The digital economy, privacy, and CBDC*

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Abstract

We study a model of financial intermediation, payment choice, and privacy in the digital economy. While digital payments enable merchants to sell goods online, they also reveal information to banks. By contrast, cash guarantees anonymity, but limits distribution to less efficient offline venues. In equilibrium, merchants trade off the efficiency gains from online distribution (with digital payments) and the informational rents from staying anonymous (with cash). The introduction of central bank digital currency (CBDC) raises welfare because it reduces the privacy concerns associated with online distribution. Payment tokens issued by digital platforms crowd out CBDC unless the latter facilitates data-sharing.

Keywords: Central Bank Digital Currency, Privacy, Payments, Digital Platforms, Financial Intermediation.

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1 Introduction

The growing dominance of e-commerce has profound implications for the economics of payments. Since more and more transactions are conducted online, physical currency ("cash") is becoming impractical as means of payment for a growing share of economic activity. At the same time, new electronic payment services (e.g. mobile wallets) provide increased speed and convenience to merchants and consumers. Accordingly, the use of cash is declining fast.[1] Seizing the opportunity, large technology firms ("BigTech") are incorporating payment services into their digital ecosystems. While particularly salient in China, where WeChat and AliPay account for more than 90% of digital retail payments, the rest of the world is catching up rapidly.[2]

Unlike cash, digital payments generate troves of data, and private enterprises have incentives to use them for commercial purposes. This gives rise to privacy concerns because the increased availability of personal information can have important welfare implications.[3] While a proliferation of data promises efficiency gains, policy makers have become increasingly uneasy about the dominance of data-centric business models and their anti-competitive potential.[4] At the same time, scandals such as the one surrounding Facebook and Cambridge Analytica have heightened public sensitivity about data privacy issues in the context of the digital economy.

Fuelled by this debate, policy makers have advanced the idea of creating a central bank digital currency (CBDC). One motivation is that public digital money has a comparative advantage at providing privacy because, unlike private sector alternatives, it is not bound by profit-maximization incentives.[5] Although ultimately not realized, Facebook's Libra proposal catapulted the entire debate

[1]See, for example, Table III.1 in Bank for International Settlements (2021).

[2]Most large technology firms have expanded into retail payments services, with popular products such as ApplePay or GooglePay growing at the expense of traditional instruments.

[3]See Acquisti et al. (2016) for a comprehensive overview of the economics of privacy.

[4]See, e.g., Bergemann et al. (2015), Jones and Tonetti (2020), and Ichihashi (2020).

[5]Consistent with this view, privacy has been named as number one concern in the Eurosystem's public consultation on a digital euro (European Central Bank, 2021).

into the public limelight in 2019, and efforts towards the introduction of CBDCs have intensified since then. According to a 2020 survey by the Bank for International Settlements, more than 80% of all responding central banks were actively researching CBDCs (Boar and Wehrli, 2021).

This paper aims to speak to this debate. It develops a stylized model of financial intermediation to analyze the interconnections of payments and privacy in the context of the digital economy. In our model, sellers can distribute their goods offline (through a brick-and-mortar store) or online. Offline sales can be settled with both cash and a digital means of payment, but their physical nature gives rise to an inefficient matching with potential buyers. By contrast, online distribution enables a more efficient matching with potential buyers, and thus generates a higher surplus. At the same time, online sales can only be settled with a digital means of payment.

Sellers are heterogeneous and require outside finance in two rounds of production. They privately learn their type (high (H) or low (L)) in the initial round of production. Only H-sellers can generate a continuation payoff that merits further financing for a second round of production. Since types are private information, financiers face an adverse selection problem and will only provide a continuation loan if they can learn the seller's type.

We first study a setting in which a bank is the only financier. When sales are settled digitally in bank deposits, the bank can extract information about sellers from payment flows. By contrast, cash transactions are anonymous. The bank therefore must elicit information through contractual arrangements ("screening"), which leaves informational rents to sellers.

We show that, in equilibrium, sellers opt for online distribution and settlement with bank deposits if the benefits of more efficient matching outweigh the loss of informational rents associated with privacy. This is the case if the resulting efficiency gains that sellers can appropriate are large enough. Otherwise, goods are distributed offline, which is inefficient due to imperfect matching.

When sellers can use a CBDC—electronic cash—they can trade online without revealing any information to the bank. This enables sellers to capture the best of both worlds. They can reap some of the efficiency gains of online distribution, and at the same time earn informational rents from remaining anonymous. From a social welfare perspective, there are two efficiency gains from the introduction of CBDC. First, sellers are more likely to trade online when sales are settled with CBDC, which ensures efficient matching. Second, with CBDC, the bank always chooses to elicit as much information as possible through contracting. This increases the efficiency of continuation financing.

We then extend the model to include a digital platform, which provides a settlement token and competes with the bank for continuation loans to sellers. The platform only observes sellers' type whenever they use tokens as a means of payment. Perhaps surprisingly, we show that sellers always prefer settlement in tokens over CBDC or deposits. Since the bank elicits information through contracting for the initial loan, the use of tokens ensures that the platform and the bank can compete for the continuation loan. This raises sellers' surplus relative to CBDC or deposits, where the bank is the only informed lender. As a result, sellers always opt for online distribution, which is the socially optimal outcome.

We also highlight a "dark side" of token use. More specifically, we show that tokens enable the platform to fend off potential competitors by creating a "walled garden". While deposits or CBDC enable sellers to potentially benefit from switching to a more efficient entrant platform, the resulting lack of competition in the lending market ensures that all efficiency gains are appropriated by the bank. Accordingly, sellers are better off with tokens.

Next, we enrich the CBDC with a data-sharing functionality, consistent with a broader definition of privacy (Acquisti et al., 2016). This enables sellers to reveal their type costlessly to both the bank and the platform. Importantly, they can do so *after* repaying their initial bank loan to avoid ceding any surplus to the bank. Sellers then enjoy perfect competition in the second round of lending. So they always opt for online sales through CBDC, which is the socially efficient outcome.

Finally, we show that a CBDC with a data-sharing feature also enhances competition among platforms by preventing the incumbent from creating a "walled garden". Accordingly, sellers are able to reap the additional efficiency gains associated with entrant platforms.

Literature. Our paper is related to the literature on privacy in payments. In Kahn et al. (2005), cash payments preserve the anonymity of the purchaser, which provides protection against moral hazard (modelled as the risk of theft). This is different from the benefit of anonymity in our model, which is reduced rent extraction in the lending market. Moreover, we also study new trade-offs associated with the choice of trading venues and their interactions with different means of payments, including CBDCs and tokens issued by digital platforms.

The paper by Garratt and Van Oordt (2021) is also closely related. They study a setting in which merchants use information gleaned from current customer payments to price discriminate future customers. While customers can take costly actions to preserve their privacy in payments, they fail to appreciate the full social value of doing so. Therefore, overall investment in privacy falls short of the social optimum—similar to a public goods problem. In contrast to their focus on an externality and the social value of privacy, our emphasis is on the private benefit of preserving privacy.

Our paper builds on work studying the interaction of payments and lending. Empirical evidence suggests that payment flows are informative about borrower quality (see, e.g., Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017). Parlour et al. (2022) study a model where banks face competition for payment flows by FinTechs. While this may improve financial inclusion, it affects lending and payment pricing by threatening the information flow to banks. He et al. (2021) study competition between banks and Fintech in lending markets with consumer data sharing. Data sharing enhances competition, but borrowers may still be worse off since their sign-up decisions reveal information about credit quality.

Finally, our paper is part of a fast-growing literature on CBDC.[6] Brunnermeier and Payne (2022) develop a model of platform design under competition with a public marketplace and a potential entrant, and study how different forms of interoperability are affected by regulation (including CBDC). Their model is complementary to ours since it studies the nexus of CBDC and the digital economy, but abstracts from privacy issues altogether. In Garratt and Lee (2021), privacy features of CBDC are a way to maintain an efficient monopoly in data collection. Apart from privacy, the preservation of monetary sovereignty and an avoidance of digital dollarization can motivate the introduction of CBDC (Brunnermeier et al., 2019; Benigno et al., 2022). Several recent papers investigate how CBDC may affect credit supply (Keister and Sanches, 2022; Andolfatto, 2021; Chiu et al., 2021), bank runs (Fernández-Villaverde et al., 2020, 2021; Ahnert et al., 2023), the efficacy of government interventions (Keister and Monnet, 2022), and the monetary system (Niepelt, 2020).

Structure. The remainder of the paper is organized as follows. We introduce the basic model with cash and bank deposits in Section 2, and solve for the equilibrium in Section 3. We then introduce a CBDC with anonymity in Section 4, and consider competition between the bank and a digital platform in Section 5. Finally, we study data-sharing features of CBDC in Section 6. Section 7 concludes. All proofs are found in Appendix A and additional results are described in Appendix B.

2 The basic model

There are four dates $t = 0, 1, 2, 3$ and no discounting. There are three classes of risk-neutral agents: banks, buyers, and sellers of measure one each. There is a consumption good and an investment good. Both goods are indivisible.[7]

Sellers have no resources at $t = 0$ and need to borrow from a bank to finance

[6]See Ahnert et al. (2022) for a comprehensive overview of recent work.
[7]Making goods indivisible greatly simplifies the exposition and the analysis.

production. They can produce one unit of the consumption good at $t = 1$ by using one unit of the investment good at $t = 0$. A mass $q \in (0, 1)$ of sellers are of high type (H) and produce a good of high quality, while the remaining $1 - q$ sellers are of low type (L) and produce a good of low quality. Sellers are initially uncertain about their persistent type and privately learn it at beginning of $t = 1$. H-sellers can also produce $\theta > 1$ units of the consumption good at $t = 3$ using one unit of the investment good at $t = 2$. By contrast, L-sellers can produce nothing at $t = 3$.

Buyers have deep pockets and are heterogeneous in their preferences. A measure q cares about quality and derives utility u_H from consuming one unit of the high-quality good, and u_L from consuming one unit of the low-quality good, with $u_L < u_H$. We call them H-buyers. The remaining measure $1 - q$ of L-buyers do not care about quality and obtain utility u_L independently of quality.[8]

Banks are endowed with one unit of the investment good at $t = 0$ and $t = 2$, which they can lend to sellers. Their opportunity cost is 1 per unit of investment. Bankers can neither commit to long-term contracts, nor to not renegotiating loan terms. Hence, it is as if they could set the interest rates at $t = 1$ and $t = 3$. Banks make take-it-or-leave-it offers, but sellers can abscond with a fraction $\lambda \in (0, 1)$ of their sales.

Sellers can distribute their goods through two types of venues, a brick-and-mortar store ("Offline" or OFF) or over the internet ("Online" or ON). Since their unit production is indivisible, sellers can choose only one trading venue. Offline, sellers and buyers are matched randomly. This gives rise to four types of meetings $m = (s, b)$, where s and b denote seller and buyer types, respectively. By contrast, matching is perfect when sellers distribute their goods online, so that there are only two types of meetings.[9] Sellers make take-it or leave-it offers to buyers, and

[8] The assumption that the measure of H-sellers equals the measure of H-buyers is merely for analytical convenience. Assuming different measures would make the analysis more cumbersome, but not deliver additional insights.

[9] More specifically, we have the following offline meetings: a measure q^2 of (H, H) meetings, a measure $q(1 - q)$ of (H, L) meetings, a measure $(1 - q)q$ of (L, H) meetings, and a measure $(1 - q)^2$ of (L, L) meetings. There are two online meetings, a measure q of (H, H) meetings and a measure $(1 - q)$ of (L, L) meetings.

consume their production to obtain utility λ in case the offer is rejected.[10] Since buyers have deep pockets and no bargaining power, the price p_m for meeting m is

$$p_{HH} = u_H > u_L = p_{HL} = p_{Lb}. \tag{1}$$

We assume there are initially two means of payment (cash and bank deposits) and that buyers can costlessly exchange one for the other.[11] Due to their physical nature, offline purchases can be settled both in cash (C) and in deposits (D), e.g. via debit or credit card. By contrast, the exchange of physical currency is too cumbersome for online sales, so they require a digital payment instrument such as deposits. We assume that the use of deposits enables banks to observe the sellers' realized meeting m because payment flows are informative about borrowers' financial situation (Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017). This is not the case when cash is used. When bank deposits are used as means of payment, absconding at $t = 1$ has a fixed effort cost of $e > 0$. This captures the notion that deposit flows enable the bank to monitor sellers' activity more closely, which makes absconding more difficult and requires additional effort. When sellers abscond, which is off the equilibrium path, we assume that the bank does not learn their type but uses the prior distribution of seller type as its belief.

We refer to the combination of trading venue and payment means as a *trading scheme*, denoted by τ. There are three possibilities in the basic model: offline-cash (OFF-C), offline-deposits (OFF-D), and online-deposits (ON-D).

The timing is shown in Figure 1. At $t = 0$, sellers and banks are matched, sellers borrow one unit of the good and choose their trading scheme τ. At $t = 1$, sellers learn their type and are then matched with a buyer. Given the meeting m, sellers offer p_m. At the end of $t = 1$, given the means of payment used, the bank offers a menu $\{(r_m, k_m)\}$, where r_m is the seller's repayment of the initial

[10] In a previous version (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4110431), we study a more general Nash bargaining problem between buyers and sellers. While the analysis is more complex, the main results are unchanged.

[11] This assumption can be micro-founded using a new monetarist model, where the central bank implements the Friedman rule and thus ensures that buyers are indifferent about holding any particular means of payment. Notes are available upon request from the authors.

loan and $k_m \in \{0,1\}$ is the value of the continuation loan. The bank chooses an interest rate i on the continuation loan at $t = 3$. Subsequently, H-sellers who have received a continuation loan produce θ and repay i to the bank, or abscond with production to obtain a payoff $\lambda\theta$. L-sellers who have received a loan abscond with investment to obtain a payoff λ.

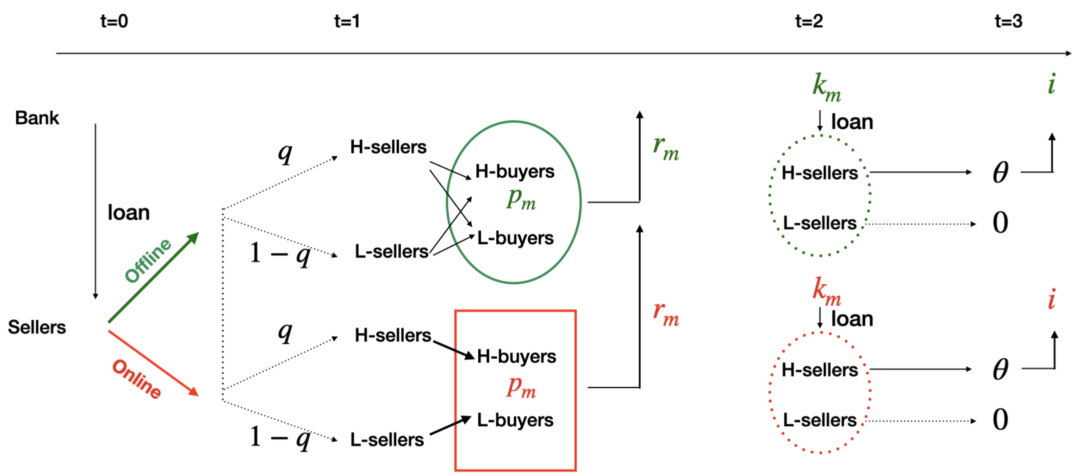

Figure 1: Timeline.

As a benchmark, consider the economy with full information. Welfare is maximized whenever all sellers distribute their goods online and banks grants a second loan to all H-sellers and no loan to L-sellers. Offline distribution is always inefficient because it leads to fewer (H, H) meetings. This benchmark is useful as we now study the equilibrium in the economy with asymmetric information.

3 Equilibrium

To solve for the equilibrium, we proceed backwards. We start with banks' decision whether to extend a continuation loan. We then solve for the optimal contract menu, and then study sellers' choice of trading scheme. Our equilibrium definition follows.

Definition 1. *An equilibrium consists of choices* $(\ell, \{(r_m, k_m)\}, i, \tau, p_m)$ *such that*

1. *banks choose initial investment* $\ell \in \{0, 1\}$*, a menu of repayment and continuation investment* $\{(r_m, k_m)\}$*, and repayment* i *to maximize expected profits, taking* τ *and* p_m *as given;*

2. *sellers choose a trading scheme* $\tau \in \{OFF\text{-}C, ON\text{-}D, OFF\text{-}D\}$ *to maximize expected profits, taking* $(\ell, \{(r_m, k_m)\}, i, p_m)$ *as given; and*

3. *bilateral prices* p_m *are given by (1).*

3.1 Bank's refinancing choice

The bank possibly faces adverse selection, so its lending decision at $t = 2$ depends on whether it is informed about the seller's type. When the bank is informed, L-sellers do not receive a continuation loan because they will produce nothing. By contrast, H-sellers receive financing if the bank can recover its unit cost of investment. Since the bank is a monopolist at $t = 2$, it sets the repayment on the second loan to

$$i^* = (1 - \lambda)\theta, \tag{2}$$

so that H-sellers just obtain their outside option $\lambda\theta$. We assume that it is profitable to extend a continuation loan to H-sellers, but the level of adverse selection is high enough to render uninformed lending unprofitable.[12] This can be summarized as follows.

Assumption 1. $1/q > (1 - \lambda)\theta > 1$.

Assumption 1 also implies that the bank finds it optimal to lend to H-sellers at $t = 2$ even upon default on their first loan. In the same way that the bank cannot commit to loan terms, it cannot commit to not extending a loan upon default. In Appendix B.1, we consider an alternative setup in which banks can

[12] If the level of adverse selection is low, banks prefer to lend to sellers of unknown type in the second stage. We analyse this case in Appendix B.2.

commit to not extending a loan upon seller default, and show that it leads to the same qualitative trade-offs between the deposits and cash.

3.2 Loan repayment

Consider the repayment of the initial loan at $t = 1$. When sellers accept payment in bank deposits (under the OFF-D or ON-D schemes), the bank directly observes the sellers realized meeting and can set the interest rate accordingly. When sales are settled in cash under the OFF-C scheme, however, the bank can only elicit this information by offering a menu of contracts ("screening").

To make matters interesting, we assume that the payoff on the continuation project exceeds u_L, but at the same time is sufficiently smaller than u_H. This ensures that the bank faces a non-trivial choice among different types of contract menus under the OFF-C scheme, because it can extract the full continuation surplus from HH-sellers, but not HL-sellers.

Assumption 2. $u_H - u_L \geq \theta > u_L$.

To simplify the exposition in the main text, we also assume that $u_L > \frac{e}{\lambda}$. This parameter restriction eliminates the need for having to study various cases with identical economic implications but different payoffs.[13]

Settlement in cash. We first consider the OFF-C scheme. Ideally, the bank wants to learn both the type of the seller (to choose refinancing appropriately) as well as the sales price (to set the interest rate as high as possible). However, the fact that H-sellers sometimes realize low sales complicates the bank's inference problem and prevents it from soliciting all this information.

In choosing the optimal contract, the bank faces a trade-off. It can either offer a *separating contract* that identifies all H-sellers, or alternatively offer a *partial pooling* contract that only singles out HH-sellers, while the remaining HL-sellers

[13] Specifically, these assumptions ensure that the feasibility constraint of the HH-seller and the feasibility constraints under the ON-D scheme are always slack. See Appendix A for details.

are pooled with L-sellers.[14] While the first contract menu generates more information, it requires the bank to leave additional informational rents to sellers by foregoing some interest rate income. Lemma 1 summarizes the bank's trade-off.

Lemma 1. *Suppose that sellers choose the OFF-C trading scheme. Then, the bank offers a separating contract (S) for*

$$(1-q)(\theta-1) > \lambda(\theta-u_L), \tag{3}$$

and a partial pooling contract (P) otherwise. The respective interest rates are $r^S_{Lb} = (1-\lambda)u_L$, $r^S_{Hb} = u_L$, $r^P_{Lb} = r^P_{HL} = (1-\lambda)u_L$, *and* $r^P_{HH} = (1-\lambda)u_L + \lambda\theta$.

Equation (3) captures the trade-off inherent in the bank's screening problem. Under separation, the bank elicits more information than with partial pooling, so the continuation surplus $\theta - 1$ is generated more frequently. At the same time, the bank must cede a some share of the resulting surplus to ensure that HL-sellers can afford the loan repayment. More specifically, it must lower the "spread" between high and low interest rates from $\lambda\theta$ to λu_L.

As usual under monopolistic screening with two types (Bolton and Dewatripont, 2004), the low interest rate is always pinned down by the participation constraint of L-sellers, who just earn their outside option λu_L. The spread between the high and the low interest rate is determined by the incentive constraint of HH-sellers in the partial pooling contract, and the feasibility constraint of HL-sellers in the separating contract.

Settlement in deposits. When the seller chooses settlement in deposits (either under the OFF-D or ON-D scheme), the bank observes the seller's realized meeting, so the contract does not have to satisfy any incentive constraints for truthful reporting. Accordingly, all interest rates are pinned down by the relevant participation constraints, which include the cost e that sellers incur when forging their accounts. Since the bank is informed, all H-sellers get refinanced at $t = 2$.

[14] It is straightforward to show that full pooling is never optimal for the bank, since it generates no information at all and also implies lower interest rate income.

Lemma 2. *Suppose that sellers choose settlement in deposits (either OFF-D or ON-D). Then the bank charges* $r^D_{HH} = (1-\lambda)u_H + e$ *and* $r^D_{HL} = r^D_{Lb} = (1-\lambda)u_L + e$.

The only difference between the OFF-D and ON-D schemes is that r^D_{HL} does not arise arises under the ON-D scheme. With online distribution, there are no (H, L)-meetings due to perfect matching, so that the bank only sets r^D_{HH} and r^D_{Lb}.

Bank profits. In order for the bank to engage in lending at $t = 0$, its profits must be non-negative under each of these types of contracts. Given the contract menu $\{(r_m, k_m)\}$, expected bank profits are

$$B = E_m \left[r_m - 1 + k_m \big(\theta(1-\lambda) - 1\big) \right], \tag{4}$$

where $E_m[\cdot]$ denotes the expectations over all possible meetings m, and we have already substituted for the equilibrium interest rate on the second loan, i^*. Evaluating Equation (4) for all three contract menus (the expressions are given in Appendices A.1 and A.2), the following condition ensures that bank profits are always positive.

$$u_L \geq \max\left\{ \frac{1-q^2(\theta-1)}{1-\lambda}, \frac{1-q[(1-\lambda)\theta-1]}{1-\lambda(1-q)} \right\} \tag{5}$$

We henceforth assume this inequality to hold, so that the bank always extends the initial loan, $\ell^* = 1$.

3.3 Seller's choice of trading scheme

We can now determine the seller's choice of trading scheme at $t = 0$. His expected profits are sales minus interest payment, $p_m - r_m$, plus the benefits from obtaining continuation financing, where the expectation is taken over all possible meetings m, and the bank's choices of repayment menu and refinancing are taken as given.

Under the partial pooling contract, only HH-sellers get refinanced when trading offline with physical cash. We can then write sellers' expected profits as

$$\begin{aligned} S^P_{OFF-C} &= q^2(u_H - r^P_{HH} + \lambda\theta) + q(1-q)(u_L - r^P_{HL}) + (1-q)(u_L - r^P_{Lb}) \\ &= q^2[\lambda u_H + (1-\lambda)(u_H - u_L)] + (1-q^2)\lambda u_L. \end{aligned} \tag{6}$$

In this case, HH-sellers earn an informational rent equal to $(1-\lambda)(u_H - u_L)$, while all other sellers just obtain their outside option.

With the separating contract, by contrast, all H-sellers are refinanced under the OFF-C scheme. Thus, expected profits are given by

$$\begin{aligned} S^S_{OFF-C} &= q^2(u_H - r^S_{HH} + \lambda\theta) + q(1-q)(u_L - r^S_{HL} + \lambda\theta) + (1-q)(u_L - r^S_{Lb}) \\ &= q^2[\lambda u_H + (1-\lambda)(u_H - u_L) + \lambda(\theta - u_L)] + q(1-q)[\lambda u_L + \lambda(\theta - u_L)] + (1-q)\lambda u_L. \end{aligned} \tag{7}$$

Unlike with partial pooling, all H-sellers earn a rent. Since the bank wants to induce HL-sellers to opt for the high repayment, it must to lower the "spread" from $\lambda\theta$ to λu_L (the maximum spread that HL-sellers are able to pay). Accordingly, the bank no longer extracts the full surplus from continuation financing.

Expected profits under the ON-D and OFF-D schemes are

$$S_{ON-D} = q\lambda u_H + (1-q)\lambda u_L - (e - q\lambda\theta) \tag{8}$$

$$S_{OFF-D} = q^2\lambda u_H + (1-q^2)\lambda u_L - (e - q\lambda\theta) \tag{9}$$

When payments are settled in deposits, all sellers receive exactly their reservation utility, minus a term that represents the cost of forging their accounts net of the benefit from strategically defaulting on the first loan.[15] The following assumption provides a sufficient condition to rule out such strategic default.

Assumption 3. *$e \geq q\lambda\theta$.*

[15] With deposits, the bank learns sellers' type independently of the loan repayment. Accordingly, H-sellers can in principle default on their first loan and still obtain continuation financing at $t = 2$, since the bank will find the extension of a new loan optimal (Assumption 1). With cash, this cannot happen as the bank only learns the seller's type through repayment.

It is immediate that $S_{ON-D} > S_{OFF-D}$, so sellers never choose the OFF-D scheme. Intuitively, conditional on using deposits, sellers can only lose from remaining offline through inefficient matches with buyers. Lemma 1 and Equations (6)-(8) then lead to the next result.

Proposition 1. ***(Equilibrium in the baseline model)***

1. For $(1-q)(\theta-1) < \lambda(\theta-u_L)$, the bank offers a partial pooling contract under the OFF-C scheme. Sellers distribute online if $q(\lambda-q)(u_H-u_L) \geq (e-q\lambda\theta)$, and offline otherwise.

2. For $(1-q)(\theta-1) > \lambda(\theta-u_L)$, the bank offers a separating contract under the OFF-C scheme. Sellers distribute online if $q(\lambda-q)(u_H-u_L) \geq (e-q\lambda\theta)+q\lambda(\theta-u_L)$, and offline otherwise.

3. All online sales are settled in deposits (by assumption).

When choosing among trading schemes, sellers trade off the efficiency gains from online distribution and the informational rents that arise from staying anonymous with cash. To understand how this trade-off varies with the model's parameters, it is most instructive to look at the case where the bank offers a partial pooling contract under the OFF-C scheme. Ignoring the term $e - q\lambda\theta$, we can write the difference $S_{ON-D} - S^P_{OFF-C}$ as

$$q(1-q)\lambda(u_H-u_L) - q^2(1-\lambda)(u_H-u_L). \tag{10}$$

The first term of (10) represents the efficiency gains from online distribution. Under the ON-D scheme, (H, L)-meetings are no longer possible, which increases sales from u_L to u_H for a fraction $q(1-q)$ of all meetings. Sellers reap a share λ of these gains. The second term of (10) represents the private gains from anonymity with cash. Under the ON-D scheme, banks learn sellers' types for free, so that the mass q^2 of HH-sellers no longer earn the informational rent $(1-\lambda)(u_H-u_L)$. It is straightforward to deduce that Equation (10) is positive if and only if $\lambda > q$.

The intuition for the case where the bank offers the separating contract under the OFF-C scheme is similar, but the interaction between both q and λ becomes more complex. The reason for this is twofold, as can be seen from Equation (7). First, with separation, the mass of sellers earning an informational rent increases to $1-q$. Second, unlike with partial pooling, these rents are no longer strictly decreasing in λ because of the additional component $\lambda(\theta - u_L)$.

Whenever sellers opt for offline distribution, the equilibrium is inefficient because of the relatively low utility generated in (H,L)-meetings. However, an additional inefficiency arises under the partial pooling contract. In this case, the bank fails to provide continuation financing to HL-sellers, so that the extra surplus $\theta - 1$ is realized less often.

4 Central bank digital currency

In this section, we expand the set of payment instruments by introducing a central bank digital currency. We think of CBDC as a digital version of cash. In our context, this means that CBDC enables sellers to conduct online sales (like deposits), but at the same time does not reveal any information to the bank (like cash). Accordingly, sellers can also choose an online-CBDC trading scheme (ON-CBDC).[16]

Lemma 3. *Suppose that sellers choose the ON-CBDC scheme. Then, the bank always offers a separating contract with interest rates* $r_H^{CBDC} = (1-\lambda)u_L + \lambda\theta$ *and* $r_L^{CBDC} = (1-\lambda)u_L$.

With online distribution, the matching of buyers and sellers is efficient. Accordingly, the bank can no longer opt for partial pooling, and thus always offers a separating contract. Sellers' expected payoff is given by

$$S_{ON-CBDC} = q\left[\lambda u_H + (1-\lambda)(u_H - u_L)\right] + (1-q)\lambda u_L. \tag{11}$$

Comparison with Equation (8) shows that $S_{ON-CBDC} > S_{ON-D}$, and hence CBDC fully displaces deposits. The separating contract enables the bank to appropriate

[16] We do not consider an offline-CBDC scheme because it is the same as the OFF-C scheme.

the continuation surplus, but leaves all the gains from more efficient matching to the seller. With deposits, some of these gains also go to the bank, making the seller strictly better off with CBDC. Further comparison of Equations (6) and (11) leads to the following result.

Proposition 2. ***(Equilibrium with CBDC)***

1. For $(1-q)(\theta-1) > \lambda(\theta-u_L)$, the bank offers a separating contract under the OFF-C scheme. Then, sellers distribute online if $(1-q)(u_H-u_L) \geq \lambda(\theta-u_L)$, and offline otherwise.

2. For $(1-q)(\theta-1) < \lambda(\theta-u_L)$, sellers always distribute online.

3. All online sales are settled in CBDC.

Comparing Propositions 1 and 2 shows that the introduction of CBDC leads to an increase in online sales. The effect is most pronounced in the parameter region where the bank offers a partial pooling contract under the OFF-C scheme. In this case, sellers *always* opt for for online distribution with CBDC. Intuitively, digital cash enables sellers to capture the best of both worlds. They can reap the efficiency gains of online distribution, and at the same time earn informational rents from remaining anonymous towards the bank.

However, cash is not fully crowded out. If the bank offers a separating contract under the OFF-C scheme, sellers stay offline for some parameter combinations. In this case, the rents from using cash are strictly higher than those earned with CBDC. Since HL-sellers generate lower sales offline, the bank can no longer extract the entire surplus generated from continuation financing. Accordingly, if the benefits from online distribution are not too large, sellers are better off with cash.

The introduction of CBDC raises welfare through two channels. First, the increase in online distribution implies that the matching of buyers and sellers becomes more efficient, so the utility u_H is reaped more frequently. Second, with CBDC, the bank always opts for full separation, and thus provides continuation financing to *all* H-sellers. This is not the case under the OFF-C scheme with the partial pooling contract, where only HH-sellers are granted a second loan.

5 Digital platforms with financial services

So far, we have been silent about the way online sales are conducted. In this section, we consider a richer environment in which online sales occur through a digital platform. We first study the case where the platform can also lend to sellers and provide payment tokens. Perhaps surprisingly, we show that sellers will abandon CBDC and adopt the platform token instead, which achieves the social optimum. We then study an extension where the platform uses tokens to fend off competition by potential entrants. In this case, tokens remain used, but the social welfare is no longer maximized.

5.1 Competition in the loan market

Here we assume that the platform can lend to the seller at $t = 2$. Moreover, it can provide a digital token as means of payment at $t = 0$, giving rise to an online-token (ON-T) trading scheme. However, we assume that banks remain monopolists for the first loan.[17] The platform has the same funding costs as the bank.

Clearly, the distribution of information between the bank and the platform is critical for competition in the market for continuation loans. We assume that the platform learns the meeting m only if the seller uses tokens to settle his online transactions. In Appendix B.3, we study an extension of the model in which the platform also derives information from observing the sales it intermediates. We show that all of our results, especially the seller's choice between tokens and

[17] This can be rationalized by assuming that banks, unlike platforms, are able to resolve an adverse selection problem at $t = 0$. Suppose that there are productive and entirely unproductive sellers seeking to borrow. Unproductive sellers never produce anything but consume the loan, while productive sellers become H-sellers with probability q or L-sellers with probability $1 - q$. The bank's screening technology determines which seller is productive, enabling the bank to engage in profitable lending at $t = 0$. By contrast, the platform cannot screen and thus finds it unprofitable to lend in the initial round of financing.

CBDC, are unchanged as long as tokens provide some informational value.

We assume that the platform and the bank engage in Bertrand competition at $t = 2$ when both lenders have the same information. In this case, the seller obtains a share $s = 1 - \frac{1}{\theta}$ of the surplus θ.[18] When there is no competition in the lending market at $t = 2$, we assume that the seller can extract a share λ from his sales at $t = 3$ when borrowing from either the bank or the platform.

Settlement in deposits. To start, suppose that sellers use the platform and choose deposits as means of payment. This implies that only the bank knows the sellers' type and the platform does not lend. Accordingly, the bank is a monopolist (as in Section 3) and sellers obtain

$$S^{COMP}_{ON-D} = S_{ON-D}, \tag{12}$$

where the superscript COMP denotes competition in the lending market.

Settlement in CBDC. Next, suppose the seller uses CBDC. This implies that neither the platform nor the bank can learn his type from his payments activity. Since the platform cannot lend, the analysis is the same as in Section 4. The bank always uses the separating contract, and the seller's payoff is given by

$$S^{COMP}_{ON-CBDC} = S_{ON-CBDC}. \tag{13}$$

Settlement in tokens. Finally, suppose that the seller uses the platform's tokens as means of payment (the ON-T scheme). Thus, the platform learns the seller's meeting m from his payment activity, while the bank can only acquire information through screening. The following lemma summarizes the bank's choice of lending contract.

Lemma 4. *Suppose that sellers choose the ON-T trading scheme. Then, for*

$$\frac{1+\lambda}{1-\lambda} \leq \theta \tag{14}$$

[18] Lenders net profit is $(1 - s)\theta - 1$, which must be equal to zero under Bertrand competition.

the bank offers a separating contract with $r_L^T = (1-\lambda)u_L$ *and* $r_H^T = r_L + (s-\lambda)\,\theta$. *Otherwise, the bank offers a pooling contract with* $\bar{r} = (1-\lambda)u_L$.

While the bank would always prefer to opt for separation, Lemma 4 shows that this is not always feasible when sellers choose settlement in tokens—unlike under the ON-CBDC scheme. This result arises because the platform is informed when tokens are used, and thus always willing to lend. The presence of a competing informed lender at $t = 2$ alters H-sellers' incentives to mimic the behaviour of L-sellers towards the bank, and can therefore limit the bank's ability to elicit information.

Under the separating contract, the bank is also informed, so that H-sellers can reap the competitive surplus $s\theta$ from the second loan upon repaying r_H^T at $t = 1$. Incentive compatibility then requires that they must prefer truthful reporting to lying. Pretending to be an L-seller, they would only repay r_L^T, but the bank would not learn their type. Accordingly, the platform would act as a monopolist at $t = 2$, and only leave sellers with their outside option $\lambda\theta$. The spread in the lending rate must therefore satisfy $(s-\lambda)\theta \geq r_H^T - r_L^T$.

The incentives for L-sellers are identical to the case without the platform because an informed lender will never grant them a loan. Thus, as before, incentive compatibility dictates that the cost of lying must exceed the benefit from absconding with the continuation loan, $r_H^T - r_L^T \geq \lambda$. Taken together, a separating contract requires that both types of sellers report truthfully. This is feasible only if $(s-\lambda)\theta > \lambda$, which can be simplified to Condition (14).

Interestingly, expected seller profits are the same for both types of contracts. In either case, they earn

$$S_{ON-T}^{C} = q\left[\lambda u_H + (1-\lambda)(u_H - u_L) + \lambda\theta\right] + (1-q)\lambda u_L. \tag{15}$$

To gain intuition for this result, note that the H-seller's surplus from competition in the lending market between the bank and the platform is equal to $(s-\lambda)\theta$.

Lemma 4 shows that this is exactly equal to the difference between the high interest rate in the separating equilibrium and the pooling rate, $r_H^T - \bar{r}$.

The contract menu for the first loan does not affect the seller's payoff, but it determines the split of profits between the bank and the platform. When the separating contract is used, there is perfect competition for the second loan, so the platform makes zero profits and the entire surplus goes to the bank. By contrast, when separation is infeasible, the pooling contract is used and the platform is a monopolist lender for the continuation loan and earns positive profits.

Comparing Equations (11), (13), and (15), we see that sellers always prefer tokens over CBDC or deposits, because the use of tokens enable competition (since the bank elicits information via the separating contract) while the use of CBDC suppresses it (since the platform remains uninformed). Further comparison with the seller's payoff under the OFF-C scheme (Equations (6) and (7)) allows us to conclude the following.

Proposition 3. ***(Equilibrium with a digital platform)***
Sellers always distribute their goods online. All online sales are settled with tokens.

The use of tokens enables the economy to reach the social optimum. It is an improvement upon anonymous CBDC because goods are *always* distributed online. Intuitively, increased competition in the credit market ensures that sellers are able to reap part of the extra surplus $\theta - 1$ that is generated through informed lending at $t = 2$. This helps to align private incentives with social welfare.

5.2 Platform innovation

Digital platforms are often blamed for anti-competitive practices. One example in this direction is the concept of a "walled garden," which aims to lock in consumers by limiting interoperability with other platforms. To analyze this issue, we modify our setup as follows. Suppose that a second platform (the "entrant") is set up at $t = 2$ with probability π. The new platform offers a better matching technology which enables sellers to generate a payoff $\hat{\theta} > \theta$ with a second loan. Otherwise, the entrant is identical to the incumbent, it can also grant loans and issue tokens as payment means, and faces a unit funding cost.

The incumbent is a walled garden in the sense that sellers will not learn about the emergence of the competitor platform if they use tokens as means of payment. When using deposits or CBDC, the seller learns at $t = 2$ that a new platform has entered only after repaying the initial loan to the bank.

We denote ex-ante expected productivity by $\tilde{\theta} \equiv \pi\hat{\theta} + (1 - \pi)\theta$. To keep matters simple, we adjust Assumptions 1 and 3 to reflect the extended setup.

Assumption 1′. *$1/q > (1 - \lambda)\hat{\theta}$ and $(1 - \lambda)\theta > 1$.*

Assumption 2′. *$u_H - u_L > \tilde{\theta}$ and $\theta > u_L$.*

Assumption 3′. *$e \geq q\lambda\tilde{\theta}$.*

We assume that the bank can compete with platforms, and that platforms with identical information compete with each other. Bertrand competition implies that the seller appropriates the entire surplus net of funding costs, $\theta' - 1$, for $\theta' \in \{\theta, \hat{\theta}\}$.

As before, the incumbent platform only learns the seller's type if he uses its token as means of payment. In Appendix B.3, we consider the case where the platform also learns from observing the sales it intermediates. As long as tokens provide some incremental information, our results are unchanged.

Settlement in token of incumbent. If the seller uses the incumbent platform's token, he does not learn about the existence of the new platform, and his payoff is as in the case with a single platform studied above:

$$S_{ON-T}^{PCOMP} = S_{ON-T}^{COMP}, \tag{16}$$

where $PCOMP$ stands for platform competition.

Settlement in deposits. Now suppose instead that the seller uses deposits. Accounting for the increased productivity, the seller's payoff using deposits is

$$S_{ON-D}^{PCOMP} \quad = \quad q\lambda u_H + (1-q)\lambda u_L - (e - q\lambda\tilde{\theta}) > S_{ON-D}.$$

Settlement in CBDC. Finally, suppose that the seller uses CBDC, so neither the bank nor the platform learn his type. While the seller learns about the emergence of the new platform, neither platform is informed and thus unwilling to provide continuation finance. Thus, the seller is stuck with the bank, who pockets the additional surplus. Accordingly, the payoff under CBDC is

$$S_{ON-CBDC}^{PCOMP} = S_{ON-CBDC}$$

It directly follows from Assumption 3′ that $S_{ON-CBDC}^{PCOMP} > S_{ON-D}^{PCOMP}$ and deposits are thus never used. Moreover, direct calculations reveal that $S_{ON-T}^{PCOMP} > S_{ON-CBDC}^{PCOMP}$, and thus tokens remain the payment method of choice for sellers.

Proposition 4. ***(Equilibrium with platform innovation)***
The equilibrium with platform innovation is the same as the equilibrium with a single digital platform characterized in Lemma 4 and Proposition 3. All sales take place online on the incumbent platform and are settled with tokens.

The seller opts for the lesser of two evils. When using the incumbent platform's token, he does not learn about the entrant platform. This allows him to limit the bank's market power, but prevents the realization of the efficiency gains associated with platform entry. By contrast, if the seller uses deposits, he learns about the entrant, but faces a monopoly bank. While this increases investment efficiency, the bank appropriates all of the additional surplus through the interest rate on the first loan. Accordingly, the seller is better off with tokens. CBDC eliminates competition in lending, so it is an unattractive alternative.

Note that this economy no longer achieves the social optimum. Sellers stay with the incumbent platform even when a more efficient entrant is available.

6 Data sharing through CBDC

As the previous sections highlight, sellers can choose which financier gets informed by opting for the right payment instrument. Leaving contractual arrangements aside, cash or CBDC leave all creditors uninformed. In this section, we expand the features of CBDC and assume it is designed such that sellers can control the information revealed to any lenders, at any point in time. This is consistent with a broader concept of privacy that goes beyond the dimension of anonymity, as summarized succinctly by Acquisti et al. (2016): "Privacy is not the opposite of sharing—rather it is control over sharing."

We first consider the previous model in which the bank competes with a digital platform for the continuation loan. Then, we consider the model with the more efficient entrant platform, which also allows us to study the effects of data-sharing on inter-platform competition.

6.1 Loan competition and data sharing

The ability to share data through CBDC has profound consequences for the equilibrium in the lending market at $t = 2$. The seller has no incentive to reveal his type before repayment because the bank cannot commit to the contract terms. However, H-sellers have an incentive to reveal their type after the repayment because it enables them to introduce perfect competition between the bank and the platform for the continuation loan. Given Assumption 1, the bank will find it optimal to compete for such a loan, and H-sellers will obtain $s\theta$ from the continuation investment. Formally, if the bank uses a separating contract, the ICs read

$$\begin{aligned} u_H - r_H + s\theta &\geq u_H - r_L + s\theta \\ u_L - r_L &\geq u_L - r_H + \lambda \end{aligned}$$

which implies $r_L \geq r_H \geq r_L + \lambda$, a contradiction. Hence a separating contract is never feasible, and the bank can only offer a pooling contract with the interest rate $\bar{r} = (1-\lambda)u_L$. Therefore, seller's ex-ante expected payoff is given by

$$S_{ON-CBDC}^{COMP,\,DS} = q[\lambda u_H + (1-\lambda)(u_H - u_L) + s\theta] + (1-q)\lambda u_L, \tag{17}$$

where DS indicates that the CBDC allows for data-sharing. Comparing with Equation (16) reveals that $S_{ON-CBDC}^{COMP,\,DS} > S_{ON-T}^{COMP}$,[19] we can conclude the following.

Proposition 5. ***(Equilibrium with a digital platform and data sharing via CBDC)***

Sellers always distribute their goods online. All online sales are settled with CBDC.

6.2 Platform competition and data sharing

We now turn to analyze the implications of data sharing for platform competition. Suppose the seller uses CBDC, which implies that he becomes aware of the new platform. Since H-sellers can reveal their type after repayment of the first loan, only the pooling contract is feasible, with $\bar{r} = (1-\lambda)u_L$. The seller's expected payoff under CBDC with data sharing is then equal to

$$\begin{aligned} S_{ON-CBDC}^{PCOMP,\,DS} &= q\left[\lambda u_H + (1-\lambda)(u_H - u_L) + (\tilde{\theta} - 1)\right] + (1-q)\lambda u_L \\ &= S_{ON-CBDC}^{PCOMP} + q(\tilde{\theta} - 1) \qquad (18) \\ &= S_{ON-CBDC}^{COMP} + q(\tilde{\theta} - \theta). \qquad (19) \end{aligned}$$

The last term in Equation (18), $q(\tilde{\theta} - 1)$, captures the additional benefit of competition that data sharing provides relative to an environment where CBDC only allows sellers to hide their type. Similarly, the term $q(\tilde{\theta} - \theta)$ in (19) captures the additional benefit of platform innovation that data sharing allows to reap relative to an environment with only a single platform. Since payoffs under deposits and tokens are identical to those in Section 5.2, we can directly conclude the following.

Proposition 6. ***(Equilibrium with platform competition and data sharing***

[19]This ranking arises because $s\theta = (\theta - 1)$, and $s > \lambda$, and Assumption 1.

via CBDC)

Sellers always distribute their goods online, and use the entrant platform whenever available. All online sales are settled with CBDC. The economy reaches first best.

If follows from Proposition 6 that a CBDC with data sharing capabilities achieves the first-best allocation in the sense that (1) all sellers use the more efficient online platform technology at $t = 1$, (2) all H-sellers get a second loan, and (3) all H-sellers use the most efficient platform at $t = 3$.

7 Conclusion

We analyzed how digital privacy concerns give rise to the need for a payment instrument that permits competition through allowing selective data sharing. Our findings have important implications for the design of CBDC. In particular, CBDC may only become successful if it facilitates data sharing. While private means of payment may in principle also provide such functionalities, incentives for the monopolization of data access may be too strong. However, absent data-sharing, private payment instruments such as digital tokens issued by platforms may crowd out CBDC, and also threaten the role of deposits as payment instrument in the digital sphere. As we have shown, sellers always prefer to use these tokens to deposits when they are available because they can then escape banks' capture. In other words, in our environment disintermediation takes place because the banking sector is not competitive and platform tokens discipline banks into competition.

We have left unspecified the details of how financiers can learn by inspecting payment flows. Further investigation in this direction may give interesting insights. Also, we have not considered how data generated on a platform can be used to improve future sales, (i.e. how trading on the platform at $t = 1$ may lead to better trading at $t = 3$). These are important topics that we leave for future research.

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A Proofs

A.1 Proof of Lemma 1

First, consider the **separating contract**. Since the bank provides re-financing to all H-sellers, the incentive compatibility constraints (ICs) imply $r^S_{HH} = r^S_{HL}$. Hence, the contract must satisfy the following simplified ICs:

$$\begin{aligned} u_H - r^S_{HH} + \lambda\theta &\geq u_H - r^S_{Lb} \\ u_H - r^S_{HL} + \lambda\theta &\geq u_L - r^S_{Lb} \\ u_L - r^S_{Lb} &\geq u_L - r^S_{Lb} + \lambda, \end{aligned}$$

which yields $\lambda\theta \geq r^S_{HH} - r^S_{Lb} \geq \lambda$. The participation constraints (PCs) are

$$\begin{aligned} u_H - r^S_{HH} + \lambda\theta &\geq \lambda u_H, \\ u_L - r^S_{HL} + \lambda\theta &\geq \lambda u_L, \\ u_L - r^S_{Lb} &\geq \lambda u_L, \end{aligned}$$

because the bank does not learn the seller's type upon absconding at $t = 1$, uses the prior that a fraction q of sellers are of type H and, thus, does not grant a continuation loan due to high adverse selection (Assumption 1). Moreover, the feasibility constraints of sellers having enough funds for repayment at $t = 1$ are

$$u_H \geq r^S_{HH}, \quad u_L \geq r^S_{HL}, \quad u_L \geq r^S_{L}.$$

Clearly, only the second feasibility constraint may be binding in equilibrium.

Under profit maximization, the last participation constraint binds, so $r^S_{Lb} = (1-\lambda)u_L$. (Note that this participation constraint could have been slack and the IC of HH-sellers could have been binding but this would yield strictly lower expected bank profits.) Then, Assumption 2 implies that the feasibility constraint of HL-sellers to have sufficient funds for repayment, $u_L \geq r^S_{HH}$, binds before the

IC of HH-seller binds, resulting in the following interest rate, $r^S_{HH} = u_L$. Taken together, the separating contract yields an expected bank profit of

$$\begin{aligned} B^S_{OFF-C} &= q(r^S_{HH} - 1) + (1-q)(r^S_L - 1) + q\left[(1-\lambda)\theta - 1\right] \\ &= (1-\lambda)u_L - 1 + q(\theta - 1) - q\lambda(\theta - u_L), \end{aligned} \tag{20}$$

which is the interest income net of funding costs for the H-sellers and L-sellers as well as the income from extending a continuation loan to all H-sellers at $t = 2$.

Second, consider the **partial pooling** contract, under which the bank only extends continuation finance to HH-sellers. Since HL-sellers do not obtain re-financing, $r^P_{HL} = r^P_{Lb}$ follows. Hence, the simplified ICs read

$$\begin{aligned} u_H - r^P_{HH} + \lambda\theta &\geq u_H - r^P_{Lb}, \\ u_L - r^P_{HL} &\geq u_L - r^P_{HH} + \lambda\theta, \\ u_L - r^P_{Lb} &\geq u_L - r^P_{HH} + \lambda, \end{aligned}$$

because misreporting your type allows a seller to receive a continuation loan, which is worth $\lambda\theta$ to a HL-seller (who can abscond with future production at $t = 3$) and λ to a L-seller (who can abscond with the loan at $t = 2$). The first two incentive compatibility constraints directly yield $r^P_{HH} = r^P_{Lb} + \lambda\theta$ and the third constraint is slack. The partial pooling contract must satisfy the following PCs:

$$\begin{aligned} u_H - r^P_{HH} + \lambda\theta &\geq \lambda u_H, \\ u_L - r^P_{HL} &\geq \lambda u_L, \\ u_L - r^P_{Lb} &\geq \lambda u_L, \end{aligned}$$

Profit maximization yields $r^P_{Lb} = (1-\lambda)u_L$, where the PC of HL-sellers and L-sellers bind while the PC of H-seller is slack, and $r^P_{HH} = (1-\lambda)u_L + \lambda\theta$. Thus, the low interest rate is again pinned down by L-sellers' PC. The feasibility constraint for all sellers is ensured by the bounds on u_H and u_L introduced in the main text (below Assumption 2). Expected bank profits under partial pooling are

$$\begin{aligned} B^P_{OFF-C} &= q^2(r^P_{HH}-1) + (1-q^2)(r^P_{HL}-1) + q^2\left[(1-\lambda)\theta - 1\right] \\ &= (1-\lambda)u_L - 1 + q^2(\theta-1). \end{aligned} \tag{21}$$

Comparing Equations (20) and (21) leads to the inequality stated in Lemma 1.

We make a final remark to close the proof. A pooling contract would imply an interest rate $\bar{r} = (1-\lambda)u_L$ for all sellers and would yield strictly lower bank profits than the contracts characterized above.

A.2 Proof of Lemma 2

When deposits are used, the bank learns the realized meeting m. Thus, no ICs are needed and the relevant PCs are

$$\begin{aligned} u_H - r^D_{HH} + \lambda\theta &\geq \lambda u_H - e + \lambda\theta \\ u_L - r^D_{HL} + \lambda\theta &\geq \lambda u_L - e + \lambda\theta \\ u_L - r^D_{Lb} &\geq \lambda u_L - e, \end{aligned}$$

where the use of deposits implies that the bank always learns the seller type and, thus, extends a continuation loan to all H-sellers even upon absconding at $t = 1$.

Profit maximization implies that each of these PCs bind, resulting in the interest rate stated. Note that the bounds on u_L and u_H (just below Assumption 2) ensures that the feasibility constraints, which read $e \leq \lambda u_H$ and $e \leq \lambda u_L$, are always slack. Thus, the expected profit of the bank under the ON-D scheme is

$$\begin{aligned} B_{ON-D} &= q(r^D_{HH}-1) + (1-q)(r^D_L - 1) + q\left[(1-\lambda)\theta - 1\right] \\ &= (1-\lambda)u_L - 1 + q(\theta-1) + (e - q\lambda\theta) + q(1-\lambda)(u_H - u_L). \end{aligned} \tag{22}$$

It follows immediately that $B_{ON-D} > \max\{B^S_{OFF-C}, B^P_{OFF-C}\}$.

A.3 Proof of Proposition 2

Since there are only two types of matches with online sales, the bank's choice under the ON-CBDC scheme is either a separating or a pooling contract. As usual, the PC of L-sellers binds under separation, $r_L^{CBDC} = (1-\lambda)u_L$. The ICs are

$$\begin{aligned} u_H - r_{HH}^{CBDC} + \lambda\theta &\geq u_H - r_L^{CBDC} \\ u_L - r_L^{CBDC} &\geq u_L - r_{HH}^{CBDC} + \lambda, \end{aligned}$$

which together with profit-maximization yields

$$r_{HH}^{CBDC} = r_L^{CBDC} + \lambda\theta,$$

which is feasible given the lower bound on u_H. The bank's expected profits are

$$\begin{aligned} B_{ON-CBDC}^S &= q\left[r_{HH}^{CBDC} + (1-\lambda)\theta - 1\right] + (1-q)r_L^{CBDC} - 1 \\ &= (1-\lambda)u_L + q(\theta - 1) - 1 \end{aligned}$$

A pooling contract with $\bar{r} = (1-\lambda)u_L$ yields strictly lower profits, $(1-\lambda)u_L - 1$, so the bank always chooses separation. Finally, comparing the expected profits of the seller, we observe $S_{ON-CBDC} > S_{OFF-C}^P$ always holds, while $S_{ON-CBDC} > S_{OFF-C}^S$ may or may not hold, and rewriting yields the condition given in the proposition.

A.4 Proof of Lemma 4

The separating contract under the ON-T scheme has to satisfy the following ICs:

$$\begin{aligned} u_H - r_H^T + s\theta &\geq u_H - r_L^T + \lambda\theta \\ u_L - r_L^T &\geq u_L - r_H^T + \lambda. \end{aligned}$$

When an H-seller pretends to be an L-seller, he forgoes the competitive surplus $s\theta$ and instead obtains $\lambda\theta$ by borrowing from the (monopoly) platform. Similarly, an

L-seller can obtain λ when pretending to be an H-seller through absconding with the continuation loan. Combining both inequalities, we get

$$(s-\lambda)\,\theta \geq r_H^T - r_L^T \geq \lambda$$

While the separating contract was always feasible without competition, it is now no longer feasible if $\lambda > (s-\lambda)\,\theta$, or $\frac{1+\lambda}{1-\lambda} > \theta$. In this case, L-sellers derive a higher benefit from pretending to be H-sellers than H-sellers themselves. Participation by L-sellers together with profit maximization imply a low rate of $r_L^T = (1-\lambda)u_L$.

Assuming feasibility ($\theta \geq \frac{1+\lambda}{1-\lambda}$), the profit-maximizing bank sets $r_H^T = r_L^T + (s-\lambda)\,\theta$, provided H-sellers can repay the high rate, $u_H \geq r_H^T$. That is, feasibility of the H-seller requires

$$\frac{u_H+1}{1-\lambda} - u_L \geq \theta, \tag{23}$$

which holds given the assumed lower bound on u_H (stated below Assumption 2). Thus, bank profits are

$$\begin{aligned} B_{ON-T}^S &= q\left[r_H^T - 1 + \frac{1}{2}\left((1-s)\theta - 1\right)\right] + (1-q)(r_L^T - 1) \\ &= (1-\lambda)u_L + q(s-\lambda)\theta - 1. \end{aligned}$$

As usual, the rate for the pooling contract is pinned down by the participation constraint of L-sellers, $\bar{r} = (1-\lambda)u_L$. It is straightforward to verify that this implies lower bank profits, $\bar{B}_{ON-T} = (1-\lambda)u_L - 1$, than the separating contract, so the bank chooses to offer the pooling contract only when separation is infeasible.

A.5 Proof of Proposition 3

Using the interest rates from Lemma 4, the expected profit to the seller, S_{ON-T}^C, is given in Equation (15). Because of the additional benefit from competition in the lending market, $\lambda\theta$, tokens dominate CBDC for the seller, $S_{ON-T} > S_{ON-CBDC}$. Moreover, tokens dominate cash when the bank offers a pooling contract, $S_{ON-T} > S_{OFF-C}^P$, and when it offers a separating contract, $S_{ON-T} > S_{OFF-C}^S$.

B Additional results

B.1 Commitment to punish upon default

We have so far assumed that the bank cannot commit to punish the seller upon default on the loan. While this assumption is fully in line with the bank also not being able to commit to the loan terms, we consider the alternative case in which the bank *can* commit to such a punishment in this section. In this case, H-sellers who want refinancing must repay their loan when deposits are used.

Consider the OFF-D trading scheme (which nests ON-D). The PCs become

$$\begin{aligned} u_H - r_{HH}^D + \lambda\theta &\geq \lambda u_H \\ u_L - r_{HL}^D + \lambda\theta &\geq \lambda u_L \\ u_L - r_{Lb}^D &\geq \lambda u_L. \end{aligned}$$

Assumption 2 and the bounds on u_L and u_H stated below it imply that the feasibility constraint of the L-type is slack and the feasibility constraint of the HL-type binds. We assume that $\frac{e}{\lambda} > u_H - \theta$, so the feasibility constraint of the HH-type is slack. In sum, the interest rates are

$$r_{HH}^D = (1-\lambda)u_H + \lambda\theta + e \quad (24)$$

$$r_{HL}^D = u_L$$

$$r_{Lb}^D = (1-\lambda)u_L + e. \quad (25)$$

Following the same logic, interest rates for the ON-D scheme are given by (24) and (25). Thus, the bank can charge higher interest rates with commitment to punishment upon default, so the expected seller profit is lower with commitment:

$$\begin{aligned} S_{OFF-D} &= q^2\lambda u_H q(1-q)\lambda\theta + (1-q)\lambda u_L - e(q^2+1-q) \\ S_{ON-D} &= q\lambda u_H + (1-q)\lambda u_L - e \end{aligned}$$

Since the ability to commit does not affect expected payoffs when sales are settled in cash (the bank learns nothing upon default and thus does not lend), they are still given by Equations (6) and (7). As before, it readily follows that $min\{S^S_{OFF-D}, S^P_{OFF-C}\} > S_{OFF-D}$, so deposits are never used to settle offline sales. Because of the higher interest rates charged in the ON-D scheme under bank commitment, the seller prefers to use the OFF-C scheme for a larger range of parameters. However, the qualitative results are unchanged:

Proposition 7. ***(Equilibrium with commitment to punish upon default.)***
1. For $(1-q)(\theta-1) < \lambda(\theta-u_L)$, the bank offers a partial pooling contract. Sellers distribute online if $q(\lambda-q)(u_H-u_L) \geq e$, and offline otherwise.
2. For $(1-q)(\theta-1) > \lambda(\theta-u_L)$, the bank offers a separating contract. Sellers distribute online if $q(\lambda-q)(u_H-u_L) - q\lambda(\theta-u_L) \geq e$, and offline otherwise.
3. All online sales are settled in deposits (by assumption).

B.2 Low adverse selection

In this section we analyze the case of low adverse selection. First, we relax Assumption 1 and assume instead that bank lending to all seller types is profitable at $t = 2$, $q(1-\lambda)\theta > 1$. Second, we assume that some adverse selection remains. In particular, the bank does not lend to a pool of HL-sellers and L-sellers, so no lending occurs at $t = 2$ when only HH-sellers are separated out. The cost of such lending is $1-q^2$ (both HL- and L-types are funded) and the expected payoff is $q(1-q)(1-\lambda)\theta$ (because only HL-types generate positive output at $t = 3$). Rearranging yields $q(1-\lambda)\theta < 1+q$. Assumption 1″ summarizes these conditions:

Assumption 1″. $\frac{1}{q} < (1-\lambda)\theta < 1 + \frac{1}{q}$.

This new assumption affects the various participation constraints of investors. As before, we have to consider a separating and partial pooling. (Below we will show that the complete pooling contract is again dominated.)

Separating pricing scheme. We again have $r^S_{HH} = r^S_{HL} \equiv r^S_H$, so the ICs are:

$$u_H - r^S_H + \lambda\theta \geq u_H - r^S_L,$$
$$u_L - r^S_H + \lambda\theta \geq u_L - r^S_L,$$
$$u_L - r^S_L \geq u_L - r^S_H + \lambda,$$

because the bank grants a continuation loan to each seller reporting as H-type. Combining ICs again yields $\lambda\theta \geq r^S_H - r^S_L \geq \lambda$, as before. The PCs change because an uninformed bank (in case of absconding) always lends to the seller (because the bank uses its prior about the seller type and Assumption 1″ implies that uninformed lending is profitable):

$$\begin{aligned} u_H - r^S_H + \lambda\theta &\geq \lambda u_H + \lambda\theta, \\ u_L - r^S_H + \lambda\theta &\geq \lambda u_L + \lambda\theta, \\ u_L - r^S_L &\geq \lambda u_L + \lambda. \end{aligned}$$

Hence, the first and third PC are slack, while PC_{HL} may bind. The feasibility constraints of enough funds for repayment at $t = 1$ are $u_H \geq r^S_H$, $u_L \geq r^S_H$, and $u_L \geq r^S_L$, which are all slack (given the PCs). In sum, the bank's problem is:

$$\max_{r^S_H, r^S_L} \quad q(r^S_H - 1) + (1-q)(r^S_L - 1) + q[(1-\lambda)\theta - 1] \text{ s.t. } IC, PC_{HL}, \tag{26}$$

because all H-sellers receive a continuation loan at $t = 2$ under separation, generating surplus $q[(1-\lambda)\theta - 1]$. Profit maximization then implies:

$$r^S_H = (1-\lambda)u_L \text{ and } r^S_L = (1-\lambda)u_L - \lambda. \tag{27}$$

The separating contract yields expected bank profits of

$$B^S_{OFF-C} = (1-\lambda)u_L - 1 - (1-q)\lambda + q[(1-\lambda)\theta - 1]. \tag{28}$$

Partial pooling. We have again $r^P_{HL} = r^P_{Lb} \equiv r^P_L$. Given Assumption 1″, HL-sellers do not obtain re-financing when pooled with L-sellers, so the ICs read:

$$u_H - r^P_{HH} + \lambda\theta \geq u_H - r^P_L,$$
$$u_L - r^P_L \geq u_L - r^P_{HH} + \lambda\theta,$$
$$u_L - r^P_L \geq u_L - r^P_{HH} + \lambda,$$

because receiving continuation finance allows the HL-type to abscond with future production (worth $\lambda\theta$), while the L-type can abscond with the loan (worth λ). The first two constraints yield $r^P_{HH} = r^P_L + \lambda\theta$ and the third constraint is slack.

The PCs under partial pooling change to

$$\begin{aligned} u_H - r^P_{HH} + \lambda\theta &\geq \lambda u_H + \lambda\theta, \\ u_L - r^P_L &\geq \lambda u_L + \lambda\theta, \\ u_L - r^P_L &\geq \lambda u_L + \lambda, \end{aligned}$$

because the bank learns nothing upon seller default, uses its prior, and it refinances all sellers of unknown type by Assumption 1″ (first inequality). In contrast, when the seller pays back r_L, the bank infers that the meeting is either Lb or HL and, thus, the bank does not refinance seller by Assumption 1″ (second inequality).

Using the IC, one can see that the first and third PC are slack, while PC_{HL} may bind. Moreover, both feasibility constraints are slack, $u_H \geq r^P_{HH}$ and $u_L \geq r^P_L$. Taken together, the bank's problem is

$$\max_{r^P_{HH}, r^P_L} \quad q^2(r^P_{HH} - 1) + (1 - q^2)(r^P_L - 1) + q^2[(1 - \lambda)\theta - 1] \text{ s.t. } IC, PC_{HL}, \quad (29)$$

where only HH-types receive continuation finance. Profit maximization yields

$$r^P_{HH} = (1 - \lambda)u_L \text{ and } r^P_L = (1 - \lambda)u_L - \lambda\theta. \quad (30)$$

Thus, expected bank profits under partial pooling is

$$B^P_{OFF-C} = (1-\lambda)u_L - 1 + q^2(\theta - 1) - \lambda\theta. \tag{31}$$

For completeness, note that the complete pooling contract offers an interest rate $\bar{r} = (1-\lambda)u_L$ and yields $\bar{B} = (1-\lambda)u_L - 1 + q(1-\lambda)\theta - 1$, with $\bar{B} < B^S_{OFF-C}$.

Comparing separation to partial pooling, we have $B^S > B^P$ as $q[(1-\lambda)\theta - 1] > 0 > \lambda[1-(1+q)\theta]$, so the bank always chooses separation. Intuitively, the bank can charge higher rates and finances more H-sellers at $t = 2$ under separation.

Finally, we describe the seller's choice of the trading scheme. Her expected payoff under ON-D is unchanged and the expected payoff under OFF-C is:

$$\begin{aligned} S^{SEP}_{OFF-C} &= q^2(u_H - r^S_H + \lambda\theta) + q(1-q)(u_L - r^S_H + \lambda\theta) + (1-q)(u_L - r^S_L) \\ &= q^2[\lambda u_H + (1-\lambda)(u_H - u_L)] + (1-q^2)\lambda u_L + \lambda[1 + q(\theta - 1)], \end{aligned} \tag{32}$$

where the first two terms are standard and the final term is the additional surplus the seller receives because the bank extends continuation finance when uninformed. Thus, the seller chooses ON-D whenever

$$q(\lambda - q)(u_H - u_L) \geq e - q\lambda\theta + \lambda[q(\theta - 1) + 1]. \tag{33}$$

The following proposition summarizes.

Proposition 8. ***(Equilibrium with weak adverse selection.)***
1. The bank always offers a separating contract in the OFF-C scheme. Sellers distribute online if $q(\lambda - q)(u_H - u_L) \geq e - q\lambda\theta + \lambda[q(\theta - 1) + 1]$, and offline otherwise.
2. All online sales are settled in deposits (by assumption).

We can now study how introducing CBDC affects the equilibrium when the level of adverse selection is low.

Since there are only two types of matches with online sales, the bank's choice under the ON-CBDC scheme is either a separating or a pooling pricing scheme that we analyze in turn, starting with the pooling case.

Pooling pricing scheme. The bank could offer a pooling pricing scheme and refinance all sellers. Then the PC of the L-sellers is binding and it implies that the interest rate is $r^P = (1-\lambda)u_L$. The Banks' profit under pooling is

$$B^P_{CBDC} = (1-\lambda)u_L - 1 + q(1-\lambda)\theta - 1$$

Separating pricing scheme. Since sellers trade online, there are only H and L match. Hence the participation constraints (PCs) are (separating)

$$\begin{aligned} u_H - r^S_H + \lambda\theta &\geq \lambda u_H + \lambda\theta, \\ u_L - r^S_L &\geq \lambda u_L + \lambda \end{aligned}$$

because the bank does not learn the seller's type upon absconding at $t = 1$. The incentive compatibility constraints (IC) are

$$\begin{aligned} u_H - r^S_H + \lambda\theta &\geq u_H - r^S_L \\ u_L - r^S_L &\geq u_L - r^S_H + \lambda, \end{aligned}$$

It is tedious but routine to show that there are only two cases: the PC of L-sellers always binds, and either the PC of H-sellers binds (when $\lambda(\theta-1) \geq (1-\lambda)(u_H - u_L) \geq 0$) or the IC of H-sellers binds (when $(1-\lambda)(u_H - u_L) \geq \lambda(\theta-1)$). If the PC of H-sellers binds, the interest rates are

$$\begin{aligned} r^S_H &= (1-\lambda)u_H \\ r^S_L &= (1-\lambda)u_L - \lambda \end{aligned}$$

while if the IC of H-sellers binds, the interest rates are

$$r_H^S = r_L^S + \lambda\theta = (1-\lambda)u_L + \lambda(\theta - 1).$$

Next we analyze each case in turn.

B.2.1 Case 1: $\lambda(\theta-1) \geq (1-\lambda)(u_H - u_L)$

In this case, the PC of H-sellers binds, and the interest rates are

$$\begin{aligned} r_H^S &= (1-\lambda)u_H, \\ r_L^S &= (1-\lambda)u_L - \lambda. \end{aligned}$$

Then seller's expected payoff is

$$\begin{aligned} S_{ON}^{CBDC} &= q\left[u_H - r_H^S + \lambda\theta\right] + (1-q)\left[u_L - r_L^S\right] \\ &= q\lambda u_H + (1-q)\lambda u_L + q\lambda(\theta-1) + \lambda \end{aligned}$$

and the bank's expected profits are

$$\begin{aligned} B_{ON-CBDC}^S &= q\left[r_H^S + (1-\lambda)\theta - 1\right] + (1-q)r_L^S - 1 \\ &= (1-\lambda)u_L + q(1-\lambda)(u_H - u_L) + q(\theta-1)(1-\lambda) - 1 - \lambda \end{aligned}$$

Finally, we describe the seller's choice of the trading scheme. Her expected under OFF-CBDC is the same as with OFF-Cash that we have computed in Appendix B2 (the bank always use separating with low adverse selection). Hence, sellers prefer CBDC online (with separating) to CBDC offline whenever $\lambda > q$. It is straightforward to show that the bank always prefers the separating pricing scheme.

B.2.2 Case 2: $\lambda(\theta - 1) < (1 - \lambda)(u_H - u_L)$

In this case, the PC of H-sellers binds, and the interest rates are

$$\begin{aligned} r_H^S &= (1-\lambda)u_L + \lambda(\theta - 1) \\ r_L^S &= (1-\lambda)u_L - \lambda \end{aligned}$$

The seller's and bank's expected payoff are respectively

$$\begin{aligned} S_{ON}^{CBDC} &= q[\lambda u_H + (1-\lambda)(u_H - u_L)] + (1-q)\lambda u_L + \lambda \\ B_{ON-CBDC}^S &= (1-\lambda)u_L + q(\theta - 1) - \lambda - 1 \end{aligned}$$

and sellers prefer CBDC online (with separating) to CBDC offline whenever

$$(1-q)(u_H - u_L) \;\; > \;\; \lambda(\theta - 1).$$

The bank prefers pooling over separating for ON-CBDC whenever $q+\lambda-q\lambda\theta > 1$. Sellers' payoff under ON-CBDC-pooling is

$$\begin{aligned} S_{CBDC}^{Pooling} &= q(u_H - r^P + \lambda\theta) + (1-q)(u_L - r^P + \lambda) \\ &= q(u_H - u_L) + \lambda u_L + q\lambda\theta + (1-q)\lambda \end{aligned}$$

and we can show sellers always prefer using CBDC online (with pooling) to trading offline with CBDC. The following Propositioni summarizes our results.

Proposition 9. ***Equilibrium with CBDC and weak adverse selection.***

1. When $\lambda(\theta - 1) \geq (1 - \lambda)(u_H - u_L)$ the bank always uses a separating contract in the ON-CBDC scheme . Sellers trade online iff $\lambda > q$ and offline otherwise.

2. When $\lambda(\theta - 1) < (1 - \lambda)(u_H - u_L)$, the bank uses a pooling contract ON-CBDC whenever $q + \lambda - q\lambda\theta > 1$ and a separating contract otherwise. If the bank uses a pooling contract, sellers always trade online. When the bank uses a separating contract ON-CBDC, sellers trade online iff $(1 - q)(u_H - u_L) > \lambda(\theta - 1)$.

B.3 A more informed platform

In this section we relax the assumption that payment tokens are the only source of information for the platform. Instead, we assume that the platform receives a perfect signal about the seller's type with probability $\xi < 1$, and it remains uninformed with probability $1 - \xi$ (so the main text corresponds to $\xi = 0$). To simplify the exposition, we assume that the bank observes whether the platform has received a signal. Otherwise, solving for the equilibrium would be considerably more complex—without providing more economic insight.

B.3.1 Lending market competition

Settlement with CBDC. Suppose that sellers settle with CBDC. If the bank chooses to become informed through a separating contract, it will compete with the platform with probability ξ, and act as a monopolist otherwise. Accordingly, this allows H-sellers to reap an expected surplus of $s_\xi \theta$, where

$$s_\xi \equiv \xi s + (1 - \xi)\lambda \in [\lambda, s). \tag{34}$$

Thus, the separating contract has to satisfy the following ICs

$$\begin{aligned} u_H - r_H + s_\xi \theta &\geq u_H - r_L + \xi \lambda \theta \\ u_L - r_L + &\geq u_L - r_H + \lambda, \end{aligned}$$

which implies $(s_\xi - \xi\lambda)\theta \geq r_H - r_L \geq \lambda$. L-sellers' PC again yields $r_L = (1-\lambda)u_L$. To keep the exposition focused, we henceforth assume that a separating contract is feasible, i.e. $(s_\xi - \xi\lambda)\theta > \lambda$, which holds for a small enough ξ. Profit-maximization implies

$$r_H = r_L + (s_\xi - \xi\lambda)\theta,$$

because the feasibility constraint of the H-seller is slack for any value of ξ by the stated lower bound assumption on u_H (just below Assumption 2). Note that a pooling contract would yield lower bank profits because it prevents the bank from charging higher interest rates from from H-sellers and extract the continuation surplus, so the bank prefers separation. Thus, the expected surplus of the sellers under ON-CBDC is

$$S^{C,AMIP}_{ON-CBDC} = q[\lambda u_H + (1-\lambda)(u_H - u_L) + \xi\lambda\theta] + (1-q)\lambda u_L,$$

where the existence of a more informed platform (AMIP) sometimes generates future competition in the lending market and, thus, additional surplus $\xi\lambda\theta$ to the seller. Thus, $S^{C,AMIP}_{ON-CBDC} = S^{C}_{ON-CBDC} + q\xi\lambda\theta$. In other words, the existence of the platform limits the surplus the bank can extract by providing an alternative source of financing for the second loan. Anything beyond what sellers can obtain from a monopoly platform ($\xi\lambda\theta$) is appropriated by the bank. Note that we have $S^{C,AMIP}_{ON-CBDC} = S_{ON-CBDC}$ when $\xi = 0$, which corresponds to the main text.

As $\xi \to 1$, the informational value of tokens diminishes, so $S^{C,AMIP}_{ON-CBDC} \to S^{C}_{ON-T}$. Notice that $S^{C,AMIP}_{ON-T} = S^{C}_{ON-T}$, whereby the platform is perfectly informed when tokens are used independently of what the platform knows without. Accordingly, sellers prefer tokens to CBDC whenever $\xi < 1$.

Settlement with bank deposits. Next, consider the case where sellers opt for deposits as means of payments. With probability ξ, the bank and the platform are informed, leading to perfect competition. By contrast, the bank is a monopolist with probability $1-\xi$. Thus, sellers earn

$$S^{C,AMIP}_{ON-D} = q\lambda u_H + (1-q)\lambda u_L - (e - qs_\xi\theta),$$

and so sellers would prefer tokens over deposits whenever

$$q(1-\lambda)(u_H - u_L) > q(s_\xi - \lambda)\theta - e. \tag{35}$$

The LHS of (35) is always positive, so a sufficient condition for the above inequality to hold is that the RHS is non-positive. Since $e \geq q\lambda\theta$ by Assumption 3, this is always the case for

$$\xi \leq \frac{\lambda}{s - \lambda}. \tag{36}$$

B.3.2 Platform innovation

Now consider the case of platform innovation. When sales are settled with **tokens**, the seller does not learn about the new platform, and the resulting payoff is the same as without the platform, so $S^{PC,AMIP}_{ON-T} = S^{C,AMIP}_{ON-T} = S^{C}_{ON-T}$.

When **CBDC** is used instead, the seller does learn about the new platform. Substituting expected productivity $\tilde{\theta}$ into the payoffs from the previous subsection:

$$S^{PC,AMIP}_{ON-CBDC} = q\left[\lambda u_H + (1-\lambda)(u_H - u_L) + \xi\lambda\tilde{\theta}\right] + (1-q)\lambda u_L.$$

Sellers thus prefer tokens to CBDC whenever $S^{PC,AMIP}_{ON-T} > S^{PC}_{ON-CBDC}$, or $\xi \leq \frac{\theta}{\tilde{\theta}}$.

The use of **bank deposits** also enables sellers to learn about the entrant. Sellers obtain

$$S^{PC}_{ON-D} = q\lambda u_H + (1-q)\lambda u_L - (e - q\tilde{s}_\xi\tilde{\theta}),$$

where $\tilde{s} = 1 - \tilde{\theta}^{-1}$ and $\tilde{s}_\xi = \xi\tilde{s} + (1-\xi)\lambda$. Accordingly, tokens are preferred to deposits when

$$q(1-\lambda)(u_H - u_L) > q(\tilde{s}_\xi\tilde{\theta} - \lambda\theta) - e$$

The LHS is always positive, so this condition is satisfied if the RHS is non-positive. Since $e \geq q\lambda\theta$ by assumption, this is always the case for $2\lambda\theta \geq \tilde{s}_\xi\tilde{\theta}$, or

$$\xi \leq \frac{2\lambda\theta - \lambda\tilde{\theta}}{(\tilde{s} - \lambda)\tilde{\theta}}. \tag{37}$$

Finally, a **CBDC with data sharing** leads to the same payoffs as in the main text. Hence it would be the payment instrument chosen by sellers, i.e. CBDC with data-sharing is always preferred over tokens.