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. Cash preserves anonymity but cannot be used for more efficient online transactions. By contrast, bank deposits can be used online but do not preserve anonymity. Banks use the information contained in deposit flows to extract rents from merchants in need of financing. Payment tokens issued by digital platforms allow merchants to hide from banks but enable platforms to stifle competition. An independent digital payment instrument (a CBDC) that allows agents to share their payment data with selected parties can overcome all frictions and achieves the efficient allocation.

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 fast.[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 potential to stifle competition, avoid creative destruction, and engage in price discrimination.[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

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[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.[6] 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. 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. H-sellers generate higher sales when matched correctly, while L-sellers generate higher sales otherwise. However, only H-sellers are able to generate a continuation payoff that merits further financing in the second round of production. Since types are private information, H-sellers only obtain a continuation loan if the financier can learn their type.

We first study a setting in which a bank is the only financier. When bank deposits are the only digital means of payments, the bank directly observes online sales and thus infers sellers' type. As a result, the bank does not have to leave any informational rents to online sellers. By contrast, cash transactions are not observable, so the bank has to make inference based on reported sales and can elicit information through contractual arrangements.

We show that, in equilibrium, sellers opt for online distribution and settlement with bank deposits if the benefits of more efficient matching outweigh the costs of freely revealing their type to the bank. This is the case if the resulting

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[6]See "Facebook gives up on crypto ambitions with Diem asset sale", Financial Times, January 27, 2022.

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 to trade online, the bank can only learn the type by leaving some rents to online sellers. There are two efficiency gains: First, sellers are more likely to trade online when sales are settled with CBDC, which ensures efficient matching. Second, with CBDC, the bank always elicits information through a separating contract. This ensures that H-sellers are more likely to receive continuation investment from the bank, which further raises welfare.

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 the 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. The reason is intuitive: since banks can elicit information through contracting for the initial loan, the use of tokens ensures that the platform and the bank can compete for the continuation loan. By contrast, with either CBDC or deposits, only the bank is informed and acts as a monopolist. Accordingly, sellers opt for tokens.

However, we show that tokens also enable the platform to fend off competitors by creating a so-called "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 the efficiency gains are appropriated by banks. Accordingly, sellers are better off with tokens.

Next, we enrich the CBDC with a data-sharing functionality. 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 banks. 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.

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Finally, we show that a CBDC with a data-sharing feature also enhances competition among platforms by preventing the incumbent from acting as "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. This 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 engage in price discriminate against 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 and—similar to a public goods problem—insufficiently preserve their privacy. 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 also builds on a literature 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. (2021) 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 because their sign-up decisions reveal information about credit quality.

Finally, our paper is part of a fast-growing literature on CBDC. 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), the efficacy of government interventions (Keister and Monnet, 2020), 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 subsequently introduce a CBDC with anonymity in Section 4. We consider competition between the bank and a digital platform in Section 5. Finally, we examine data-sharing features of CBDC in Section 6. Section 7 concludes.

2 The basic model

The model has four dates $t = 0, 1, 2, 3$ and there is no discounting. There are three types of risk-neutral agents: buyers, sellers, and banks, each of which with measure one. There are two goods: an investment good and a consumption good.

Sellers have no resources at $t = 0$ and need to borrow from a bank to finance production. Sellers can produce one unit of the indivisible 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 $1 - q$ 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 $t = 1$. H-sellers can also produce θ units of the consumption good at $t = 3$, using one unit of the investment good at $t = 2$. By contrast, L-sellers 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 $u < u_H$ from consuming one unit of the low-quality good. We call them H-buyers. The remaining $1 - q$ L-buyers do not care about quality and obtain utility u independently of the quality of the good consumed.[7]

Banks are endowed with one unit of the investment good at $t = 0$ and $t = 2$, and their opportunity cost is 1 per unit of investment.[8] They can lend the investment good to sellers at $t = 0$ and $t = 2$. Bankers can neither commit to long-term contracts, nor to not renegotiating loan terms. Hence, it is as if they could set the terms at $t = 1$ and $t = 3$. When setting those terms, bankers make take-it-or-leave-it offers. However, sellers can abscond with a fraction λ of their sales. If they use bank deposits as means of payment, absconding at $t = 2$ has a fixed effort cost of e. This cost captures the notion that deposit flows enable the bank to monitor sellers' activity more closely, which makes absconding more difficult and requires additional effort.

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 only choose one trading venue. Offline, sellers and buyers are matched randomly. This gives rise to four types of meetings $\mu = (s, b)$, 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

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[7]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.

[8]This unit cost may reflect the bank's cost of funding or an alternative safe investment opportunity.

only two types of meetings.[9] When meeting, buyers and sellers determine the price through bilateral Nash bargaining. We denote buyers' market power by $\sigma \in [0,1]$, which is constant across trading venues. If the negotiation fails, sellers consume their production to obtain utility λ and exit the economy.

We assume there are initially two means of payment (cash and bank deposits) and that buyers can costlessly exchange one for the other. Crucially, online and offline transactions differ in the means of payment that can be used. 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 payment with a digital payment instrument such as deposits. We assume that payments in deposits enable the bank to observe the sales of the seller. This is not the case when cash is used. We refer to the combination of trading venue and payment means as a *trading scheme*. There are three possibilities: offline-cash (OFF-C), offline-deposits (OFF-D), and online-deposits (ON-D).

To simplify the exposition, we abstract from details about the exact way payments are made in our economy. However, Appendix C provides explicit foundations in the spirit of new monetarist models.

The timing shown in Figure 1 is as follows. At $t = 0$, sellers and banks are matched and sellers borrow one unit of the investment good. At $t = 1$, sellers first choose their trading scheme, learn their type, and are matched with a buyer for bargaining over the terms of trade. Otherwise, the good is delivered against payment. At $t = 2$, given the means of payment used, the bank sets the interest payment schedule $r(\hat{p})$ conditional on the seller sales report $\hat{p}$.[10] The seller reports sales $\hat{p}$ such that $r(\hat{p}) \leq p$ to the bank, where p denotes his true sales. Note that $\hat{p} = p$ when the seller used deposits. Subsequently, the seller and the bank agree

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[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. Online, we have a measure q of (H, H) meetings and a measure $(1-q)$ of (L, L) meetings.

[10]Since the bank cannot commit at $t = 0$ not to renegotiate at $t = 2$, any loan rate set at $t = 0$ would be renegotiated to $r(\hat{p})$.

on a continuation loan $k(\hat{p}) \in \{0, 1\}$ at interest rate $i(\hat{p})$. At $t = 3$, H-sellers produce θ and repay $i(\hat{p})$ to the bank, or abscond with the production to obtain a payoff $\lambda\theta$. L-sellers produce nothing and abscond with the investment good to obtain a payoff λ.
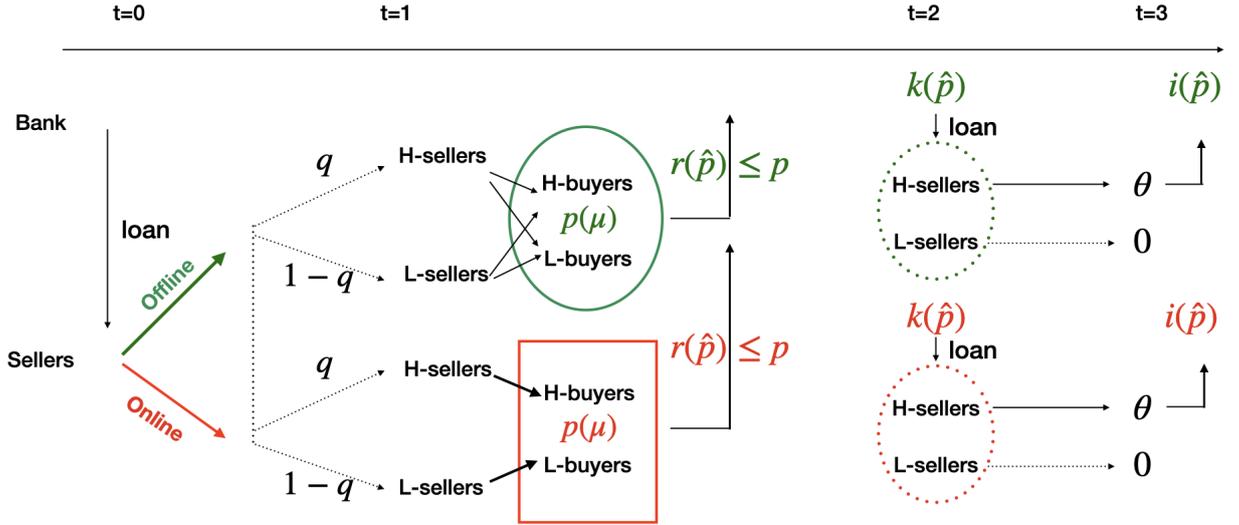

Figure 1: Timeline

3   Equilibrium

We now solve for the equilibrium. We proceed backwards, starting with banks' choice on whether to extend a second loan at $t = 2$. We then solve for the sales prices and sellers' choice of trading scheme at $t = 1$. We close by solving for banks' choice of loan contract at $t = 0$. Our equilibrium definition follows.

Definition 1. *An equilibrium is a choice by banks of initial investment $l \in \{0, 1\}$ and loan contracts $(r, k, i)(\hat{p})$ as a function of reported sales $\hat{p}$ and a choice of trading schemes by sellers such that (1) given banks' choice and the bargaining solution $p(\mu)$ for each meeting μ, sellers maximize expected profit by choosing the*

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trading scheme and announcing sales $\hat{p} \leq p(\mu)$ to banks, and (2) banks maximize expected profits, anticipating how contracts affect sellers' choice of trading schemes.

3.1   Banks' choice at t=2

Banks possibly face adverse selection, so their lending decision at $t = 2$ depends on whether they are informed about the seller's type. First, suppose that banks are informed. In this case, L-sellers do not receive a new loan because they will produce nothing. By contrast, H-sellers receive financing if the resulting output at $t = 3$ is sufficient to cover bank's unit cost of investment plus H-sellers' outside option $\lambda\theta$, that is

$$\theta > 1 + \lambda\theta.$$

Next, when banks are uninformed, the return on H-sellers' project must be higher in order to ensure funding, since loans to L-sellers will lead to a full loss. Thus, banks will re-finance sellers of unknown type if

$$q\theta > 1 + q\lambda\theta.$$

In order to simplify the exposition, we henceforth assume that the level of adverse selection is relative high, so that banks will only fund H-sellers at $t = 2$.

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

If adverse selection is low, it will be profitable for banks to lend to sellers of unknown type in the second stage. We relegate the analysis of this case to Appendix B.3 because it is tedious and the results are unchanged.

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

where the bank can commit to not extending a loan upon default, and show that it leads to the same trade-offs among the deposits and cash.

3.2 Bargaining between buyers and sellers at $t = 1$

In solving for the bargaining solution between buyers and sellers, we treat sellers and banks as a coalition.[11] Once the negotiation is concluded, sellers and banks can decide on how to share the joint surplus. If bargaining fails, we assume that sellers abscond with a fraction λ of the production, and exit the economy.

To determine the joint surplus from trade, we need to condition on banks' lending decision at $t = 2$. If a loan is extended, H-sellers will generate an additional payoff $\theta - 1$ for the bank/seller coalition. To this end, let $m = (\mu, k)$ denote a meeting conditional on the bank's future lending decision $k \in \{0, 1\}$, and let $p(m)$ be the associated bilateral price. Assumption 1 implies that no loan is extended to L-sellers, so the continuation payoff $\Delta(m)$ earned by the seller/bank coalition at $t = 3$ is given by

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

If buyer and seller agree to trade at $p(m)$, the seller/bank coalition earns $p(m) - 1 + \Delta(m)$. By contrast, without trade, the seller walks away with his outside option and obtains utility λ. Since the bank has sunk its unit investment, the joint payoff is $\lambda - 1$. Combining the previous two equations, the joint surplus of the seller/bank coalition is

$$p(m) - \lambda + \Delta(m).$$

Since buyers have deep pockets, their surplus from trade is $u(m) - p(m)$, where $u(m) = u_H$ for $m = (H, H, k)$ and $u(m) = u$ otherwise. The price in meeting m is

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[11]See Petrosky-Nadeau and Wasmer (2017) for this approach as well as other types of solution to solving bargaining problems involving three parties.

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then given by the Nash solution[12]

$$p(m) = (1 - \sigma)u(m) + \sigma\lambda - \sigma\Delta(m).$$

The first and the last term of the price depend on the type of the meeting m. First, H-buyers value quality, which implies a higher price for (H, H, k)-meetings. Second, their bargaining power allows buyers to extract some of the continuation surplus $\Delta(m)$ that accrues following $(H, b, 1)$-meetings at $t = 3$. Intuitively, the H-seller/bank coalition is willing to cede part of it because it cannot be reaped if trade breaks down. Since L-sellers never receive re-financing, the full set of possible prices is given by

$$p(m) = \begin{cases} p_H \equiv (1 - \sigma)u_H + \sigma\lambda - \sigma\left(\theta - 1\right) & \text{if } m = (H, H, 1), \\ \tilde{p}_H \equiv (1 - \sigma)u_H + \sigma\lambda & \text{if } m = (H, H, 0), \\ p_h \equiv (1 - \sigma)u + \sigma\lambda - \sigma\left(\theta - 1\right) & \text{if } m = (H, L, 1), \\ \tilde{p}_h \equiv (1 - \sigma)u + \sigma\lambda & \text{if } m = (H, L, 0), \\ p_L \equiv (1 - \sigma)u + \sigma\lambda & \text{if } m = (L, b, 0). \end{cases} \quad (1)$$

Furthermore, we assume the following.

Assumption 2. $(1 - \sigma)\left(u_H - u\right) > \sigma\left(\theta - 1\right)$.

This assumption implies that the surplus which H-sellers can extract from H-buyers exceeds the surplus that L-sellers can extract from any buyer. Intuitively, it is satisfied if H-buyers do not have much bargaining power $((1 - \sigma)/\sigma$ is high) relative to what they bring to the negotiation table $((\theta - 1)/(u_H - u)$ is low). We thus have $p_H > p_L > p_h$.

Finally, we also assume that the gains from trade for the bank-seller pair are higher in the first production stage than in the second one. This renders the information extraction problem non-trivial. More specifically, it ensures that

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[12]Formally, $p(m)$ solves $\max \left[u(m) - p(m)\right]^\sigma \left[p(m) - \lambda + \Delta(m)\right]^{1-\sigma}$.

H-sellers generate sufficient sales in (H,L)-meetings to allow for full separation.

Assumption 3. $(1 - \sigma)u + \sigma\lambda > \theta$.

3.3 Loan contract at $t = 0$

We turn to the loan contract at $t = 0$. We analyze three types of contracts. The contract is *separating* whenever the bank offers a menu of contracts and an H-seller *at the time of repayment* selects contract $(r_H, 1)$ and an L-seller selects contract $(r_L, 0)$, where $r_H \neq r_L$. A contract is *pooling* if sellers face a single interest payment and extension of the new loan (r_u, k_u) such that both types of sellers pay r_u. A contract is *partially pooling* whenever the bank offers a menu of contracts and an H-seller in meeting $\mu = (H, H)$ selects contract $(r_H, 1)$ and an L-seller or an H-seller in meeting $\mu = (H, L)$ select contract $(r_L, 0)$, where $r_H \neq r_L$. When setting the contract, the bank takes into account how it affects the seller's choice of trading scheme. To simplify the exposition, we will sometimes refer to H sellers in $\mu(H, L)$-meetings as h-sellers.

Offline-Cash. First, suppose the seller chooses the offline-cash (OFF-C) trading scheme. Under the pooling contract, the bank does not learn the seller's type, so that no loan will be extended at $t = 2$ and bilateral prices are $\tilde{p_H}$ and p_L. Given that $\tilde{p_H} > p_L$, the relevant participation constraint (PC) is

$$p_L - r_u \geq \lambda p_L.$$

Since the bank maximizes profits, it must hold with equality, so that

$$r_u = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right]$$

Under the separating contract, the bank lends to H-sellers and bilateral prices are p_H, p_h, and p_L. The contract has to satisfy the following three incentive constraints

(IC)

$$p_H - r_H + \lambda\theta \geq p_H + \max\{-r_h + \lambda\theta, -r_L\},$$
$$p_h - r_h + \lambda\theta \geq p_h + \max\{-r_H + \lambda\theta, -r_L\},$$
$$p_L - r_L \geq p_L + \max\{-r_H + \lambda, -r_h + \lambda\}.$$

An L-seller pretending to be an H/h-seller would pay r_H or r_h, obtain one unit of investment from the bank, and abscond to obtain payoff λ (Assumption 3 ensures this is feasible). Combining the first two incentive constraints yields $r_h = r_H$, since an H-seller can always reveal his type by choosing the lower interest rate. The ICs can be combined to $\lambda\theta \geq r_H - r_L \geq \lambda$, and profit-maximization then yields

$$r_H = r_L + \lambda\theta. \tag{2}$$

The separating contract also has to satisfy the following three PCs

$$p_H - r_H + \lambda\theta \geq \lambda p_H,$$
$$p_h - r_H + \lambda\theta \geq \lambda p_h,$$
$$p_L - r_L \geq \lambda p_L.$$

Substituting r_H from (2) and using the ordering $p_H > p_L > p_h$ then leads us to conclude that

$$r_L = (1 - \lambda)[(1 - \sigma)u + \sigma\lambda - \sigma(\theta - 1)]. \tag{3}$$

Notice that to achieve separation, the bank extracts the entire surplus from h-sellers, who only receive their reservation utility. By contrast, the payoffs of H-sellers in meeting $\mu = (H, H)$ and all L-sellers exceeds their respective reservation utility.

Next, consider the partially pooling contract, under which the bank only lends to H-sellers who met H-buyers. In this case, bilateral prices are given by p_H,

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$\tilde{p}_h$ and p_L, so the ICs read

$$p_H - r_H + \lambda\theta \geq p_H - r_L,$$

$$\tilde{p}_h - r_L \geq \tilde{p}_h - r_H + \lambda\theta,$$

$$p_L - r_L \geq p_L - r_H + \lambda.$$

Since $\tilde{p}_h = p_L$, we directly obtain

$$r_H - r_L = \lambda\theta. \tag{4}$$

The PCs are

$$p_H - r_H + \lambda\theta \geq \lambda p_H$$

$$\tilde{p}_h - r_L \geq \lambda\tilde{p}_h$$

$$p_L - r_L \geq \lambda p_L$$

which, using $\tilde{p}_h = p_L$ again, yields

$$r_L = (1 - \lambda)[(1 - \sigma)u + \sigma\lambda] \tag{5}$$

The bank chooses the contract that maximizes expected profits. Under the pooling contract, the bank earns

$$B_{OFF-C}^{pooling} = r_u - 1 = (1 - \lambda)[(1 - \sigma)u + \sigma\lambda] - 1, \tag{6}$$

whereas the separating contract yields

$$B_{OFF-C}^{separating} = q(r_H - 1) + (1 - q)(r_L - 1) + q[(1 - \lambda)\theta - 1]$$

$$= (1 - \lambda)[(1 - \sigma)u + \sigma\lambda] + (\theta - 1)[q - (1 - \lambda)\sigma] - 1. \tag{7}$$

and the partially pooling contract returns

$$B_{OFF-C}^{partpool} = q^2(r_H - 1) + q(1-q)(r_L - 1) + (1-q)(r_L - 1) + q^2[(1-\lambda)\theta - 1]$$
$$= (1-\lambda)[(1-\sigma)u + \sigma\lambda] + q^2(\theta - 1) - 1. \tag{8}$$

Direct inspection reveals that $B_{OFF-C}^{partpool} > B_{OFF-C}^{pooling}$, meaning the partially pooling contract always dominates the pooling contract from the bank's viewpoint. Thus, the pooling contract will never be offered. Then it is immediate that the bank will choose the partially pooling contract whenever

$$\sigma(1-\lambda) \geq q(1-q) \tag{9}$$

and otherwise opt for the separating contract.

Inequality (9) contrasts the costs and benefits of using a partially pooling contract, relative to full separation. The RHS represents the cost in terms of foregone profits. Since partial pooling only filters out some of the H-sellers (those that have met H-buyers), the probability of reaping the continuation investment declines from q to q^2.

The LHS represents the relative benefit of partial pooling in terms of higher interest revenue. Full separation of types is costly because it implies a decline in sales: a share σ of the continuation surplus must be ceded to buyers in (H, L)-meetings. The bank bears a fraction $(1 - \lambda)$ of this cost. Importantly, the cost of separation accrues with probability 1 because the bank must lower *all* interest rates in order to ensure participation.

Offline-Deposit. Now suppose the seller chooses the offline-deposit (OFF-D) scheme. Recall that when sellers use deposits, the bank can perfectly observe sales and, ex-post, the contract does not have to satisfy any ICs for truthful reporting. Moreover, H-sellers can abscond with a fraction λ of their sales only if they incur the cost e of forging their accounts, but they still receive a second

loan at $t = 2$ since the bank knows their type (it is optimal for the bank to do so, following Assumption 1). As long as this does not actually occur in equilibrium, the observed prices are p_H, p_h and p_L from Equation (1). Thus, the PCs are

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\begin{aligned}
p_H - r_H^d + \lambda\theta &\geq \lambda p_H - e + \lambda\theta \\
p_h - r_h^d + \lambda\theta &\geq \lambda p_h - e + \lambda\theta \\
p_L - r_L^d &\geq \lambda p_L - e,
\end{aligned}
$$

where the superscript d indicates the use of deposits. The profit-maximizing bank then sets the following interest rates

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\begin{aligned}
r_H^d &= (1-\lambda)\left[(1-\sigma)u_H + \sigma\lambda - \sigma(\theta - 1)\right] + e \qquad (10) \\
r_h^d &= (1-\lambda)\left[(1-\sigma)u + \sigma\lambda - \sigma(\theta - 1)\right] + e \qquad (11) \\
r_L^d &= (1-\lambda)\left[(1-\sigma)u + \sigma\lambda\right] + e \qquad (12)
\end{aligned}
$$

Since the bank is perfectly informed, the interest rates capture the entire surplus of all types of sellers and leave them indifferent between forging their accounts or not.

Online-Deposit. Finally, suppose that the seller chooses the online-deposit (ON-D) scheme. Since matching is perfect, there are no (H,L)-meetings, so the interest rates under this contract are given by equations (10) and (12).

3.4 Seller's choice of trading scheme at $t = 1$

At $t = 1$, sellers choose their trading scheme. Their expected profits from choosing the OFF-C scheme depends on the type of contract that the bank offers. Under

the partially pooling contract, they earn

$$S_{OFF-C}^{partpooling} = q^2 (p_H - r_H + \lambda\theta) + (1 - q^2) (p_L - r_L)$$
$$= \lambda [(1 - \sigma)u + \sigma\lambda] + q^2 [(1 - \sigma)(u_H - u) - \sigma(\theta - 1)] \quad (13)$$

and under the separating contract they obtain

$$S_{OFF-C}^{separating} = q^2(p_H - r_H + \lambda\theta) + q(1 - q)(p_h - r_H + \lambda\theta) + (1 - q)(p_L - r_L)$$
$$= \lambda[(1 - \sigma)u + \sigma\lambda - \sigma(\theta - 1)] + q^2(1 - \sigma)(u_H - u) + (1 - q)\sigma(\theta - 1)$$
$$(14)$$

If, instead, sellers choose the offline-deposit scheme, they earn

$$S_{OFF-D} = q^2[p_H - r_H^d + \lambda\theta] + q(1 - q)[p_h - r_h^d + \lambda\theta] + (1 - q)[p_L - r_L^d]$$
$$= \lambda[(1 - \sigma)u + \sigma\lambda] + q^2\lambda(1 - \sigma)(u_H - u) - q\lambda\sigma(\theta - 1) - (e - q\lambda\theta)$$

In the following, we assume that the additional cost of absconding when deposits are used, e, is sufficiently high to prevent strategic default at $t = 2$ by H-sellers.

Assumption 4. $e \geq q\lambda\theta$.

Direct comparison of the payoffs reveals that $min\{S_{OFF-C}^{partpooling}, S_{OFF-C}^{separating}\} > S_{OFF-D}$, so sellers always use cash when selling offline. We close the analysis by comparing the seller's payoff from selling online with that under the offline-cash scheme. Under the online-deposit scheme, expected profits of sellers are equal to

$$S_{ON-D} = q[p_H - r_H^d + \lambda\theta] + (1 - q)[p_L - r_L^d]$$
$$= \lambda[(1 - \sigma)u + \sigma\lambda] + q\lambda[(1 - \sigma)(u_H - u) - \sigma(\theta - 1)] - (e - q\lambda\theta). \quad (15)$$

Direct calculations lead to the following result.

Proposition 1. *(Equilibrium in the baseline model.)*
1. For $\sigma(1 - \lambda) \geq q(1 - q)$, banks offer a partially pooling contract under the

OFF-C scheme. In this case, sellers distribute their goods online if $q(\lambda - q)(1 - \sigma)(u_H - u) - (e - q\lambda\theta) \geq q(\lambda - q)\sigma(\theta - 1)$, and offline otherwise.

2. For $\sigma(1 - \lambda) < q(1 - q)$, banks offer a separating contract under the OFF-C scheme. In this case, sellers distribute their goods online if $q(\lambda - q)(1 - \sigma)(u_H - u) - (e - q\lambda\theta) \geq (1 - q)(1 - \lambda)\sigma(\theta - 1)$, and offline otherwise.

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

Figure 2 illustrates the equilibrium by highlighting the relevant regions from Proposition 1 in the (λ, q)-space. The solid black curve defined by $\sigma(1 - \lambda) = q(1 - q)$ delineates the regions of the parameter space for which the bank uses a separating contract (above) or a partially pooling contract (below).

First, consider the region above the bold line in which the bank offers a separating contract for offline sales. Such a contract entails rents for all sellers except in (H, L)-meetings, which occur with probability $q(1 - q)$. Moreover, these rents are decreasing in sellers' bargaining power (see the discussion following equation (9)). Therefore, it is most attractive to switch to online distribution for intermediate values of q, and high values of λ.

Now consider the region where banks offer partial pooling whenever sales take place offline. In this case, goods are distributed online whenever λ is large relative to q. To understand this result, it is useful to abstract from the term $(e - q\lambda\theta)$. Notice that L-sellers obtain exactly the same payoffs under partial pooling and ON-D, so that the choice is entirely determined by the relative payoffs of H-sellers. Trading online with deposits, H-sellers always meet H-buyers, and they exactly earn their reservation value, λp_H. By contrast, offline distribution gives rise to the risk of low sales from meetings with L-buyers, but the partial pooling contract allows them to appropriate the *entire* gains from (H, H)-meetings. In expectation, they earn $\lambda p_L + q(p_H - p_L)$. Based on these considerations, sellers opt for online distribution with deposits whenever $\lambda > q$.

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Equilibrium with low adverse selection.   Our derivation of the equilibrium was based on the assumption that adverse selection is sufficiently high to render uninformed lending unprofitable (see Assumption 1). In Appendix B.3, we show that precisely the same equilibrium obtains when adverse selection is low, or $q(1-\lambda)\theta > 1$. Intuitively, a pooling contract prevents the bank from fully appropriating the gains arising from the continuation investment through the interest rate on the first loan. Accordingly, a contract that reveals some information to the bank yields a strictly higher payoff. This result is already reflected in Figure 2, which spans the parameter space for both high and low adverse selection.
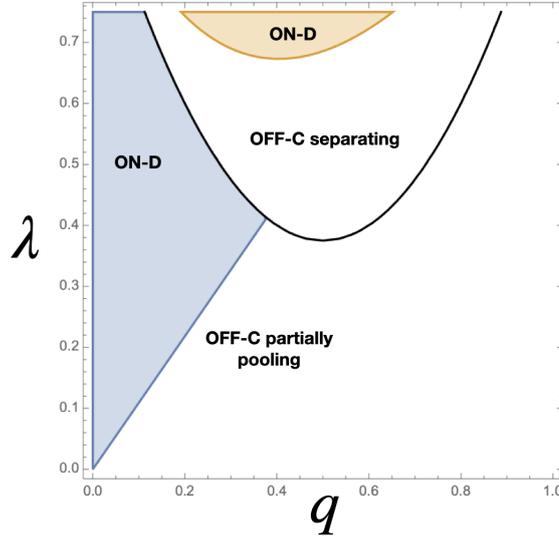

Figure 2: Equilibrium map in (λ, q)-space.

Notes: In all figures we use the following parameters that satisfy Assumption 2: $\sigma = 0.4$, $\lambda_P = 0.05$, $\theta = 4$, $u_H = 12$, $u = 8$. Also e is such that $e = (1 + 0.025)q\lambda\theta$ such that Assumption 4 is always satisfied. The range of λ is such that the constraint $(1 - \lambda)\theta > 1$ of Assumption 1 is satisfied. The figures shows the solution under both high adverse selection $(q(1 - \lambda)\theta < 1$ and low adverse selection $(q(1 - \lambda)\theta > 1)$ that we analyze in the Appendix.

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 an electronic version of cash. In our

context, this means that CBDC allows sellers to conduct online sales without revealing their type to the bank. Accordingly, sellers can now also choose an online-CBDC trading scheme (ON-CBDC). Note that an offline-CBDC scheme is the same as the OFF-C scheme, so we do not need to consider it separately. In the Appendix, we prove the following result.

Lemma 1. *If sellers choose the ON-CBDC trading scheme, the bank always uses a separating contract (r_s, k_s), where $k_H = 1$, $k_L = 0$, and*

$$r_s = (1-\lambda)\left[(1-\sigma)u + \sigma\lambda\right] + \begin{cases} \lambda\theta & \text{if } s = H \\ 0 & \text{if } s = L. \end{cases}$$

Since online distribution implies perfect matching, the bank's choice is limited to a separating and a pooling contract. However, the pooling contract does not allow the bank to extract any of the surplus that arises from continuation investment. Accordingly, it always opts for separation.

Under the ON-CBDC scheme, bilaterally negotiated prices are p_H and p_L. Using the contract in Lemma 1, it follows that sellers' expected payoff is

$$S_{ON-CBDC} = \lambda\left[(1-\sigma)u + \sigma\lambda\right] + q\left[(1-\sigma)(u_H - u) - \sigma(\theta - 1)\right] \quad (16)$$

Comparison with equation (15) shows that $S_{ON-CBDC} > S_{ON-D}$, and hence CBDC fully displaces deposits. The separating contract allows the bank to appropriate the continuation surplus, but leaves all the gains from more efficient matching to the seller. With deposits, some of these gains are also reaped by the bank. Further comparison with the other equations in Section 3.4 leads to the following result.

Proposition 2. *(Equilibrium with CBDC)*
1. For $\sigma(1-\lambda) \geq q(1-q)$, banks offer a partially pooling contract under the OFF-C scheme. In this case, sellers always distribute their goods online.
2. For $\sigma(1-\lambda) < q(1-q)$, banks offer a separating contract under the OFF-C

scheme. In this case, sellers distribute their goods online if $q(1-q)(1-\sigma)(u_H - u) \geq$
$(1-\lambda)\sigma(\theta - 1)$, and offline otherwise.

3. All online sales are settled in CBDC.

Comparing Proposition 1 and 2 reveals that the introduction of CBDC leads to an increase in online sales. As sellers can stay anonymous, they can capture some of the benefits related to more efficient matching through the separating contract. This is shown by Figure 3, which plots the equilibrium under CBDC in the (λ, q)-space (overlaying the depiction of the equilibrium with only cash and deposits shown of Figure 2).

A change from offline to online sales improves welfare through two channels. First, the matching of buyers and sellers is more efficient, which means that utility u_H is reaped more frequently. Second, banks provide more continuation financing to H-sellers, so that the surplus θ can be realized whenever possible. This second effect arises in the region of the parameter space that, absent CBDC, gives rise to offline distribution with cash and a partially pooling contract. Under this constellation, adding CBDC induces the bank to gather more precise information through contracting, and thus increases the efficiency of re-financing.
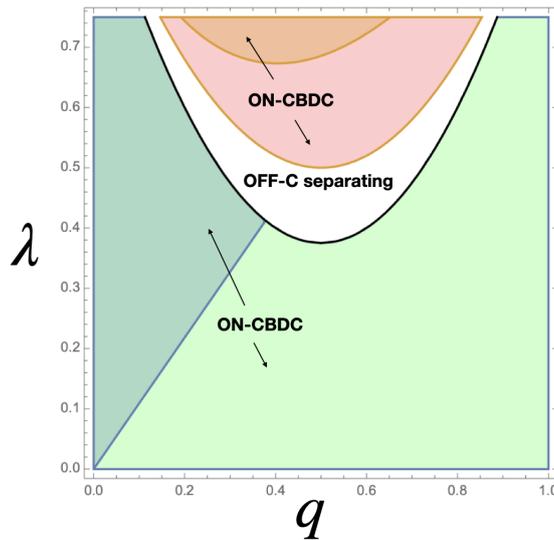

Figure 3: Equilibrium map in (λ, q)-space

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 then study a model in which the incumbent platform faces competition from a potential entrant.

5.1 Competition in the loan market

Here we assume that the platform is able to lend to the seller at $t = 2$. Moreover, at $t = 0$, it can also provide a digital token as means of payment, giving rise to an online-token (ON-T) trading scheme. However, we assume that banks remain monopolists for the first loan.[13] The platform has the same fundings costs as the bank.

Clearly, the distribution of information between the bank and the platform is key for competition. We assume that the platform learns the seller's type only if he uses tokens to settle his online transactions. In Appendix B.2, we study an extension of the model where the platform also derives information from observing the sales it intermediates. We show all our results remain unchanged provided that tokens provide sufficient informational value. In particular, sellers' choice between tokens and CBDC remains the same as long as tokens provide positive, but arbitrarily small informational value.

We assume that the platform and the bank engage in Bertrand competition at $t = 2$ if both have the same information. Let $s = 1 - \frac{1}{\theta}$ denote the share

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[13]This can be rationalized by assuming that banks, unlike platforms, are able to resolve an initial adverse selection problem. Suppose that there are productive and unproductive sellers seeking to borrow at $t = 0$. Unproductive sellers never produce anything but consume the loan, while productive sellers become H-sellers with probability q and L-sellers otherwise. The bank has a screening technology to determine who is productive or who is not, which enables it to engage in profitable lending. By contrast, the platform cannot screen, and thus finds it unprofitable to lend.

of the surplus θ that is appropriated by the seller in this case.[14] If there is no competition in the lending market at $t = 2$, we assume that the seller can extract a share λ_P from his sales at $t = 3$ when borrowing from the platform, and a share λ when borrowing from the bank. In line with Assumption 1, we impose $1/q > (1 - \lambda_P)\theta > 1$.

To start, assume 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 cannot lend. Accordingly, the bank is a monopolist as in Section 3 and sellers obtain

$$S_{ON-D}^{C} = S_{ON-D} \tag{17}$$

where the superscript C denotes competition in the lending market.

Now, instead, assume that the seller uses the platform's tokens as means of payment. In this case, the platform learns the seller's type from his payment activity, but the bank does not. However, the bank can choose to become informed by offering a separating contract, which has to satisfy the following two ICs

$$p_H - r_H + s\theta \geq p_H - r_L + \lambda_P\theta$$
$$p_L - r_L \geq p_L - r_H + \lambda.$$

When an H-seller pretends to be an L-seller, he forgoes the competitive surplus $s\theta$ and instead obtains $\lambda_P\theta$ 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

$$(s - \lambda_P)\theta \geq r_H - r_L \geq \lambda \tag{18}$$

Interestingly, while the separating contract was always feasible without competition, a separating contract is now no longer feasible if $\lambda > (s - \lambda_P)\theta$, or $\frac{1+\lambda}{1-\lambda_P} > \theta$. In this case, L-sellers derive a higher benefit from pretending to be H-sellers than

---

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

H-sellers themselves.

A separating contract also has to satisfy the PCs, which read

$$
\begin{aligned}
p_H - r_H + s\theta &\geq \lambda p_H + \lambda_P \theta \\
p_L - r_L &\geq \lambda p_L
\end{aligned}
$$

Given r_L and assuming feasibility ($\theta < \frac{1+\lambda}{1-\lambda_P}$), the profit-maximizing bank will set

$$
r_H = r_L + (s - \lambda_P)\,\theta \tag{19}
$$

Substitution into the PCs together with $p_H > p_L$ from Assumption 2 then implies

$$
r_L = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right]. \tag{20}
$$

Alternatively, the bank can offer a pooling contract where all borrowers pay the same rate.[15] Since this contract only reflects the PCs, we directly get

$$
r_u = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right]. \tag{21}
$$

Banks' choice regarding contract terms is determined by profit maximization. The separating contract yields

$$
\begin{aligned}
B_{ON-T}^{separating,C} &= q\left[r_H - 1 + \frac{1}{2}\left\{(1 - s)\theta - 1\right\}\right] + (1 - q)(r_L - 1) \\
&= (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right] + q(s - \lambda_P)\theta - 1,
\end{aligned}
$$

while the pooling contracts leads to

$$
B_{ON-T}^{pooling,C} = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right] - 1. \tag{22}
$$

We can directly observe that $B_{ON-T}^{separating,C} > B_{ON-T}^{pooling,C}$. This implies that the bank

---

[15]Notice that there can be no partially pooling contract because there are only two types of meetings, (H, H) and (L, L).

will offer a separating contract whenever feasible, and a pooling contract otherwise.

Turning to the seller, we find that he earns the same payoff under the separating and the pooling contract. To understand the intuition behind this result, note that the H-seller's surplus from competition in the lending market between the bank and the platform is equal to $(s - \lambda_P)\theta$. While he reaps this benefit when the separating contract is used, equation (19) implies that the bank can recoup all of it through the interest rate on the first loan. By contrast, there is no competition in the lending market under the pooling contract, but H-sellers enjoy a lower interest rate. These two effects exactly offset each other. Hence, the seller's payoff is not affected by the contract type, and it is given by

$$
\begin{aligned}
S^C_{ON-T} &= q\left[p_H - r_u + \lambda_P\theta\right] + (1-q)\left[p_L - r_u\right] \\
&= q\left[p_H - r_H + s\theta\right] + (1-q)\left[p_L - r_L\right] \\
&= \underbrace{\lambda\left[(1-\sigma)u + \sigma\lambda\right] + q\left[(1-\sigma)(u_H - u) - \sigma(\theta - 1)\right]}_{=S_{ON-CBDC}} + q\lambda_P\theta \quad (23)
\end{aligned}
$$

While the type of lending contract for the first loan does not affect the seller's payoff, it determines the way profits are allocated between the bank and the platform. When the separating contract is used, there is perfect competition for the second loan, and the platform makes zero profits and the entire surplus goes to the bank. By contrast, if the pooling contract is used because separation is infeasible, the platform becomes a monopolist lender for the continuation loan and makes positive profits.

Finally, 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 uses a separating contract, and the seller's payoff is given by

$$
S^C_{ON-CBDC} = S_{ON-CBDC} \quad (24)
$$

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Comparing equations (17), (23), and (24), we directly see that sellers will always prefer to use tokens over CBDC or deposits. Intuitively, CBDC prevents competition in the lending market by ensuring that the platform remains uninformed. By contrast, tokens enable competition, since the bank can also acquire information through the use of a separating contract. We then can thus conclude the following.

Proposition 3. *(Equilibrium with a digital platform)*
1. For $\sigma(1-\lambda) \geq q(1-q)$, banks offer the partially pooling contract of the OFF-C scheme. In this case, sellers always distribute their goods online.
2. For $\sigma(1-\lambda) < q(1-q)$, banks offer the separating contract of the OFF-C scheme. In this case, sellers distribute their goods online if $q(1-q)(1-\sigma)(u_H-u) \geq (1-\lambda)\sigma(\theta-1) - q\lambda_P\theta$, and offline otherwise.
3. All online sales are settled in tokens even when a CBDC is available.

Figure 4 shows the equilibrium map in the (λ, q)-space when sellers can use the platform's tokens. We see that the availability of tokens expands the use of the online sales through the platform relative to CBDC, which arises from competition in the lending market.
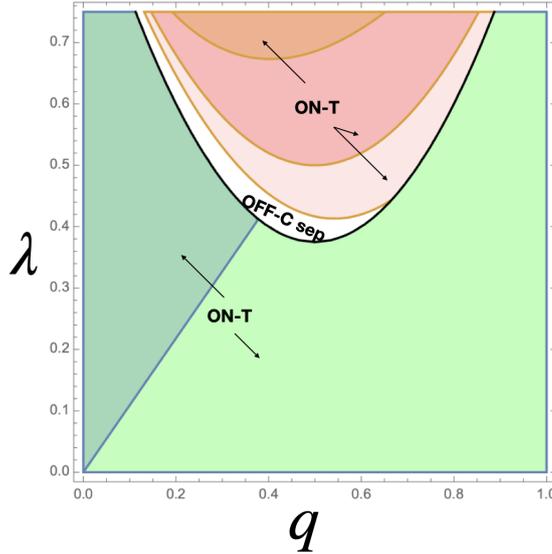

Figure 4: Equilibrium map in (λ, q)-space

5.2 Platform innovation

Digital platforms are often blamed for anticompetitive 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 such a setting, 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 surplus $\hat{\theta} > \theta$. 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 come in operation 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 - 4 to reflect the extended setup.

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

Assumption 2′. $(1 - \sigma)(u_H - u) > \sigma(\tilde{\theta} - 1)$.

Assumption 3′. $(1 - \sigma)u + \sigma\lambda > \tilde{\theta}$

Assumption 4′. $e \geq q\lambda\tilde{\theta}$.

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

As before, the incumbent platform only learns the seller's type if he uses its token as means of payment at $t = 1$. In the Appendix, we consider the case where the platform also learns from observing the sales it intermediates. As long as tokens provide sufficient incremental information, our results are unchanged.

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,

$$S_{ON-T}^{PC} = S_{ON-T}^{C} \qquad (25)$$

Now suppose instead that the seller uses deposits. This implies that he learns about the new platform, and H-sellers generate continuation surplus $\tilde{\theta}$ in expectation. Therefore, the price in (H, H) meetings, denoted by $\hat{p}_H$, now reflects the increased expected productivity $\tilde{\theta}$, and is thus given by

$$\hat{p}_H = (1 - \sigma)u_H + \sigma\lambda - \sigma(\tilde{\theta} - 1)$$

By contrast, the price p_L from equation (1) continues to prevail in (L, L) meetings. Since none of the two platforms know the seller's type, the bank is a monopolist. Accounting for the increased productivity, the sellers' payoff using deposits is

$$S_{ON-D}^{PC} = \lambda\left[(1 - \sigma)u + \sigma\lambda\right] + q\lambda\left[(1 - \sigma)(u_H - u) - \sigma\left(\tilde{\theta} - 1\right)\right] + q\lambda\tilde{\theta} - e.$$

Finally, suppose that the seller uses CBDC. In this case, neither the bank nor the platform learn the seller's type, but the seller learns about the emergence of the new platform. Accordingly, the payoff under CBDC is

$$S_{ON-CBDC}^{PC} = \lambda\left[(1 - \sigma)u + \sigma\lambda\right] + q\left[(1 - \sigma)(u_H - u) - \sigma\left(\tilde{\theta} - 1\right)\right]$$

It directly follows from Assumption 4′ that $S_{ON-CBDC}^{PC} > S_{ON-D}^{PC}$ and deposits are thus never used. Moreover, direct calculations reveal that $S_{ON-T}^{PC} > S_{ON-CBDC}^{PC}$, 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 Proposition 3. All online sales take place on the incumbent platform and are settled with tokens.

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

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 where the bank competes with a digital platform for the continuation loan. Then, we additionally 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

$$p_H - r_H + s\theta \geq p_H - r_L + s\theta$$
$$p_L - r_L \geq p_L - r_H + \lambda$$

which implies $r_L \geq r_H \geq r_L + \lambda$, a contradiction. Hence a separating contract is not feasible, and the bank can only offer a pooling contract with the interest rate r_u given by equation (21). Therefore, seller's ex-ante expected payoff is given by

$$\begin{aligned}
S^C_{ON-CBDC^*} &= q[p_H + s\theta] + (1-q)p_L - r_u \\
&= \lambda\left[(1-\sigma)u + \sigma\lambda\right] + q\left[(1-\sigma)(u_H - u) - \sigma(\theta - 1)\right] + q(\theta - 1)
\end{aligned}$$
(26)

Recall that $s\theta = (\theta - 1)$ and $s > \lambda_p$. Accordingly, comparison with equation (25) reveals that $S^C_{ON-CBDC^*} > S^C_{ON-T}$. We then 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 in 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 and sales prices are given by $\hat{p}_H$ and p_L. Since H-sellers can reveal their type after repayment of the first loan, only a pooling contract is feasible, and Assumption 2' implies that $\hat{p}_H > p_L$, so that $r_u = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right]$. The

seller's expected payoff under CBDC with data sharing is then equal to

$$
\begin{aligned}
S^{PC}_{ON-CBDC^*} &= q\hat{p}_H + (1-q)p_L - r_u + q(\tilde{\theta} - 1) \\
&= \lambda[(1-\sigma)u + \sigma\lambda] + q\left[(1-\sigma)(u_H - u) - \sigma\left(\tilde{\theta} - 1\right)\right] + q(\tilde{\theta} - 1) \\
&= S^{PC}_{ON-CBDC} + q(\tilde{\theta} - 1) \qquad (27) \\
&= S^{C}_{ON-CBDC^*} + q(1-\sigma)(\tilde{\theta} - \theta). \qquad (28)
\end{aligned}
$$

The last term in equation (27), $q(\tilde{\theta} - 1)$, 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 $q(1-\sigma)(\tilde{\theta} - \theta)$ in (28) 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 onlines sales are settled in CBDC.

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 payment objects may in principle also provide such functionalities, incentives for the monopolization of data access may be too strong. However, absent data-sharing, private payments 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.

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A Proofs

A.1 Proof of Lemma 1

Since there are only two types of matches with online sales, the bank's choice is limited to a separating and a pooling contract. The separating contract with CBDC has to satisfy the following two ICs

$$
\begin{aligned}
p_H - r_H + \lambda\theta &\geq p_H - r_L \\
p_L - r_L &\geq p_L - r_H + \lambda,
\end{aligned}
$$

which together with profit-maximization yields

$$
r_L = r_H - \lambda\theta
$$

The two PCs read

$$
\begin{aligned}
(1-\lambda)p_H &\geq r_L \\
(1-\lambda)p_L &\geq r_L
\end{aligned}
$$

Since $p_H > p_L$, only the PC for L-sellers binds, so that

$$
r_L = (1-\lambda)\left[(1-\sigma)u + \sigma\lambda\right].
$$

The bankers' expected payoff with the separating CBDC contract is

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

Next, consider the pooling equilibrium. Since, $p_H > p_L$, the pooling rate is

$$
r_u = (1-\lambda)\left[(1-\sigma)u + \sigma\lambda\right],
$$

and the banker's payoff is

$$B_{ON-CBDC}^{pooling} = (1 - \lambda)\left[(1 - \sigma)u + \sigma\lambda\right] - 1.$$

Since $B_{ON-CBDC}^{separating} > B_{ON-CBDC}^{pooling}$, the bank will use the separating contract when sellers select the ON-CBDC trading scheme.

B   Additional results

B.1   Commitment to punish upon default

We have assumed that the bank cannot commit to punish the seller if he defaults on the loan. While this is in line with the bank also not being able to commit to the loan terms, we here consider the alternative case where the bank *can* commit to such a punishment. To keep matters simple, we drop the assumption that absconding under deposits generates an additional fixed cost of e.

If the bank can commit to not extending a loan upon default, H-sellers must repay their loan in the case deposits are used. Consider the OFF-D trading scheme. The PCs become

$$
\begin{aligned}
p_H - r_H^d + \lambda\theta &\geq \lambda p_H \\
p_h - r_h^d + \lambda\theta &\geq \lambda p_h \\
p_L - r_L^d &\geq \lambda p_L,
\end{aligned}
$$

which can be solved for the interest rates

$$
\begin{aligned}
r_H^d &= (1 - \lambda)\left\{(1 - \sigma)u_H + \sigma\lambda - \sigma(\theta - 1)\right\} + \lambda\theta & (29) \\
r_h^d &= (1 - \lambda)\left\{(1 - \sigma)u + \sigma\lambda - \sigma(\theta - 1)\right\} + \lambda\theta \\
r_L^d &= (1 - \lambda)\left\{(1 - \sigma)u + \sigma\lambda\right\} & (30)
\end{aligned}
$$

Following exactly the same logic, interest rates for the ON-D scheme are given by (29) and (30). Straightforward computations then show that sellers' expected profit from both schemes is given by

$$S_{OFF-D} = \lambda[(1 - \sigma)u + \sigma\lambda] + q^2\lambda(1 - \sigma)(u_H - u) - q\lambda\sigma(\theta - 1)$$

and

$$S_{ON-D} = \lambda[(1 - \sigma)u + \sigma\lambda] + q\lambda[(1 - \sigma)(u_H - u) - \sigma(\theta - 1)]$$

Since the ability to commit does not affect payoffs when sales are settled in cash (in case of default the bank learns nothing, and thus does not lend), they are still given by equations (13) and (14) in the main text. It can be seen readily that $min\{S_{OFF-D}^{separating}, S_{OFF-C}^{partpooling}\} > S_{OFF-D}$, so deposits are never used to settle offline sales. We then obtain the following result, which corresponds to Proposition 1 for the case where $e = q\lambda\theta$.

Proposition 7. (Equilibrium with commitment to punish upon default)
1. For $\sigma(1 - \lambda) \geq q(1 - q)$, banks offer a partially pooling contract under the OFF-C scheme. In this case, sellers distribute their goods online if $\lambda \geq q$, and offline otherwise.
2. For $\sigma(1 - \lambda) < q(1 - q)$, banks offer a separating contract under the OFF-C scheme. In this case, sellers distribute their goods online if $q(\lambda - q)(1 - \sigma)(u_H - u) \geq (1 - q)(1 - \lambda)\sigma(\theta - 1)$, and offline otherwise.
3. All online sales are settled in deposits (by assumption).

B.2 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 ξ, while it remains uninformed with probability $1 - \xi$ (so the main text corresponds to $\xi = 0$). Moreover, to simplify the exposition, we also assume that the bank observes whether the platform

has received a signal or not.[16]

B.2.1 Lending market competition

Suppose that sellers opt for CBDC. If the bank chooses to become informed through a separating contract, it will compete with the platform with probability ξ, and otherwise act as a monopolist. Accordingly, this allows H sellers to reap an expected surplus of $s^*\theta$, where $s^* = \xi s + (1-\xi)\lambda < s$. The separating contract thus has to satisfy the following ICs

$$p_H - r_H + s^*\theta \geq p_H - r_L + \xi\lambda_p\theta$$
$$p_L - r_L+ \geq p_L - r_H + \lambda,$$

This implies

$$(s^* - \xi\lambda_p)\theta \geq r_H - r_L \geq \lambda$$

Moreover, L-sellers' PC yields

$$r_L = (1-\lambda)[(1-\sigma)u + \lambda\sigma]$$

We henceforth assume that $(s^* - \xi\lambda_p)\theta > \lambda$, so a separating contract is feasible.[17] Profit-maximization by the bank then implies

$$r_H = r_L + (s^* - \xi\lambda_p)\theta$$

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

---

[16]If the bank does not know whether she faces an informed or uninformed competitor in the lending market, solving for the equilibrium would be considerably more complex.

[17]The analysis for the case when the separating contract is not feasible is slightly more tedious, and available upon request. It does not deliver any further insights, since sufficiently low values of ξ lead to the same conclusions.

continuation surplus. Sellers' payoff is given by

$$S^{C*}_{CBDC-ON} = \lambda[(1-\sigma)u + \lambda\sigma] + q[(1-\sigma)(u_H - u) - \sigma(\theta-1)] + q\xi\lambda_p\theta$$

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 $(\xi\lambda_p\theta)$ is appropriated by the bank. Notice that we have $S^{C*}_{CBDC-ON} = S_{CBDC}$ as $\xi = 0$, which corresponds to the main text. As $\xi \to 1$, the informational value of tokens diminishes, so $S^{C*}_{CBDC-ON} \to S^C_{ON-T}$.

Notice that $S^{C*}_{ON-T} = S^C_{ON-T}$, i.e. the platform is perfectly informed when tokens are used independently of what the platform knows without. Accordingly, sellers prefer tokens to CBDC whenever $\xi < 1$.

Finally, 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

$$S^{C*}_{ON-D} = \lambda[(1-\sigma)u + \sigma\lambda] + q\lambda[(1-\sigma)(u_H - u) - \sigma(\theta-1)] - (e - qs^*\theta)$$

and so sellers would prefer tokens over deposits whenever

$$q(1-\lambda)[(1-\sigma)(u_H - u) - \sigma(\theta-1)] > q(s^* - \lambda_p)\theta - e.$$

Note that the LHS is always positive, so a sufficient condition the above inequality to hold is that the RHS is non-negative. Since $e \geq q\lambda\theta$ by assumption, this is always the case for

$$\frac{\lambda_P}{s - \lambda} \geq \xi. \tag{31}$$

B.2.2 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 $S_{ON-T}^{PC*} = S_{ON-T}^{C*} = S_{ON-T}^{C}$.

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, we get

$$S_{ON-CBDC}^{PC*} = \lambda\left[(1-\sigma)u + \sigma\lambda\right] + q\left[(1-\sigma)(u_H - u) - \sigma\left(\tilde{\theta} - 1\right)\right] + q\xi\lambda_P\tilde{\theta},$$

Sellers thus prefer tokens to CBDC whenever $S_{ON-T}^{PC*} > S_{ON-CBDC}^{PC}$, or

$$(\sigma - \lambda_P\xi)\pi\hat{\theta} + \lambda_P\theta(1 - \xi(1 - \pi)) > 0$$

Since the second term is always positive, a sufficient condition for the inequality to hold is

$$\frac{\sigma}{\lambda_P} \geq \xi. \tag{32}$$

The use of deposits also enable sellers to learn about the entrant. Sellers obtain

$$S_{ON-D}^{PC} = \lambda\left[(1-\sigma)u + \sigma\lambda\right] + q\lambda\left[(1-\sigma)(u_H - u) - \sigma\left(\tilde{\theta} - 1\right)\right] - (e - q\tilde{s}^*\tilde{\theta})$$

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

$$q(1-\lambda)[(1-\sigma)(u_H - u) - \sigma(\theta - 1)] + q\sigma\lambda[\tilde{\theta} - \theta]$$
$$> q(\tilde{s}^*\tilde{\theta} - \lambda_P\theta) - e$$

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 $(\lambda_P + \lambda)\theta \geq \tilde{s}^*\tilde{\theta}$, or

$$\frac{\lambda_p\theta - \lambda(\tilde{\theta} - \theta)}{(\tilde{s} - \lambda)\tilde{\theta}} \geq \xi. \tag{33}$$

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.

B.3   Low adverse selection

In this section, we analyze the case where adverse selection is low and uninformed lending is profitable. Formally, this corresponds to $q(1 - \lambda)\theta > 1$. We have to consider the following cases.

1. The bank uses a pooling contract and lends to all sellers at $t = 2$.

2. The bank uses a partially pooling contract that separates H-sellers in (H,H)-meetings, but pools L sellers and H sellers in (H,L)-meetings, and only lends to the first set of H-sellers.[18]

3. The bank uses a separating contract and only lends to all H-sellers at $t = 2$.

Note that the first contract differs from the pooling contract in the main text, since it is now profitable to lend to all sellers when using a pooling contract. The remaining two contracts are identical to the ones studied in the main text. Accordingly, the banks' payoffs are given by equations 8) and (7), respectively.

Pooling contract with lending to all sellers at $t = 2$. When the bank

---

[18]Notice that lending to all sellers would violate incentive compatibility. H-Sellers in (H,H)-meetings would want to pretend to be H-sellers in (H,L)-meetings and enjoy a lower interest rate, but still receive continuation financing.

lends to all sellers at $t = 2$, bilateral prices are given by

$$p(m) = \begin{cases} p_H \equiv (1 - \sigma)u_H + \sigma\lambda - \sigma\,(\theta - 1) \\[2mm] p_h \equiv (1 - \sigma)u + \sigma\lambda - \sigma\,(\theta - 1) \\[2mm] p_L \equiv (1 - \sigma)u - \sigma \end{cases}$$

Here, p_L now accounts for the fact that L-sellers will generate a payoff of $\lambda - 1 < 0$ for the bank/seller coalition (sellers will get a loan of 1 but abscond to obtain λ). Note that

$$p_h - p_L = \sigma\,[1 + \lambda - (\theta - 1)]$$

which can be positiv or negative. We thus have two cases to analyze, in which either the PC of h-sellers binds (for $1 + \lambda < \theta - 1$) or the one of L-sellers binds (for $1 + \lambda > \theta - 1$).

First, suppose $min(p_L, p_H) > p_h$, so the PC of h-sellers will bind. The pooling rate is

$$r_u(h) = (1 - \lambda)p_h = (1 - \lambda)[(1 - \sigma)u + \sigma\lambda - \sigma\,(\theta - 1)]$$

and bank profits are

$$\begin{aligned} B_h^* &= r_u(h) - 1 + [q\theta(1 - \lambda) - 1] \\ &= (1 - \lambda)[(1 - \sigma)u + \sigma\lambda)] + (q - \sigma)(1 - \lambda)\,(\theta - 1) - (1 - q(1 - \lambda)) - 1 \quad (34) \end{aligned}$$

Next, suppose $min(p_h, p_H) > p_L$, so that the PC of L-sellers binds. Then the pooling rate is

$$r_u(L) = (1 - \lambda)p_L = (1 - \lambda)[(1 - \sigma)u - \sigma]$$

and bank profits are

$$\begin{aligned} B_L^* &= r_u(L) - 1 + [q\theta(1 - \lambda) - 1] \\ &= (1 - \lambda)[(1 - \sigma)u + \sigma\lambda] + (1 - \lambda)\,[q\theta - \sigma(1 + \lambda)] - 1 - 1. \quad (35) \end{aligned}$$

Banks' contract choice. Recall that the choice between separating and partially pooling contracts is governed by inequality (9). Straightforward algebra reveals that

$$B_h^* - B_{OFF-C}^{partpool} = (\theta - 1)\left[(q(1-q) - \sigma(1-\lambda) - q\lambda\right] - (1 - q(1-\lambda)) < 0$$

where the inequality follows from the fact that $1 - q(1-\lambda) > 0$ and $q(1-q) \leq \sigma(1-\lambda)$ in any equilibrium with partial pooling. Moreover, we have

$$B_h^* - B_{OFF-C}^{separating} = (\theta - 1)\left[q(1-\lambda) - q\right] - (1 - q(1-\lambda)) < 0.$$

Together, this implies that We thus have $min\{B_{OFF-C}^{separating}, B_{OFF-C}^{partpool}\} > B_h^*$, and banks never lends to all sellers in equilibrium when the IC of h-sellers binds.

Now, consider the case where L-sellers' PC binds, so that $1 + \lambda > \theta - 1$. Direct calculations reveal

$$B_L^* - B_{OFF-C}^{separating} = -\lambda q\theta - \sigma(1-\lambda)\left[(1+\lambda) - (\theta - 1)\right] - 1 + q < 0$$

and

$$\begin{aligned} B_L^* - B_{OFF-C}^{partpool} &= (1 - \lambda)\left[q\theta - \sigma(1+\lambda)\right] - 1 - 1 - q^2[\theta - 1] + 1 \\ &= (-\lambda q\theta + q - 1) + \left[q(1-q) - (1-\lambda)\sigma\right][\theta - 1] \\ &\quad + (1-\lambda)\sigma[\theta - 1 - (1+\lambda)] < 0 \end{aligned}$$

The second inequality is established as follows. The first term is obviously negative, the second term is negative because we must have $(1 - \lambda)\sigma \geq q(1-q)$ whenever the bank uses a partially pooling contract, and the third term is negative because the incentive constraint of L-sellers only binds for $1 + \lambda > \theta - 1$. Thus, $min\{B_{OFF-C}^{separating}, B_{OFF-C}^{partpool}\} > B_L^*$, and banks never lend to all sellers when L-sellers PC is binding.

To conclude, pooling is never optimal even if adverse selection is sufficiently

low to render uninformed lending profitable. Intuitively, separation (either full or partial) allows banks reduce future losses from inefficient investment by L-sellers, and thus leads to higher bank profits.

C   Micro-foundations for payments

In this section, we sketch the setup of a model with micro-foundations for payments, in the spirit of the new-monetarist literature. Time is discrete and continues forever. Each period has 4 subperiods ($s = 0, 1, 2, 3$ as in the model). There is a continuum of buyers, sellers, banks, and a platform. Buyers are infinitely lived, while sellers, bankers and the platform live for one period. There are two types of sellers and buyers, H and L. Taking the viewpoint of sellers, we refer to subperiods 0 (1) and 2 (3) as the first and second investment (production) stage.

There are two goods: goods that buyers can produce (B-goods) and goods that sellers can produce (S-goods). Buyers produce B-goods in the two investment stages, while sellers produce S-goods in the two production stages. Goods are not storable, once produced they have to be consumed.

Buyers produce B-goods at will by incurring a linear cost of production. Sellers need to invest one unit of the B-good in the first investment stage to produce 1 unit of the S-good in the first production stage, and H sellers need to invest one unit of the B-good in the second investment stage to produce 1 unit of the S-good in the second production stage. L-sellers cannot produce in the second production stage. All agents derive a linear utility from consuming B-goods. In the first production stage, buyers of type i derive utility u_{ij} from consuming one unit of the S-good produced by a seller of type j. We set $u_{HH} \equiv u_H$ and $u_{ij} \equiv u < u_H$ for all $ij \neq HH$. Buyers of any type derive one util from consuming one unit of the S-good produced in the second production stage.

The utility of buyers of type i when they produce y_s units of B-goods in subperiod $s = 0, 2$, consume x_s units of B goods in subperiod $s = 0, 2$ and consume

$c_{1j} \in \{0,1\}$ units of the S-good in the first production stage produced by seller j and c_3 units in the second production stage is

$$U_i(y_0, x_0, c_{1j}, y_2, x_2, c_3) = x_0 - y_0 + \sum_j c_{1j} u_{ij} + x_1 - y_1 + c_3, \qquad (36)$$

where we removed the index j in c_3 as it is inconsequential.

The utility of sellers of type j when they invest $y_s \in \{0,1\}$ units of the B-good in subperiod $s = 0, 2$, consume x_s units of B-good in subperiod $s = 0, 2$, and consume c_s units of the S-good in subperiod $s = 1, 3$ is

$$V_j(y_0, x_0, c_1, y_2, x_2, c_3) = x_0 + x_2 + \lambda(c_1 + c_3) \qquad (37)$$

with $\lambda < 1$ (alternatively, sellers face a liquidation cost when consuming their production). Notice that investment and productionis costless for sellers. Finally, banks and platform owners have the same utility as sellers, but with $\lambda = 1$.

Sellers and buyers don't trust each other, so sellers (buyers) need a means of payment to buy B-goods (S-goods). Banks and the platform are trustworthy and can issue IOUs (bank deposits and tokens respectively). A bank deposit or a token issued in the investment stage is a promise to one unit of the B-good in the next production stage. There is also cash (and CBDC) provided by the monetary authority. The stock of cash (and CBDC) in period t is M_t and the monetary authority runs the Friedman rule. The timing within each period is as follows.

First investment stage ($s = 0$). Buyers acquire cash/bank deposits/tokens, banks acquire B-goods, sellers get investment from banks and invest directly (so they cannot consume the B-good that is supposed to be invested).

First production stage ($s = 1$). Sellers choose trading venue, buyers follow (possibly exchanging cash for deposits/tokens). Sellers' learn their types, trade (production and consumption) occurs through bargaining and payment is exchanged.

Second investment stage ($s = 2$). Sellers buy B-goods with acquired means of payment, consume/repay loans. Sellers can only run away with a fraction λ of their sales. Banks/platform settle claims on deposits/tokens previously issued. Buyers acquire cash/means of payment with cash. Bank/platform lends to H-sellers.

Second production stage ($s = 3$). H-sellers produce θ units of the S-good, and they sell their goods for an equivalent of θ to buyers (their reservation price), deposits or tokens are exchanged. Sellers repay their loans or run away with a fraction λ of their sales. Sellers, banks, and the platform consume and are replaced by a new cohort of sellers, banks and platform.[19]

Buyers' problem

Let z_0, d_0, e_0 and τ_0 be the real amounts (as measured in terms of G-goods) of cash (z_0), bank deposits (d_0), CBDC (e_0) and tokens (τ_0), that buyers demand in the first investment stage. The problem of buyers is

$$V_0(m_0) = \max_{y_0, x_0, z_0, d_0, e_0, \tau_0} -y_0 + x_0 + E_v V_1^v(z_0, d_0, e_0, \tau_0)$$

$$\text{s.t. } y_0 + m_0 = x_0 + z_0 + d_0 + e_0 + \tau_0$$

where the expectations operator is taken over sellers' choice of trading venue, which buyers perfectly anticipate in equilibrium. Substituting the budget constraint,

$$\begin{aligned} V_0(m_0) &= \max_{z_0, d_0, e_0, \tau_0} m_0 - (z_0 + d_0 + e_0 + \tau_0) + E_v V_1^v(z_0, d_0, e_0, \tau_0) \\ &= m_0 + V_0(0) \end{aligned}$$

and V_0 is quasilinear as in Lagos and Wright (2001).

Given sellers' choice of trading venue of ($v = z, d, e, \tau$ where we abuse nota-

---

[19]Alternatively, one can assume that sellers change type each period, and that banks and platforms distribute their equity at the end of each period

tion and use $v = z$ to denote offline-cash, d to denote online-deposit, etc.), buyers solve

$$V_1^v(z_0, d_0, e_0, \tau_0) = \max_{c_{1j} \in \{0,1\}} E_J \{ c_{1j} u_{ij} + V_2(m_2) \}$$

$$\text{s.t. } pc_{1j} \leq v_0 \tag{38}$$

$$m_2 = z_0 + d_0 + e_0 + \tau_0 - pc_{1j}$$

where E_J is the expectation over meeting seller of type $j \in J$. In the second investment stage, only the total real value of the portfolio of payment instruments matters, so we can use m_2 as the state variable (the budget constraint ensures this amount is positive). p solves the bargaining problem (solve after we have defined the problem of sellers).

The value for buyers of entering the second investment stage with a portfolio of payment instruments worth m_2 is

$$V_2(m_2) = \max_{y_2, x_2, z_2, d_2, e_2, \tau_2} -y_2 + x_2 + V_3(z_2, d_2, e_2, \tau_2)$$

$$\text{s.t. } y_2 + m_2 = x_2 + (z_2 + d_2 + e_2 + \tau_2)$$

Notice that in the second investment stage, buyers redeem their portfolio and so they can get the equivalent in B-goods (or carry over the balance to the second production stage). Hence

$$V_2(m_2) = \max_{z_3, d_3, e_3, \tau_3} m_2 - (z_2 + d_2 + e_2 + \tau_2) + V_3(z_2, d_2, e_2, \tau_2)$$

Finally,

$$
\begin{aligned}
V_3(z_2, d_2, e_2, \tau_2) &= \max_{c_3} c_3 + \beta V_0((z_2 + d_2 + e_2 + \tau_2 - c_3 p_3)(1 + \rho)) \\
&= \max_{c_3} c_3 (1 - p_3) + \beta V_0((z_2 + d_2 + e_2 + \tau_2)(1 + \rho)) \\
&= \max_{c_3} c_3 (1 - p_3) + (z_2 + d_2 + e_2 + \tau_2) + \beta V_0(0)
\end{aligned}
$$

subject to

$$p_3 c_3 \leq z_2 + d_2 + e_2 + \tau_2$$

where p_3 is the price at $s = 3$. We have used the fact that the monetary authority implements the Friedman rule, so that the real rate of return is $1 + \rho = 1/\beta$, sobuyers have no cost of holding any means of payment and their budget constraint (38) never binds. Also, replacing the expression for V_3 into the expression for V_2, we can write

$$V_2(m_2) = m_2 + \max_{c_3, z_2, d_2, e_2, \tau_2} c_3 (1 - p_3) + \beta V_0(0)$$

$$\text{s.t. } p_3 c_3 \leq z_2 + d_2 + e_2 + \tau_2.$$

Since buyers are never constrained (thanks to the Friedman rule), we must have $p_3 = 1$. Otherwise, buyers would demand an infinite quantity of the S-good and the market would not clear.

Sellers' problem

Sellers are born at the start of each period with no endowment but only with their production technology. Their utility in the first investment stage is

$$W_0 = \max_{y \in \{0,1\}, v \in \{z,d,e,\tau\}} E_J W_{1,j}^v(y)$$

where v is the choice of trading venue, $y \in \{0, 1\}$ is the amount borrowed from the bank, and E is the expectation over types. Then, a seller of type $j = H, L$ has the following payoff

$$
\begin{aligned}
W_{1,j}^v(0) &= 0 \qquad \text{for all } v \\
W_{1,j}^v(1) &= \max\{E_i W_{2,j}(p_{ij}); \lambda\}
\end{aligned}
$$

since sellers can always consume production to obtain utility λ, and p_{ij} is the price between buyer i and seller j for one unit of production. Finally,

$$W_{2,j}(p_{ij}) = \max_{\hat{p} \le r(p_{ij})} p_{ij} - r(\hat{p}) + y_2(\hat{p})W_{3,j}$$

where $\hat{p}$ is the announcement of seller to the bank. The bank refinances sellers with probability $y_2(\hat{p})$ in which case they get $W_{3,j}$, where

$$
\begin{aligned}
W_{3,L} &= \lambda \\
W_{3,H} &= \max\{\theta p_3 - i, \lambda\theta\} = \max\{\theta - i, \lambda\theta\}
\end{aligned}
$$

so that H sellers produce θ, and either sell it at price $p_3 = 1$ to repay their debt i or consume it for utility $\lambda\theta$.

Banks' problem

Each bank is matched with one seller and issues deposits d_0^B to buyers in $t = 0$ to maximize

$$\max_{d_0^B, y_2 \in \{0,1\}} E[(d_0^B - 1) + r(\hat{p}) - d_0^B + y_2(\hat{p})W^B(\hat{p})]$$

$$\text{s.t. } d_0^B \ge 1$$

The bank issues $d_0^B \ge 1$ deposits in the first investment stage, it invests 1 with the seller and consumes $d_0^B - 1$ (B-goods are not storable). After the first production stage, the seller repays $r(\hat{p}_{ij})$ and the bank redeems deposits. Given the information it obtains, the bank refinances the seller in the second investment stage or not, so that

$$W^B(\hat{p}) = \max_{d_2^B} \left(d_2^B - y_2(\hat{p})\right) + \mathbb{I}_{\text{info } \hat{p} = H} i(\theta) - d_2^B,$$

If the bank knows the seller is L, the bank chooses $y_2(\hat{p}) = 0$ and $d_2^B = 0$.

Bargaining between buyers and sellers

We can now solve for the bargaining problem. Sellers maximizing the surplus of the seller/bank coalition, which is

$$p_{ij} - r(\hat{p}) + y_2(\hat{p})W_3^j + r(\hat{p}) - d_0 + y_2(\hat{p})W^B(\hat{p}) =$$

$$p_{ij} + y_2(\hat{p})\left(W_3^j + W^B(\hat{p})\right) - d_0 =$$

$$\begin{cases} p_{ij} - d_0 & \text{if } \hat{p} \Longrightarrow \text{L seller or no info} \\ p_{ij} - d_0 + \theta - 1 & \text{if } \hat{p} \Longrightarrow \text{H seller} \end{cases}$$

and the "outside option" is $\lambda - d_0$. Therefore, the bargaining between buyers and sellers is

$$\max_{p_{ij}} \left[u_{ij} + V_2(z + d + e + \tau - p_{ij}) - V_2(z + d + e + \tau)\right]^\sigma \left[p_{ij} - d_0 + \mathbb{I}_{\text{info=H}}(\theta - 1) - (\lambda - d_0)\right]^{1-\sigma}$$

which simplifies to

$$\max_{p_{ij}} \left[u_{ij} - p_{ij}\right]^\sigma \left[p_{ij} - \lambda + \mathbb{I}_{\text{info=H}}(\theta - 1)\right]^{1-\sigma}$$

due to the linearity of V_2, and is thus the same solution as in the paper.

The platform's problem

The platform can issue tokens in the first investment stage (but it cannot fund sellers at that stage). The problem of the platform is

$$\max_{\tau_0^P, z_0^P} \tau_0^P - z_0^P + E_J V^P(z_0^P, \tau_0^P; p_j)$$

$$\text{s.t. } z_0^P \leq \tau_0^P,$$

where E_J is the expectation over sellers' types when trading at price p_j. The constraint reflects the fact that the platform can save the profit from selling its

tokens with cash.

In the second investment stage, the platform redeems its tokens and decides whether to fund a seller (given it observed the price p_j),

$$V^P(z_0^P, \tau_0^P; p(j)) = z_0^P - \tau_0^P + \max_{\tau_2^P, y_2^P \in \{0,1\}} \left(\tau_2^P - y_2^P\right) + y_2^P i(\theta) - \tau_2^P,$$

If the platform knows the seller is of type L, it chooses $y_2^P = 0$ and $\tau_2^P = 0$.

Market clearing

The markets payment means must clear at each stage of each period. We assume CBDC is purchased with cash. Notice that at the start of the first investment stage, buyers are holding the stock of cash and possibly CBDC. In the first investment stage, market clearing is

$$
\begin{aligned}
d_0 &= d_0^B \\
\tau_0 &= \tau_0^P \\
z_0 + e_0 + z_0^P &= \phi M = (z_2(t-1) + e_2(t-1))\frac{1}{\beta}
\end{aligned}
$$

where ϕ is the real value of money and M is the nominal stock of money, and e is the demand for CBDC. In the second investment stage, market clearing is

$$
\begin{aligned}
d_2 &= d_2^B \\
\tau_2 &= \tau_2^P \\
z_2 + e_2 &= z_0 + e_0 + z_0^P
\end{aligned}
$$

Here, only buyers demand cash, while buyers and the platform bring cash to the market. Because all payment instruments have the same rate of return (independent of their payment service), and thanks to the Friedman rule, all agents are indifferent as to which instrument they hold. Therefore, in this setup all the

analysis in the main text goes through.