment instrument.

It is interesting to ask how we can see the magnitude of the welfare cost of liquidity in the data. We note first that the spread on deposits is $s = \kappa p/\phi$, where the price of asset-management services itself is $p = 1/(1 + \kappa/\phi)$. If the spread is a small decimal number, as in the data, it thus equals $\kappa/\phi$ to a close approximation. Moreover, the quantity of deposits can clarify the role of cash goods. In the model, the quantity fluctuates between odd and even periods. Taking a simple average to compare to the deposits/GDP ratio (or inverse velocity), we get

$$\frac{\text{deposits}}{\text{GDP}} = \frac{1}{2}\left(1 + \gamma\frac{2 - v_1}{v_1}\right). \tag{27}$$

It follows that the first term in the liquidity cost (25) is approximately given by the deposit spread divided by the velocity of deposits.

**The welfare gain from credit lines.** To assess the overall welfare gain from credit lines, consider an economy where they are not available. A bank that cannot offer lines must also hold capital at all dates, so its deposit spread is still given by (19). The difference is that credit-good buyers now also have to use deposits. The cost difference implied by (26) is thus added to the total welfare cost. If we set $\omega_t^2 = s_t(2 - v_2)$ in (20), the liquidity cost becomes

$$\ell = \frac{\kappa}{\phi}\left(1 + \gamma\frac{2 - v_1}{v_1} + (1 - \gamma)\frac{2 - v_2}{v_2}\right). \tag{28}$$

When credit-line customers have to switch to deposits, they also have precautionary deposit holdings. The predictability of their liquidity needs $v_2$ thus matters for welfare. In the economy with credit lines, welfare (25) does not depend on $v_2$: less predictable needs are accommodated by simply changing the use of lines and do not require more balance-sheet space.

The welfare gain from credit lines is the difference between (28) and (25). Since (26) holds, it is strictly positive. It naturally scales with overall balance-sheet costs as well as the share of credit-good buyers. In addition, it is higher when credit-good buyers' liquidity needs are less predictable (low $v_2$). This is because unpredictable liquidity needs require more precautionary deposit holdings that take balance-sheet space. Even if credit-good buyers' liquidity needs are perfectly predictable ($v_2 = 1$), however, there is still a benefit since the buffer stock of deposits held in the first period can be avoided. In addition, the welfare gain is increasing in the relative benefit of loans as collateral $\phi_l - \phi$.

## 4.2 Separating credit lines and deposits

What happens when a new bank enters the market that only offers deposits but does so more cheaply than existing banks that also offer credit lines? A special case of such an entrant is a central bank that elastically supplies deposits at marginal cost. However, the analysis of this section applies also to a competitive deposits-only banking sector that competes with commercial banks that offer both instruments. In either case, we refer to the new entrant as a *low-cost bank*, and the incumbents as high-cost banks. We introduce parameters $\kappa^* \leq \kappa$ and $\phi^* \geq \phi$ that describe the more efficient technology of the low-cost entrant.

We now briefly discuss the benchmark case of an economy without credit lines. We then characterize equilibria with two payment instruments. Here we use the previous results on bank optimization together with market clearing to arrive at Figure 2 which provides an overview of all possible equilibria as well as their welfare costs. We then use this result to interpret alternative payment systems.

**Deposit-only economy.** If all payments are done with deposits, entry of a more cost-efficient technology for making deposits is clearly beneficial. In equilibrium, only low-cost banks can survive. The spread on deposits decreases to reflect their lower marginal cost. The welfare gain can be seen in (28), the expression for the welfare cost of liquidity in a deposits-only economy. Entry of low cost banks amounts to reducing $\kappa/\phi$ to the lower value $\kappa^*/\phi^*$. The welfare gain is larger when bank customers' liquidity needs are less predictable. Since $v_i < 1$, the welfare effect in percent of consumption is typically larger than the effect on the spread, which is approximately the change in $\kappa/\phi$.

We also note that entry of a cheap deposits-only bank increases investment. In our model, banks add value only by providing liquidity. The fact that entrant banks compete deposits away from existing commercial banks therefore does not have a negative effect on capital accumulation. Instead, as $\ell_t$ declines, the effective return on capital as well as the steady state capital stock increase. A cheaper payment system lowers the relative price of capital goods as it makes it cheaper for capital-goods producers to shop for inputs.

**Hybrid economy.** Consider now an economy where high-cost incumbents can supply credit lines, whereas low-cost entrants can only supply deposits. In equilibrium, low-cost banks will always supply some deposits. If this were not the case, the spread would have to be unchanged from an equilibrium with only high-cost incumbents. It would therefore be higher than low-cost banks' marginal cost and the latter would make unbounded profits. Once low-cost banks enter, however, the spread has to be equal to their marginal cost, $s_t = \kappa^* p_t / \phi^*$. Low-cost banks have to back deposits with capital, and break even only if spreads compensate them accordingly. The spread is also independent of low-cost banks' expected deposit flows.

Can high and low cost banks coexist in equilibrium? If low-cost bank deposits are sufficiently cheap, then the answer is no. In this case, credit lines will be abandoned altogether and incumbents go out of business. The relevant condition here is whether credit-line customers prefer to switch to deposits. An equilibrium with credit lines always requires

$$f_t \leq s_t(2 - v_2). \tag{29}$$

Since the marginal cost of both credit lines in high-cost banks and deposits in low-cost banks are related to balance-sheet costs, we can use this condition to restrict the cost advantage of the more efficient entrant. Intuitively, it says that the low-cost banks' cost cannot be too low.

As long as (29) holds, there are always some customers who prefer credit lines. This means high-cost incumbents, who are the only suppliers of credit lines, survive in equilibrium. Consider the problem of high-cost banks that face a spread below the marginal cost of deposits backed with capital. From Section 3.5, this does not necessarily mean that the bank ceases to supply deposits. Instead, it offers deposits as long as the fee on credit lines and expected deposit use in the second period (described by $\sigma_t$) are sufficiently high. In contrast to the low-cost bank, deposit-use expectations are now critical. We distinguish two types of equilibria. If the deposit spread is below the critical threshold from (18), or $s_t < \kappa p_t / \phi(1 + \sigma_t)$, then banks do not issue deposits and $f_t = \nu_t \kappa p_t$.

In contrast, if the spread is above the threshold, then banks continue to issue deposits, and the equilibrium fee follows from (17) as

$$f_t = \frac{\nu_t \phi_l}{1 + \kappa^*/\phi^*} \left( \frac{1}{\sigma_t} \left( \frac{\kappa}{\phi} - \frac{\kappa^*}{\phi^*} \right) + \frac{\kappa}{\phi_l} - \frac{\kappa^*}{\phi} \right). \tag{30}$$

A high-cost bank can break even while issuing deposits at spreads below marginal cost since a high fee on credit lines earned in the second period makes up for losses made on deposits. Such losses arise in both periods. The first term compensates for losses made in the first period, where deposits have to be backed by capital. This term is decreasing in $\sigma_t$, the relative second period deposit use. The second term compensates for losses in the second period. As the cost parameters for low and high cost banks converge, the first term goes to zero and the second goes to the fee (19) in the original equilibrium with only high-cost banks.

What are equilibrium conjectures for the use of payment instruments? For credit lines, which are offered only by high-cost banks and used only by credit-good customers, we must have $\nu_t = v_2$, as before. Conjectures of deposit use, however, are not uniquely pinned down. Customers are indifferent among banks, and low-cost banks are indifferent about how many deposits to offer. At the same time, high-cost banks offer more deposits the larger is $\sigma_t$. As a result, we can have equilibria with high $\sigma_t$ and more deposits produced at high cost, but also equilibria with low $\sigma_t$ and little or no deposit supply from high-cost banks.

Consider the range of equilibria such that high-cost incumbents continue to offer deposits. In the second period, it is optimal for high-cost banks to offer as many deposits as can be backed by loans, or $\phi_l(1-\gamma)(C+I)$. Since the total quantity of deposits required to transact $C+I$ is larger than one, this does not restrict expectations: we can always have low-cost banks issue the remaining deposits. However, expected deposits in the first period must also be lower than or equal to total deposits demanded then, which requires

$$\phi_l(1-\gamma)\frac{1}{\sigma_t} \leq \frac{\gamma}{v_1}. \tag{31}$$

Measured in multiples of output, the right hand side is deposits required by cash-good buyers in the first period. The condition thus describes a lower bound, say $\underline{\sigma}$, for the belief parameter.

Now consider equilibria in which high-cost incumbents cease to offer deposits. In this case, equilibrium deposit use no longer restricts expectations. Since the high-cost bank does not service any depositors, its experience cannot contradict its expectations of deposit use. We thus allow any $\sigma_t$ that supports optimal behavior by low-cost banks. In particular, we can now have $\sigma_t < \underline{\sigma}$. For example, as $\sigma_t$ goes to zero, we capture the situation where high-cost incumbents fear a run to low-cost entrants in the second period.

Substituting formulas for prices of payment instruments into (20), we obtain the welfare cost of liquidity in a hybrid system as a function of cost parameters and expectations:

$$\ell_t = \frac{\kappa^*}{\phi^*}\left(1+\gamma\frac{2-v_1}{v_1}\right) + (1-\gamma)\min\left\{\frac{\kappa^*}{\phi^*}\frac{2-v_2}{v_2}, \kappa - \frac{\phi_l}{\sigma_t}\max\left\{\frac{\kappa^*}{\phi^*}(\sigma_t+1) - \frac{\kappa}{\phi}, 0\right\}\right\}. \quad (32)$$

As in (25), the first term is the cost of supplying deposits backed with capital to sellers and cash-good buyers. The second term is the cost of supplying payment instruments to credit-good buyers.

There are three cases for how credit-good buyers pay. If the first expression in the outer braces is lower, then (29) does not hold and all liquidity comes from deposits. Otherwise, the second expression in the outer braces applies: it is the cost of credit lines, which in turn is a minimum of two terms. The first term in the inner braces is the cost of supplying credit lines when loans are funded by equity. Finally, the last term is the cost reduction due to complementarity of deposits and credit lines—it is zero when high-cost banks do not issue deposits.

**A graphical overview of equilibria.** Figure 2 graphically summarizes the properties of feasible equilibria by plotting the welfare cost of liquidity (32) as a function of low-cost banks' marginal cost $\kappa^*/\phi^*$, showing different lines for different values of the expectation parameter $\sigma_t$. Welfare cost at the initial equilibrium, E, before entry is the value at high-cost banks' marginal cost $\kappa/\phi$: if entrants have the same technology as incumbents, then welfare is as in the original equilibrium (25).

For given $\sigma_t$, the welfare cost (32) is the lower envelope of three straight lines that reflect the three different ways of providing liquidity to credit-good buyers: deposits, credit lines funded with equity, and credit lines funded with deposits. The first line OA is the welfare cost when high-cost banks go out of business and credit-good buyers use deposits provided by low-cost banks. It starts at the origin, O, since cost is zero when low-cost banks can offer deposits for free. It is also the steepest line: changes in marginal cost have a large impact on welfare since they affect the balance-sheet cost of capital needed to back a large quantity of deposits.

The second line BC is welfare cost with credit lines funded by equity. It has an intercept, given by the balance-sheet cost of the loans for high-cost banks: if credit lines are produced, those costs accrue even if deposits are free to produce for low-cost banks. The line BC is flatter than the line OA since variation in the cost of low-cost banks now only benefits deposits used by sellers and cash-good buyers. Also, its endpoint C is located strictly above the original equilibrium: in that equilibrium, credit lines were funded with deposits which made them cheaper than if equity has to be used. We finally note that the line BC, like OA, is independent

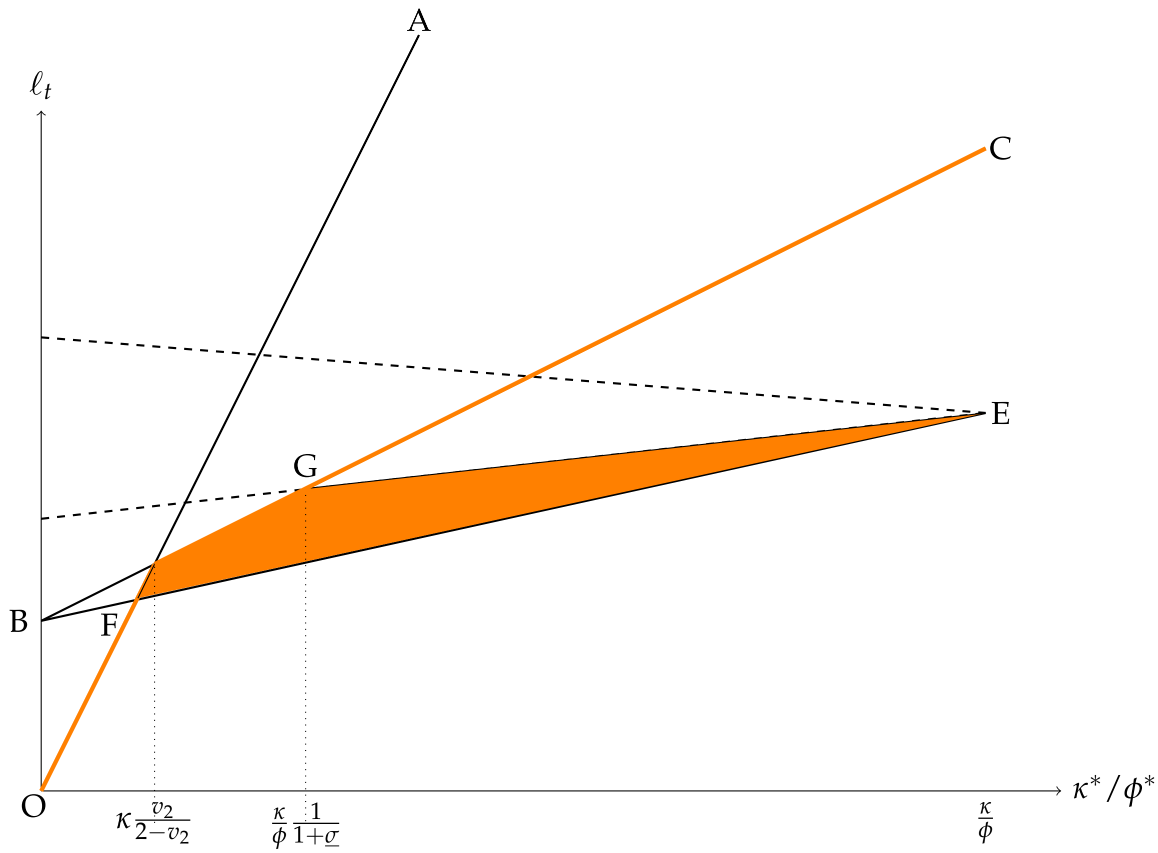


Figure 2: Welfare cost of liquidity

of $\sigma_t$: it describes equilibria where high-cost banks do not issue deposits so their deposit-use expectations are irrelevant.

A third line represents cost when loans are funded with deposits and hence depends on $\sigma_t$. The figure presents several examples. For any $\sigma_t$, these lines go through the original equilibrium point E. In contrast to the other two lines, however, it is not necessarily upward-sloping: when low-cost banks' marginal cost increases, funding credit lines becomes less costly for high-cost banks. This effect is stronger for low $\sigma_t$: the bank then attracts relative more depositors in the first period and has to buy capital to back them, which is not profitable. Graphically, $\sigma_t$ determines the intercept of the line. As $\sigma_t$ becomes very large, the intercept goes to $(1-\gamma)\kappa$, the intercept of the line BC. For smaller $\sigma_t$, the intercept is higher, and it goes to infinity as $\sigma_t$ tends to zero.

As the lower envelope, the welfare cost (32) can consist of two or three line segments. For very high $\sigma_t$, there is no marginal cost at which credit lines are funded with equity – the welfare cost function consists only of one segment of OA and one segment of the third line that depends on $\sigma_t$. A profile with high $\sigma_t$ lets deposits flow into the high cost bank "at the right time" when it also has loans to make. This saves balance-sheet space and keeps cost low. For higher $\sigma_t$ in contrast, there are three segments: for an interior interval of marginal costs of low-cost banks, high-cost banks fund loans with equity.

In equilibria with deposit issuance by high-cost banks, those banks' conjectures about deposits use must respect the lower bound $\underline{\sigma}$. For this reason, we have marked in the figure the point G at a cost of $\kappa^*/\phi^* = \kappa/\phi\,(1+\underline{\sigma})$. The segment GE describes equilibria with deposit issuance by high cost banks when $\sigma_t$ exactly achieves the lower bound. The slope of this line segment is weakly positive: it goes to zero as the share of credit goods goes to one. The line further serves as an upper bound for cost in any equilibrium where high cost banks offer deposits: for higher $\sigma$ the intercept of the line that describes the cost of this business model must be lower.

We can now use the figure to describe the full range of equilibria that exist for any marginal cost of low cost banks. To the left of the point F, high cost banks are driven out of the market and equilibrium is unique. To the right of point F, the fragile nature of deposit markets allows for multiple equilibria, indexed by high cost banks' expectations $\sigma_t$. There are two types of equilibria. On the one hand, we have equilibria where high cost banks no longer issue deposits, located along the segment GC. On the other hand, we have the shaded polygon of equilibrium points where high cost banks do issue deposits.

To draw the figure, we have assumed that $v_2/(2-v_2) < 1+\underline{\sigma}$, which essentially requires that liquidity needs of credit-good buyers are sufficiently unpredictable. If this inequality is reversed, the line OA intersects GE before it intersects BC, call the latter point H. In this case, the equilibrium set consists of a segment OF, a polygon (the triangle FEG) as well as the segments from G to H and from H to C. The qualitative message remains the same: for small improvements in the deposit cost, $\ell_t$ falls much less than for large ones, and there are multiple equilibria, including bad ones with higher cost than the original point E.

We summarize the key takeaways from equation (32) in the following proposition.

**Proposition.** *Suppose in an initial equilibrium payments are handled by commercial banks with balance sheet cost $\kappa$ and leverage parameter $\phi$. Suppose there is free entry of deposits-only banks with balance sheet cost $\kappa^*$ and leverage parameter $\phi^*$ such that $\kappa/\phi > \kappa^*/\phi^*$.*

*If $\kappa^*/\phi*$ is sufficiently small, there is a unique equilibrium in which commercial banks no longer operate and all payments are made with deposits. Welfare is higher than in the initial equilibrium.*

*If $\kappa^*/\phi^*$ is sufficiently large (so the relative cost advantage of deposit-only banks is sufficiently small), then*

*a. there are multiple equilibria that differ in deposit flows, expectations about deposit flows, and* *welfare.*

*b. in both the best and the worst equilibrium, the marginal benefit of a lower cost of deposits* $\kappa^*/\phi*$ *is smaller than in an economy where all payments are made with deposits.*

*c. the best equilibrium has commercial banks issuing deposits, and welfare is at least as high as in the initial equilibrium.*

*d. as the share of credit goods* $\gamma$ *and the collateral quality of loans* $\phi_l$ *go to one, the marginal welfare gain of lower deposit costs* $\kappa^*/\phi*$ *goes to zero, so welfare goes to that of the initial equilibrium.*

*e. the worst equilibrium has commercial banks not issue deposits, and welfare is lower than in the initial equilibrium.*

*f. all equilibria are worse than an equilibrium in which all banks are allowed to offer credit lines.*

**Problems with a hybrid system.** We draw four conclusions on the welfare properties of hybrid systems. First, complementarity between credit lines and deposits dilutes the benefits of new technology introduced by low-cost entrants. In graphical terms, the key point here is that the welfare-cost curve flattens as we get closer to the initial equilibrium. In other words, small increases in technology do not entail large welfare benefits. In particular, the realized benefits are smaller than what one might expect if the welfare calculation is based only on consideration of deposits.

The second point is that a hybrid system is fragile, in the sense that it gives rise to multiple equilibria. Since deposit flows are not plannable as neatly as, say, wholesale funding flows, banks' expectations of depositor behavior matter. The price of deposits is not the only variable coordinating behavior in the market. Concretely, if high-cost banks fear higher outflows in the second period, then deposits are less profitable for them, and they supply less. In a world with only deposits, this would not be a concern. Given complementarity with credit lines, however, self-fulfilling changes in expectations affect the cost of credit lines and hence real activity and welfare.

Third, in a hybrid system, better technology does not unambiguously improve welfare. This follows from the existence of equilibria where high-cost incumbents cease to offer deposits. As Figure 2 shows, there is always a range of cost improvements such that the worst equilibrium cost is larger than the cost at the initial equilibrium. Intuitively, if incumbents worry about deposit outflows enough so they exit the deposit market, but deposits are not cheap enough to replace credit lines, then competition has created a worse mix of payment instruments.

The final point is that a hybrid system is always worse than a system in which low-cost entrants are also allowed to offer credit lines. In Figure 2, such a system is represented by a straight line that connects the original equilibrium point E to the origin O. It is below the hybrid-system lines for any beliefs. With access to the credit-line business, a low-cost bank could fully exploit complementarities and improve welfare for all customers.

## 4.3 Interpretation

We now use the results of this section to discuss three types of deposits-only banks. In each case, we explain how to interpret the cost parameters of the entrant banks and what our result means for what the payment system looks like.

**Central Bank Digital Currency.** Our model is motivated by the impending introduction of CBDC. It is relevant for forms of CBDC that are non-anonymous and interest bearing and hence compete with commercial bank deposits, as opposed to anonymous token CBDCs that compete with currency. The implication of our main result for the design of CBDC is that even if the central bank is better at producing deposits than the private sector, it need not improve welfare since it interferes with commercial banks' ability to cheaply provide credit lines funded with deposits. This counterforce is especially pronounced in economies where liquidity needs are less predictable.

In the context of CBDC, the technology of the deposit-only bank above reflects the intermediation capabilities of the government—formally the asset management cost $\kappa^*$ and the maximal debt-to-asset ratio $\phi^*$. As we have seen, what matters for whether entry improves welfare is that the ratio of the two parameters is sufficiently small. It is not necessary for a cost advantage of the central bank, therefore, to be better at asset-management than the private sector. Instead, it is sufficient that the central bank can afford larger leverage, perhaps because its debt is implicitly backed by the government's power to tax. Reputational mechanisms that may make a government less prone to runs are also subsumed in the cost parameters.

Our result is based on the assumption that the central bank will be a deposit-only intermediary. It is thus natural to ask what happens when the central bank can also provide credit. It is clear that if the government is able to provide both payment instruments at lower cost, then it can also exploit synergies between them and welfare would increase. To date, however, credit to the general public is not part of any CBDC proposals. Moreover, while the arguments above make a case that government borrowing—including in deposits—-may be cheaper than private sector borrowing, an argument for cheaper lending is harder to make. Cost differences in credit-line provision would add another dimension.

A more practical alternative is to allow the central bank to extend *credit to banks*. However, this is generally not a solution to the problem we have described. In fact, if the central bank undoes the migration of deposits to itself by lending to banks, this does not lower balance sheet costs. To illustrate, consider a scenario such that credit-good buyers continue to use credit lines after introduction of CBDC. Suppose further that the central bank extends a credit line to banks that is priced at the higher spread $\kappa p/\phi$, the marginal cost of deposits for commercial banks. In other words, the central bank provides a funding source that is as cheap as deposits were in the original equilibrium without CBDC.

Given this cost of funds, banks' problem is again the same as in the original equilibrium, since the bank can fund holdings of capital or loans at its original marginal cost of deposits. The price of credit lines would be the same as in the absence of CBDC. However, the total cost of providing deposits to sellers after trade is now higher: in addition to asset-management services needed in the original equilibrium, further services must be used to manage assets at the central bank, which lowers the benefit of the policy.

**Early money market mutual funds and Regulation Q.** Money-market mutual funds became important in the United States in the 1970s when Regulation Q prohibited banks from paying interest on deposits, so expected inflation lowered real returns on deposits. Money-market fund shares represent a payment instrument that works much like deposits, but they are backed by short term debt, including Treasury bills and commercial paper. In other words, money-market funds do not fund credit lines, except perhaps indirectly through their (limited) holdings of bank deposits and recently through tranches of securitized credit-card receivables. Historical discussion of money-market funds has debated two explanations for their existence: regulatory distortion and superior technology.

Consider the role of inflation under Regulation Q. In terms of our model, money-market mutual funds are a deposit-only intermediary that produces deposits more cheaply than banks because of the inflation protection it is allowed to offer. A key difference to the model exercise in this Section, however, is that regulation prevented banks from matching the interest rate offered by money-market mutual funds. In our analysis above, it was feasible—and optimal—for banks to match the entrants' deposit rate and make credit lines more expensive to cover losses. Studying Regulation Q calls for not only entry of a cheaper competitor, but also an interest-rate cap.

How would the model change with an interest-rate cap? The result would be stark: because payment instruments are perfect substitutes, all deposits would be offered by the money-market mutual fund sector and all credit lines would have to be funded by equity, or more generally liabilities that are more expensive than deposits. As a result, credit lines would become more expensive and possibly also used less. The size of the welfare effect will depend on how many agents prefer to use credit lines; in the model, these are agents for whom liquidity needs are less predictable or balance-sheet costs of precautionary deposit holdings are larger.

How does this relate to the experience of the 1970s? It is a well-known stylized fact that we saw "disintermediation" and shrinkage in banking in the late 1970s and early 1980s when money-market funds grew spectacularly. Of course, migration of deposits was not 100% in the data. To capture the effect quantitatively, it would be necessary to extend our model to allow for imperfect substitutability of money-market mutual fund shares and commercial bank deposits from the perspective of households and firms. One plausible approach here could be that there are heterogenous investors with different interest sensitivities or more general switching costs.

**Stable coins and money-market mutual funds today.** Consider next the situation today where money-market mutual funds persist even though they do not have a regulatory advantage, and even though we do see banks offer money-market accounts that are close substitutes to fund shares. This perspective is interesting because it also applies to proposed stable coins, electronic currencies offered by the private sector that are backed by a portfolio of assets. The message from our analysis is similar to that for CBDC: the presence of money-market mutual funds and entry by stablecoins is beneficial only if their cost advantage is substantial.

The simplest application assumes that stablecoins indeed have some technological advantage, perhaps because of new crypto-technology. We can then apply the same results as for CBDC above. An alternative view is that the deposits-only intermediary is not special. In terms of the model, this would be an exercise like our CBDC exercise but with no technological advantage by the entrant. In this case, there would be still be multiple equilibria: bank customers are indifferent between all types of deposits, and banks can break even when issuing fewer deposits by raising credit-line fees. The model is thus consistent with the coexistence of the different intermediaries. There would be no welfare effects as costs are the same everywhere.

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