The digital economy, privacy, and CBDC*

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Abstract

We develop 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 their bank. 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 by reducing 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.

JEL Codes: D82, E42, E58, G21.

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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 2021 survey by the Bank for International Settlements, 90% of all responding central banks were actively researching CBDCs (Kosse and Mattei, 2022).

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 efficient matching, 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, their financiers face an adverse selection problem and will only provide a continuation loan if they can learn sellers' type.

We first study a setting in which a bank is the only financier. When sales are settled digitally in bank deposits, the bank directly obtains 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.

However, tokens also have a dark side because they 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 despite their anti-competitive nature.

Next, we enrich the CBDC with a data-sharing functionality, consistent with a broader definition of privacy (Hughes, 1993; 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.

Garratt and Van Oordt (2021) is also a closely related paper. They study a setting in which merchants use information gleaned from current customer payments to price discriminate future customers. Customers can take costly actions to preserve their privacy in payments but fail to appreciate the full social value of doing so. Overall investment in privacy protection thus falls short of the social optimum—similar to a public goods problem. Instead of analyzing this externality, we focus on the private benefits and costs of privacy in payments, which we endogenize. Specifically, the benefits arise from informational rents in a contracting problem, while the costs are lower sales due to inefficient offline distribution.

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. (2022) study competition between banks and Fintech in lending markets with consumer data sharing. They find that open banking can hurt borrowers because of a winner's curse arising from the information asymmetry between lenders at the heart of the open banking problem: The bank with the obligation to share information must have that information in the first place. Rather, we find that CBDC with data-sharing is unequivocally good because, crucially, CBDC creates an "informational level-playing field" among lenders.

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 paper proceeds 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 the Online Appendix.

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

[6]See Ahnert et al. (2022) for a comprehensive overview of recent work.

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 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 $u_H > u_L \geq 1$. 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 the type of the seller and the buyer, respectively. By contrast, matching is perfect when sellers distribute their goods online, so

[7] Making goods indivisible greatly simplifies the exposition and the analysis.

[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.

that there are only two types of meetings.[9] Sellers make take-it or leave-it offers to buyers, and 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 in meeting m is given by

$$p_m = u_m, \tag{1}$$

where $u_m = u_H$ if $m = (H, H)$, and $u_m = u_L$ otherwise.

There are initially two means of payment, cash (C) and bank deposits (D), and buyers can costlessly exchange one for the other.[11] Due to their physical nature, offline purchases can be settled both in cash and in deposits (e.g. via debit/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. In line with existing theoretical and empirical literature (Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017; Parlour et al., 2022), we assume that payment flows are informative about borrowers' financial situation. Accordingly, the use of deposits enables banks to observe the sellers' realized meeting m. By contrast, no information is generated for payments are settled in cash.

Sellers can easily abscond with cash. However, we assume it requires a fixed effort cost of $e > 0$ to abscond when sellers used bank deposits at $t = 1$. 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

[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.

[10] In the Online Appendix (OA.4), 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.

(OFF-C), offline-deposits (OFF-D), and online-deposits (ON-D). For example, OFF-D means that a seller trades offline and chooses to be paid with deposits.

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 buyers. Given the meeting m, sellers offer p_m. At the end of $t = 1$, given the means of payment used, banks offers a menu $\{(r_m, k_m)\}$, where r_m is the repayment of the initial loan and $k_m \in \{0, 1\}$ is the value of the continuation loan. Banks choose a repayment i on the continuation loan at $t = 3$. Subsequently, H-sellers who have received a continuation loan produce θ and repay i, or abscond with the production to obtain a payoff $\lambda\theta$. L-sellers who have received a loan abscond with the investment to obtain a payoff λ.

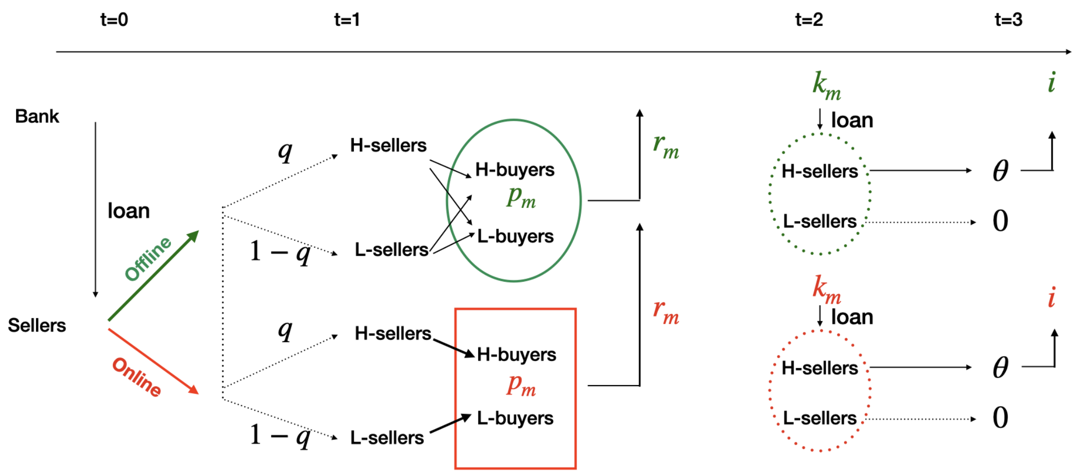

Figure 1: Timeline.

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 gives rise to (H, L) meetings. This benchmark is useful as we now study the equilibrium in the economy with asymmetric information.

3 Equilibrium

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).*

Since the model is fully symmetric, we describe the equilibrium for a representative bank-seller match. To highlight the fact that banks act as monopolists, we henceforth refer to them in the singular ("she/hers"). Since sellers can be of different types, it is more convenient to continue using the plural for them.

To solve for the equilibrium, we proceed backwards. We start with banks' decision whether to extend a continuation loan at $t = 2$. We then solve for the optimal contract menu, and then study sellers' choice of trading scheme.

3.1 Bank refinancing choice

The bank possibly faces adverse selection, so her lending decision at $t = 2$ depends on whether she is informed about sellers' 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 for uninformed lending to be unprofitable.[12] This is 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, she cannot commit to not extending a loan upon default. In the Online Appendix (OA.1), we consider an alternative setup in which the bank can 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 m 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 she can extract the full continuation surplus from HH-sellers, but not from HL-sellers.

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

In the Online Appendix (OA.4), we show that one can relax this assumption when bilateral prices are set by Nash bargaining. In that case, the bank's

[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 the Online Appendix (OA.2).

trade-off between different contract menus is driven by a feedback effect from continuation investment to sales prices. While the additional dispersion in sales prices complicates the analysis considerably, it delivers the same insights.

To simplify the exposition, 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 sellers' type (to choose refinancing appropriately) as well as their 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 her from learning all this information.

In choosing the optimal contract, the bank faces the following trade-off. She can either offer a *separating contract* that identifies all H-sellers, or alternatively offer a *partial pooling* contract that only singles out HH-sellers, and pools the remaining HL-sellers 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 states the bank's choice.

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

[13] Specifically, this assumption ensures that the feasibility constraints under the ON-D scheme are always slack. See the Proof of Lemma 2 in Appendix A.2 for details.

[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.

the continuation surplus $\theta - 1$ is generated with a higher probability. At the same time, the bank must cede a share of the resulting surplus to ensure that HL-sellers can afford the loan repayment. More specifically, she 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 sellers chooses settlement in deposits (either under the OFF-D or ON-D scheme), the bank observes their realized meeting m, 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 $t = 2$.

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 there are no (H, L) meetings when sellers use online distribution because matching is perfect. Therefore under the ON-D scheme the bank does not use r^D_{HL} but only uses 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 Sellers' choice of trading scheme

We can now determine sellers' choice of trading scheme at $t = 0$. Using the same notation as above, expected profits for a given contract menu are equal to sales minus loan repayment plus the benefits from continuation financing, that is, and after using (1):

$$S = E_m\left[u_m - r_m + k_m\lambda\theta\right]. \tag{6}$$

To build intuition, it is helpful to decompose the profits for each meeting m into sellers' outside option, λu_m, plus an informational rent. Under the partial pooling contract, only HH-sellers are refinanced when distributing goods offline. We get

$$S^P_{OFF-C} = q^2[\lambda u_H + (1-\lambda)(u_H - u_L)] + (1-q^2)\lambda u_L. \tag{7}$$

In this case, only HH-sellers earn a rent equal to $(1-\lambda)(u_H - u_L)$. All other sellers just obtain their reservation utility.

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

$$\begin{aligned} S^S_{OFF-C} &= q^2[\lambda u_H + (1-\lambda)(u_H - u_L) + \lambda(\theta - u_L)] \\ &\quad + q(1-q)[\lambda u_L + \lambda(\theta - u_L)] + (1-q)\lambda u_L. \end{aligned} \tag{8}$$

Since the bank wants to induce HL-sellers to opt for the high repayment, she must lower the "spread" from $\lambda\theta$ to λu_L, which is the maximum spread that HL-sellers are able to pay. Accordingly, the bank no longer extracts the full surplus from continuation financing, and both HH-sellers and HL-sellers earn a rent.

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

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

$$S_{OFF-D} = q^2\lambda u_H + (1-q^2)\lambda u_L - (e - q\lambda\theta) \tag{10}$$

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

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 (7)-(9) 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).

[15] With deposits, the bank learns sellers' types 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 sellers' types through repayment.

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

$$q(1-q)\lambda(u_H - u_L) - q^2(1-\lambda)(u_H - u_L). \tag{11}$$

The first term of (11) 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 (11) represents the private gains from anonymity with cash. Under the ON-D scheme, the bank learns 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 (11) 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 (8). First, with separation, the mass of sellers earning an informational rent increases from q^2 to q. Second, unlike with partial pooling, these rents are no longer strictly decreasing in λ because of the drop in the spread $\lambda(\theta - u_L)$ required to fully separate sellers.

Whenever sellers opt for offline distribution, the equilibrium is inefficient because of the relatively low utility generated in (H, L)-meetings. Moreover, 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. Due to asymmetric information, private incentives are not aligned with social welfare.

4 Central bank digital currency

In this section, we expand the set of payment instruments available 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 therefore always offers a separating contract. Sellers' expected payoff is given by

$$S_{ON-CBDC} = q\left[\lambda u_H + (1-\lambda)(u_H - u_L)\right] + (1-q)\lambda u_L. \tag{12}$$

Comparison with Equation (9) shows that $S_{ON-CBDC} > S_{ON-D}$, and hence CBDC fully displaces deposits. The separating contract enables the bank to appropriate the continuation surplus, but leaves all the gains from more efficient matching to sellers. With deposits, some of these gains also go to the bank, so that sellers are strictly better off with CBDC. Further comparison of Equations (7) and (12) 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.

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

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 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 A digital platform 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 sellers at $t = 2$. Moreover, the platform 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 the bank remains 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 sellers use tokens to settle their online transactions. In the Online Appendix (OA.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 sellers' choice between tokens and 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, sellers obtain 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 sellers can extract a share λ of their 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

[17] This can be rationalized by assuming that the bank, unlike the platform, is 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 reveals which sellers are productive, enabling her to engage in profitable lending at $t = 0$. By contrast, the platform cannot screen and will therefore find it unprofitable to lend in the initial round of financing if the share of unproductive sellers is sufficiently high.

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

sellers' type and the platform does not lend. Accordingly, the bank is a monopolist (as in Section 3) and sellers obtain

$$S^{Co}_{ON-D} = S_{ON-D}, \tag{13}$$

where the superscript Co denotes competition in the lending market.

Settlement in CBDC. Next, suppose sellers use CBDC. This implies that neither the platform nor the bank can learn their type from payment flows. Since the platform cannot lend, the analysis is the same as in Section 4. The bank always uses the separating contract, and sellers' payoff is given by

$$S^{Co}_{ON-CBDC} = S_{ON-CBDC}. \tag{14}$$

Settlement in tokens. Finally, suppose that sellers use the platform's tokens as means of payment (the ON-T scheme). Thus, the platform learns the sellers' meeting m from their 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*

$$\frac{1+\lambda}{1-\lambda} \leq \theta \tag{15}$$

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

While the bank strictly prefers separation over pooling, Lemma 4 shows that this is not always feasible—unlike under the ON-CBDC scheme. When sellers choose settlement in tokens, the platform becomes informed and is thus always willing to lend. The presence of a competing informed lender at $t = 2$ increases H-sellers' incentives to mimic the behaviour of L-sellers towards the bank, which can prevent the bank from eliciting information.

Under the separating contract, H-sellers face two informed lenders and therefore reap the competitive surplus $s\theta$ from the second loan upon repaying r_H^T. Incentive compatibility requires that they prefer truthful reporting to lying. Pretending to be an L-seller would allow them to incur a lower repayment r_L^T, but the bank would not learn their type. The platform could thus act as a monopolist at $t = 2$ and leave sellers with only their outside option $\lambda\theta$. We thus require $(s - \lambda)\theta \geq r_H^T - r_L^T$.

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, separation requires $(s - \lambda)\theta \geq \lambda$, which can be simplified to Condition (15).

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

$$S_{ON-T}^{Co} = q\left[\lambda u_H + (1-\lambda)(u_H - u_L) + \lambda\theta\right] + (1-q)\lambda u_L. \tag{16}$$

To gain intuition for this result, note that H-sellers' 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 sellers' 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 (12), (14), and (16), 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 sellers' payoff under the OFF-C scheme (Equations (7) and (8)) 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, sellers learn 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 $\tilde{\theta} \equiv \pi\hat{\theta} + (1 - \pi)\theta$. We adjust Assumptions 1-3 as follows to reflect the extended setup.

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

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

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 sellers appropriate the entire surplus net of funding costs, $\theta' - 1$, for $\theta' \in \{\theta, \hat{\theta}\}$.

As before, the incumbent platform only learns sellers' types if they use its token as means of payment. In the Online Appendix (OA.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 sellers use the incumbent platform's token, they do not learn about the existence of the new platform, and their payoff is as in the case with a single platform studied above:

$$S^{PI}_{ON-T} = S^{Co}_{ON-T}, \tag{17}$$

where PI stands for platform innovation.

Settlement in deposits. Now suppose instead that sellers use deposits. Accounting for the increased productivity, their payoff using deposits is

$$S^{PI}_{ON-D} \quad = \quad q\lambda u_H + (1-q)\lambda u_L - (e - q\lambda\tilde{\theta}) > S_{ON-D}. \tag{18}$$

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

$$S^{PI}_{ON-CBDC} = S_{ON-CBDC} \tag{19}$$

It directly follows from Assumption 3′ that $S^{PI}_{ON-CBDC} > S^{PI}_{ON-D}$ and deposits are thus never used. Moreover, direct calculations reveal that $S^{PI}_{ON-T} > S^{PI}_{ON-CBDC}$, 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.

Sellers opt for the lesser of two evils. When using the incumbent platform's token, they do not learn about the entrant platform. This allows them to limit the bank's market power, but prevents the realization of the efficiency gains associated with platform entry. By contrast, if sellers use deposits or CBDC, they learns about the entrant, but faces a monopolist lender. While this leads to the efficient outcome, the bank appropriates all of the additional surplus through the interest rate on the first loan. Accordingly, sellers are better off with tokens.

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."[19]

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

[19] In a similar vein, Hughes (1993) argues that "Privacy is the power to selectively reveal oneself to the world."

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 $t = 2$. Sellers have no incentive to reveal their 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 to the bank and the platform because they will then compete 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

$$u_H - r_H + s\theta \geq u_H - r_L + s\theta \tag{20}$$

$$u_L - r_L \geq u_L - r_H + \lambda \tag{21}$$

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, sellers' ex-ante expected payoff is given by

$$S^{Co}_{ON-CBDC^D} = q[\lambda u_H + (1-\lambda)(u_H - u_L) + s\theta] + (1-q)\lambda u_L, \tag{22}$$

where $CBDC^D$ indicates that the CBDC allows for data-sharing. Comparing with Equation (17) reveals that $S^{Co}_{ON-CBDC^D} > S^{Co}_{ON-T}$,[20] 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.

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

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 the seller 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 $\bar{r} = (1 - \lambda)u_L$. Sellers' expected payoff under CBDC with data sharing is then equal to

$$
\begin{aligned}
S^{PI}_{ON-CBDC^D} &= q\left[\lambda u_H + (1-\lambda)(u_H - u_L) + (\tilde{\theta} - 1)\right] + (1-q)\lambda u_L && (23)\\
&= S^{PI}_{ON-CBDC} + q(\tilde{\theta} - 1) && (24)\\
&= S^{Co}_{ON-CBDC} + q(\tilde{\theta} - \theta). && (25)
\end{aligned}
$$

The last term in Equation (24), $q(\tilde{\theta} - 1)$, 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 (25) 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 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

Our model provides a tractable, yet stylized framework for thinking about the interconnections between payments and privacy in the digital economy. In its most basic version, the model is centered around a simple trade-off: electronic payments enable the efficient distribution of goods via online channels, but they entail a costly loss in privacy through the resulting digital footprint. Sufficiently large privacy concerns (endogenously derived from first principles) then lead to welfare losses because of inefficient goods distribution and suboptimal investment. In this setting, an anonymous CBDC improves welfare because it enables merchants to get the best of both worlds. They can remain anonymous, but still reap the benefits of distributing their goods online.

When we extend the model to allow for a platform that also offers loans at $t = 2$, the scope for competition changes the basic trade-off. Since only informed lending is profitable, merchants are interested in revealing information to both potential lenders and reap the benefits of more competitive loan terms. Accordingly, a fully anonymous CBDC is supplanted by privately issued tokens, especially when alternative lenders have no other information sources than payment flows. However, privately issued tokens also give rise to anti-competitive practices by digital platforms. In this case, a CBDC with data-sharing functionalities can further raise welfare by creating a level playing field (in the spirit of the "open banking" debate). Accordingly, our setting provides insights for the optimal design of CBDC.

We have left unspecified the details of how financiers can learn by inspecting payment flows. Further investigation in this direction may provide 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 left 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, incentive compatibility requires $r^S_{HH} = r^S_{HL} \equiv r^S_{Hb}$. Hence, the contract must satisfy the following simplified ICs

$$\begin{aligned} u_H - r^S_{Hb} + \lambda\theta &\geq u_H - r^S_{Lb} \\ u_L - r^S_{Hb} + \lambda\theta &\geq u_L - r^S_{Lb} \\ u_L - r^S_{Lb} &\geq u_L - r^S_{Hb} + \lambda. \end{aligned}$$

Uninformed lending is unprofitable (Assumption 1), so a seller that absconds does not obtain a loan. Hence, the participation constraints (PCs) are

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

It is immediate that the first PC is slack, since the second PC is more restrictive. Moreover, feasibility requires that sellers have sufficient funds for repayment at $t = 1$, that is

$$u_H \geq r^S_{Hb}, \quad u_L \geq r^S_{Hb}, \quad u_L \geq r^S_{Lb}.$$

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

Under profit maximization, the last PC binds, $r^S_{Lb} = (1-\lambda)u_L$. Substitution into either of the first two ICs or the second PC (they have identical implications) yields $\lambda\theta + (1-\lambda)u_L \geq r^S_{Hb}$. By Assumption 2, we have $\theta > u_L$. Hence, all these three constraints are slack, so that the second feasibility constraint must bind, and we have $r^S_{Hb} = u_L$. Note that the third IC is also satisfied because $u_L \geq 1$. The separating contract thus yields expected bank profit of

$$B^S_{OFF-C} = q(r^S_{Hb} - 1) + (1-q)(r^S_{Lb} - 1) + q\left[(1-\lambda)\theta - 1\right]$$
$$= (1-\lambda)u_L - 1 + q(\theta - 1) - q\lambda(\theta - u_L), \tag{26}$$

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

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

Pretending to be a HH-seller by paying r^P_{HH} yields a continuation loan, which is worth $\lambda\theta$ to an HL-seller (who can abscond with future production at $t = 3$) and λ to an L-seller (who can abscond with the loan at $t = 2$). The first two ICs directly yield $r^P_{HH} = r^P_{Lb} + \lambda\theta$. The contract must also satisfy the following PCs

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

Profit maximization yields $r^P_{Lb} = (1-\lambda)u_L$, so $r^P_{HH} = (1-\lambda)u_L + \lambda\theta$. Assumption 2 ensures that the contract is feasible. Bank profits under partial pooling are

$$B^P_{OFF-C} = q^2(r^P_{HH} - 1) + (1-q^2)(r^P_{Lb} - 1) + q^2\left[(1-\lambda)\theta - 1\right]$$
$$= (1-\lambda)u_L - 1 + q^2(\theta - 1). \tag{27}$$

Comparing Equations (26) and (27) leads to the inequality stated in Lemma 1. Finally, a pooling contract would imply an interest rate $\bar{r} = (1-\lambda)u_L$ for all sellers and thus 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

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

because the use of deposits implies that the bank learns the seller type and therefore 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 in the Lemma. Moreover, all feasibility constraints are slack because we have assumed $u_L \geq \frac{e}{\lambda}$. Thus, expected bank profit under the ON-D scheme is

$$\begin{aligned} B_{ON-D} &= q(r^D_{HH} - 1) + (1-q)(r^D_L - 1) + q\left[(1-\lambda)\theta - 1\right] \\ &= (1-\lambda)u_L - 1 + q(\theta - 1) + (e - q\lambda\theta) + q(1-\lambda)(u_H - u_L). \end{aligned} \tag{28}$$

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

A.3 Proof of Lemma 3

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, $r^{CBDC}_L = (1-\lambda)u_L$. The ICs are

$$\begin{aligned} u_H - r^{CBDC}_H + \lambda\theta &\geq u_H - r^{CBDC}_L \\ u_L - r^{CBDC}_L &\geq u_L - r^{CBDC}_H + \lambda, \end{aligned}$$

which together with profit-maximization yield

$$r^{CBDC}_H = r^{CBDC}_L + \lambda\theta.$$

Feasible is ensured by Assumption 2. The bank's expected profits are

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

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.

A.4 Proof of Lemma 4

The separating contract under the ON-T scheme must satisfy the following ICs

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

An H-seller who pretends to be an L-seller 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 yields $(s-\lambda)\,\theta \geq r_H^T - r_L^T \geq \lambda$, so separation is feasible as long as $(s-\lambda)\,\theta \geq \lambda$, which simplifies to Inequality (15).

Suppose this condition is satisfied. Then, participation by L-sellers together with profit maximization implies $r_L^T = (1-\lambda)u_L$ and $r_H^T = r_L^T + (s-\lambda)\,\theta$. Note that H-sellers have sufficient funds for the high repayment because of Assumption 2. Thus, bank profits are

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

As usual, the rate for the pooling contract is pinned down by the participation constraint of L-sellers, $\bar{r} = (1-\lambda)u_L$. This implies bank profits $\bar{B}_{ON-T} = (1-\lambda)u_L - 1$. Accordingly, the bank prefers separation as long as it is feasible.

The digital economy, privacy, and CBDC

Online Appendix – not for publication

OA.1 Commitment to punish upon default

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

In this case, H-sellers can no longer engage in strategic default when deposits are used. If they don't repay, they will not be able to obtain a second loan, despite the bank being informed. Therefore, the PCs under the OFF-D trading scheme (which nests ON-D) become

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

where we have additionally dropped the assumption that absconding under deposits generates an additional fixed cost of e to simplify the exposition.

Assumption 2 implies that the feasibility constraint of the HH-type and the L-type is slack, but the feasibility constraint of the HL-type binds. In sum, the interest rates are

$$
\begin{aligned}
r^D_{HH} &= (1-\lambda)u_H + \lambda\theta && \text{(OA.1)}\\
r^D_{HL} &= u_L \\
r^D_{Lb} &= (1-\lambda)u_L. && \text{(OA.2)}
\end{aligned}
$$

Following the same logic, interest rates for the ON-D scheme are given by (OA.1) and (OA.2). Sellers' expected profits are then

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

Since $u_H > \theta$ (Assumption 2), sellers strictly prefer the ON-D scheme to the OFF-D scheme. Importantly, commitment to punish does not affect the payoffs when sales are settled in cash: the bank learns nothing upon default and thus does not lend. Hence, its contract choice is characterized by Lemma 1, and seller profits are still given by Equations (7) and (8). We can therefore conclude the following.

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 $\lambda \geq q$, and offline otherwise.
2. For $(1-q)(\theta-1) > \lambda(\theta-u_L)$, the bank offers a separating contract. Sellers distribute online if $\lambda\frac{u_H-\theta}{u_H-u_L} \geq q$, and offline otherwise.
3. All online sales are settled in deposits (by assumption).

OA.2 Low adverse selection

In this section we analyze the case of low adverse selection. To this end, we relax Assumption 1 and assume instead that bank lending to all seller types is profitable at $t = 2$, $q(1-\lambda)\theta > 1$. However, we also assume that some adverse selection remains. In particular, lending to a pool of HL-sellers and L-sellers is unprofitable, so the bank does not lend 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″. $\frac{1}{q} < (1-\lambda)\theta < 1 + \frac{1}{q}$.

OA.2.1 Baseline model

We first study the baseline model with cash and deposits only. As in the main text, we consider a separating and partial pooling contract.

Separating contract. Incentive compatibility requires $r^S_{HH} = r^S_{HL} \equiv r^S_H$, so the ICs are

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

because the bank grants a continuation loan to each seller reporting as H-type. Combining the ICs yields $\lambda\theta \geq r^S_H - r^S_L \geq \lambda$. The PCs change relative to the case with high adverse selection because Assumption 1″ implies that uninformed lending is profitable. Accordingly, sellers receive a loan upon absconding, since the bank uses its prior belief. Hence, we have

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

It is easy to see that the first constraint is slack. Moreover, given the remaining two PCs, we can deduce that the feasibility constraints ($u_H \geq r_H^S$, $u_L \geq r_H^S$, and $u_L \geq r_L^S$) are all slack. Therefore, profit maximization by the bank requires that the last two PCs bind, and we have

$$r_H^S = (1-\lambda)u_L \text{ and } r_L^S = (1-\lambda)u_L - \lambda. \tag{OA.3}$$

The separating contract yields expected bank profits of

$$B_{OFF-C}^S = (1-\lambda)u_L - 1 - (1-q)\lambda + q[(1-\lambda)\theta - 1]. \tag{OA.4}$$

Partial pooling. Incentive compatibility requires $r_{HL}^P = r_{Lb}^P \equiv r_L^P$. Given Assumption 1″, a pool of HL-sellers and L-sellers does not obtain re-financing, so the ICs read

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

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 $r_{HH}^P = r_L^P + \lambda\theta$ 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 absconding, uses its prior, and it refinances all sellers of unknown type (first inequality of Assumption 1″). By 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 provide a loan (second inequality of Assumption 1″).

Using the ICs, it is immediate that the first and third PC are slack. Moreover, it is easy to see that feasibility ($u_H \geq r^P_{HH}$ and $u_L \geq r^P_L$) is implied by the PCs and ICs. Thus, profit maximization requires that the PC of HL-sellers binds, and we must have

$$r^P_{HH} = (1-\lambda)u_L \text{ and } r^P_L = (1-\lambda)u_L - \lambda\theta. \tag{OA.5}$$

Thus, expected bank profits under partial pooling is

$$B^P_{OFF-C} = (1-\lambda)u_L - 1 + q^2(\theta - 1) - \lambda\theta. \tag{OA.6}$$

Comparing bank payoffs across contracts, we have $B^S > B^P$ as $q[(1-\lambda)\theta - 1] > 0 > \lambda[1-(1+q)\theta]$. The bank always chooses separation, since this guarantees higher interest rates and at the same time ensures more efficient continuation investment.

For completeness, note that the full pooling contract requires an interest rate $\bar{r} = (1-\lambda)u_L$ and yields $\bar{B} = (1-\lambda)u_L - 1 + q(1-\lambda)\theta - 1$. It can be seen readily that this contract is never used because $\bar{B} < B^S_{OFF-C}$.

Finally, we describe sellers' choice of trading scheme. Her expected payoff under OFF-C is

$$\begin{aligned} S^S_{OFF-C} &= q^2(u_H - r^S_H + \lambda\theta) + q(1-q)(u_L - r^S_H + \lambda\theta) + (1-q)(u_L - r^S_L) \\ &= q^2[\lambda u_H + (1-\lambda)(u_H - u_L)] + (1-q^2)\lambda u_L \\ &\quad +\lambda[1 + q(\theta - 1)], \end{aligned} \tag{OA.7}$$

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. Sellers' payoff under the ON-D scheme is unchanged and thus given by Equation (9) in the main text. The following proposition summarizes.

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

OA.2.2 Model with CBDC

We next study the model with CBDC. 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 that we analyze in turn.

Pooling contract. A pooling contract charges the same rate to all sellers, and the bank provides a second loan to everyone upon repayment. Then, L-sellers' PC binds, which implies that the interest rate is $r^P = (1-\lambda)u_L$. Bank profits under pooling are

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

and sellers earn

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

Comparison with equation (OA.7) reveals that sellers always prefer the CBDC-ON scheme with a pooling contract to the OFF-C scheme (where the bank always offers a separating contract).

Separating contract. Since sellers trade online, there are only (H, H) and (L, L) matches. Hence, the participation constraints (PCs) are

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

because the bank does not learn sellers' type upon absconding at $t = 1$, and thus provides a second loan based on her prior belief. The incentive compatibility constraints (IC) are

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

It is tedious but straightforward to show that the PC of L-sellers always binds, so there are only two cases: 1) the PC of H-sellers binds (for $\lambda(\theta - 1) \geq (1 - \lambda)(u_H - u_L) \geq 0$) binds, or 2) the IC of H-sellers binds (for $(1 - \lambda)(u_H - u_L) \geq \lambda(\theta - 1)$). We analyze each case in turn.

Case 1. Let $\lambda(\theta-1) \geq (1-\lambda)(u_H - u_L)$. In this case, the PC of H-sellers binds, and interest rates are

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

Then, the bank's expected profits are

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

Now consider sellers' choice of trading scheme. His expected payoff when using CBDC is

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

The alternative is to accept cash under the OFF-C scheme with a separating contract, with the payoff given by equation (OA.7). Hence, sellers prefer the ON-CBDC scheme whenever $\lambda > q$. It is straightforward to show that the bank always prefers separation over pooling.

Case 2. Suppose $\lambda(\theta-1) < (1-\lambda)(u_H - u_L)$. In this case, the IC of H-sellers binds, and interest rates are

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

Expected payoffs for sellers and the bank are

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

and sellers prefer CBDC-ON to OFF-C offline whenever

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

Summary. Straightforward algebra reveals that under the ON-CBDC scheme, the bank prefers the pooling contract over the separating contract for $q+\lambda-q\lambda\theta > 1$. The following Proposition then summarizes our findings.

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 under 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 under the ON-CBDC scheme for $q+\lambda-q\lambda\theta > 1$, and a separating contract otherwise. With the pooling contract, sellers always trade online. With the separating contract, sellers trade online iff $(1-q)(u_H - u_L) > \lambda(\theta - 1)$.

OA.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 sellers' 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.

OA.3.1 Lending market competition

Settlement with tokens. Whenever tokens are used, the platform is fully informed, irrespectively of whether it has other sources of information. Accordingly, sellers' payoff with tokens is given by equation (16) in the main text.

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

$$s_\xi \equiv \xi s + (1-\xi)\lambda \in [\lambda, s). \tag{OA.8}$$

Thus, the separating contract has to satisfy the following ICs

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

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 Assumption 2. Note that a pooling contract would yield lower bank profits because it prevents the bank from extracting the continuation surplus from H-sellers, so the bank prefers separation. Thus, the expected surplus of the sellers under ON-CBDC is

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

The platform provides an alternative sources of financing for the second loan (with probability ξ). This limits the bank's ability to extract the future surplus, since an H-seller can always walk away from the bank and reap $\xi\lambda\theta$ by borrowing from a monopoly platform. is appropriated by the bank. Note that we have $S^{Co}_{ON-CBDC} = S_{ON-CBDC}$ for $\xi = 0$, as in the main text.

It is straightforward to see that $S^{Co}_{ON-T} > S^{Co}_{ON-CBDC}$ for $\xi < 1$. In other words, they are preferred by sellers as long as they provide any informational value.

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

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

and so sellers would prefer tokens over deposits whenever

$$q(1-\lambda)(u_H - u_L) > q(s_\xi - \lambda)\theta - e. \tag{OA.9}$$

The LHS of (OA.9) 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

$$\xi \leq \frac{\lambda}{s-\lambda}. \tag{OA.10}$$

OA.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. Thus, the resulting payoff is the same as without the platform, and given by equation (16) in the main text.

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:

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

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

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

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

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

$$\xi \leq \frac{2\lambda\theta - \lambda\tilde{\theta}}{(\tilde{s}-\lambda)\tilde{\theta}}. \tag{OA.11}$$

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.

OA.4 Nash bargaining

Throughout the paper, we have assumed that sellers make take-it-or-leave-it offers. In this Section, we relax this assumption by studying the case where bilateral prices are set through Nash bargaining. While this does not change our main results, it delivers further insights. Since the logic of this analysis follows that of the main text, we only provide a sketch of the key results. Further details are available upon request.

We henceforth assume that buyers have bargaining power σ, so the baseline model corresponds to $\sigma = 0$. Crucially, with Nash bargaining, bilateral prices do not only depend on the meeting m, but also on the bank's refinancing decision k_m. The Nash solution is given by

$$p_m = (1-\sigma)u_m + \sigma\lambda - k_m\sigma\Delta_m,$$

where $u_m = u_H$ for $m = (H,H)$ and u_L otherwise, and

$$\Delta_m = \begin{cases} \theta - 1 & \text{if } m = (H,b), \\ 0 & \text{otherwise.} \end{cases}$$

In particular, if H-sellers can obtain a second loan ($k_m = 1$) and generate the extra surplus $\theta - 1$, buyers are able to extract a share σ thereof. In this case, HL-sellers reap lower sales than L-sellers.

With Nash bargaining, the bank's choice over different contract menus is driven by the feedback effect of continuation financing to sales prices. This mechanism allows us to replace Assumption 2 with the parametric restriction $(1-\sigma)(u_H - u_L) > \sigma(\theta - 1)$, which ensures that $p_{HH} > p_L$ throughout.[21]

With separation, HL-sellers generate low sales because they need to cede

[21] In line with the main text, we impose additional parameter conditions that allow us to work with a single set of expressions for seller and bank profits. We therefore assume $(1-\sigma)u_L + \sigma(1+\lambda) > (1+\sigma)\theta$ and $(1-\sigma)u_L + \lambda\sigma - \sigma(\theta-1) \geq \frac{e}{\lambda}$ so that the bank can implement the rent-maximizing contract when deposits are used.

part of the benefits from continuation financing to sellers. The resulting price dispersion increases sellers' informational rents under the separating contract. With partial pooling, this effect is absent. As the bank does not identify HL-sellers, the efficiency of continuation investment is reduced. At the same time, this eliminates the price differential between HL- and L-sellers, and thus reduces the rents the bank must offer in exchange for information.

Lemma 5. *Suppose that sellers choose the OFF-C trading scheme. Then, the bank offers a separating contract for*

$$q(1-q) \geq \sigma(1-\lambda),$$

and a partial pooling contract otherwise.

As in the main text, sellers trade off the efficiency gains from online distribution and the informational rents associated with offline cash sales. Due to Nash bargaining, this additionally depends on buyers' bargaining power σ, but the underlying economics are unchanged. The following Proposition characterizes the equilibrium.

Proposition 10. ***(Equilibrium with Nash bargaining)***
1. For $\sigma(1-\lambda) \geq q(1-q)$, sellers distribute their goods online if $q(\lambda-q)(1-\sigma)(u_H-u_L)-(e-q\lambda\theta) \geq q(\lambda-q)\sigma(\theta-1)$, and offline otherwise.
2. For $\sigma(1-\lambda) < q(1-q)$, sellers distribute their goods online if $q(\lambda-q)(1-\sigma)(u_H-u_L)-(e-q\lambda\theta) \geq (1-q)(1-\lambda)\sigma(\theta-1)$, and offline otherwise.

Extending the model to the cases of CBDC and tokens is straightforward, and follows the same logic and intuition as in the baseline model. The only difference is that the availability of tokens does not fully crowd out cash. The reason for this discrepancy across models is that, with Nash bargaining, the informational rents from cash are not always earned by the same types of sellers that benefit from online distribution.

When the bank opts for full separation under the OFF-C scheme, Nash bargaining yields rents for HH-sellers and L-sellers because the participation constraint of HL-sellers is binding. L-sellers are therefore worse off with online distribution: they lose their rents, but do not enjoy higher sales. Thus, for some parameters, cash is still used in equilibrium. By contrast, in the main text, L-sellers earn exactly their outside option because the contract is pinned down by the feasibility constraint of HL-sellers. So L-sellers are indifferent to a move towards tokens, while everyone else benefits. Hence, cash is fully displaced.

Proposition 11. ***(Additional results with Nash bargaining)***

1. Suppose that anonymous CBDC is available. Then, the bank always offers a separating contract under the CBDC-ON scheme. If $\sigma(1-\lambda) \geq q(1-q)$, sellers always distribute online (with CBDC). If $\sigma(1-\lambda) < q(1-q)$, sellers distribute their goods online (with CBDC) if $q(1-q)(1-\sigma)(u_H - u_L) \geq (1-\lambda)\sigma(\theta-1)$, and offline otherwise.

2. Suppose that tokens are available. Then, the bank offers a separating contract under the T-ON scheme for $\frac{1+\lambda}{1-\lambda} \leq \theta$, and a pooling contract otherwise. If $\sigma(1-\lambda) \geq q(1-q)$, sellers always distribute online (with tokens). If $\sigma(1-\lambda) < q(1-q)$, sellers distribute their goods online (with tokens) if $q(1-q)(1-\sigma)(u_H - u_L) \geq (1-\lambda)\sigma(\theta-1) - q\lambda\theta$, and offline otherwise. The same equilibrium obtains with platform innovation.

3. Suppose that a CBDC with data-sharing is available. Then, the bank always offers a pooling contract under the CBDC-ON scheme. Sellers always distribute online (with CBDC). The same equilibrium obtains with platform innovation.