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Payments and privacy in the digital economy

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Abstract

We propose a model of financial intermediation, payments choice, and privacy in the digital economy. While digital payments enable merchants to sell goods online, they reveal information to their lender. 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). Privacy-preserving digital payments raise welfare by reducing privacy concerns, but only arrangements that enable data-sharing through consent functionalities guarantee that the social optimum is attained.

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

JEL Codes: D82, E42, E58, G21.

Non-technical summary

The rise of the digital economy has profound implications for the economics of payments. As more goods and services are sold online, physical currency ("cash") is becoming impractical as means of payment for a growing share of economic activity. While digital payments promise increased speed and convenience, the resulting abundance of data gives rise to privacy concerns.

Traditionally, digital payments were the domain of banks as provider of both payment means ("commercial bank money") and payment rails (clearing and settlement systems). However, their dominance is increasingly challenged by competition from non-banks (e.g. payment service providers and large technology firms), who are interested in payments, and in the underlying data. At the same time, technological innovations (e.g. blockchain) and initiatives towards the introduction of central bank digital currency (CBDC) highlight the potential for digital payments with high levels of privacy.

This paper aims to inform this debate by developing a stylized model of financial intermediation to analyze the interconnections of payments and privacy in the context of the digital economy. In the model, merchants raise funds from a lender to finance sales. They can distribute their goods online or offline. Online sales generate a higher revenue, but they must be settled with digital payment means that leave a data trace observable to the merchant's bank. By contrast, offline sales generate low revenues, but do not generate any data.

The bank's ability to observe payment flows enables her to tailor the loan terms accordingly, extracting rents. This creates the following trade-off for merchants. If they sell online, they reap high sales but must cede a large part of their profits to the bank. If they stay offline, their sales are lower, but the bank must elicit (some of) the missing information by offering more favorable loan terms. The latter option is socially inefficient for two reasons. First, less surplus is generated. And second, the bank does not always elicit enough information for efficient re-financing of the merchant, losing surplus associated with future production.

We then extend the model in two directions. First, we study the introduction of privacy-preserving money (or $\mathcal{P}$-money) that allows digital settlement without providing a data signal to the lender. This is inspired by the gravitation of payments data outside of the banking system, as well as a potential future role of cryptocurrencies and CBDCs. $\mathcal{P}$-money enables merchants to reap some of the efficiency gains of online distribution, and at the same time earn informational rents from remaining anonymous. This raises welfare because i) more sales are conducted online, where higher sales are realized, and ii) the lender always elicits full information, so that its re-financing choice is efficient.

Second, we study a model where users have control over the data generated by the payments they receive. Such $\mathcal{C}$-money is consistent with initiatives aimed at increasing end-user control over their data (e.g. "open banking"). In our model, $\mathcal{C}$-money enables merchants to decide whether the lender receives a signal, and at what time. In equilibrium, they choose to reveal a perfect signal, but only after the initial loan is repaid. This prevents the lender from extracting any rents on the first loan and ensure that merchants always distribute online, which is efficient.

1 Introduction

The rise of the digital economy has profound implications for the economics of payments. As more goods and services are sold online, physical currency ("cash") is becoming impractical as means of payment for a growing share of economic activity. At the same time, the speed and convenience of digital payments has increased tremendously due to the proliferation of mobile wallets and the launch of instant payment systems. Accordingly, the use of cash is declining fast.[1]

However, these developments are not without concerns, especially about market power and user privacy. Unlike cash, digital payments generate troves of data that reveal information about those making and receiving payments. Traditionally, digital payments are the domain of bank as providers of payment means ("commercial bank money") and payment rails (clearing and settlement systems). However, their dominance is increasingly challenged by competition from non-bank payment service providers (PSPs) and large technology firms ("BigTech"), who have been successful at capturing the customer front-end of digital payment solutions, and thus the data.[2] This development amplifies existing concerns that increased market power and the lack of privacy generate inefficiencies such as price discrimination and predatory pricing.[3]

However, the fact that payment providers have access to granular information is not necessarily a hard-wired characteristic of digital money, but rather a design feature that can be tailored to meet the needs of end-users. For example, even though cryptocurrencies are not widely accepted as means of payment, the underlying blockchain technology enables the decentralized settlement of digital transactions with high levels of privacy. Moreover, public digital money in the

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

[2]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. 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]For economic models with privacy concerns, see Bergemann et al. (2015), Jones and Tonetti (2020), and Ichihashi (2020), for example. Boissay et al. (2021) provide a discussion of recent developments that are specific to the interconnection of BigTech and financial services.

form of central bank digital currencies (CBDCs) could have a comparative advantage at providing privacy because it is not bound by profit-maximizing incentives. Major central banks have pledged to include privacy-preserving features, likely also in response to citizens' concerns.[4]

This paper aims to inform this debate by developing a stylized model of financial intermediation to analyze the interconnections of payments and privacy in the context of the digital economy. In our model, heterogeneous sellers require outside finance for two rounds of production. They privately learn their type (high (H) or low (L)) in the initial round of production, and only H-sellers generate a continuation payoff that merits re-financing. The monopolistic lender wants to learn sellers' type to i) extract the maximum surplus from first-round production, and ii) to avoid adverse selection on the second loan.

Sellers can distribute their goods offline (through a brick-and-mortar store) or online (over the internet). Online distribution is efficient in the sense that it generates high sales. However, online transactions must be settled with digital payment means, which leave a trace ("signal") observable to the lender. By contrast, offline sales create a relatively low surplus, but they can be settled in cash without any digital footprint. This forces the lender to elicit information through contractual terms ("screening"), enabling sellers to retain some informational rents.

The dichotomy between sales efficiency and privacy creates the following trade-off for sellers. Online distribution creates a large surplus, but the lack of privacy that arises from the need to use digital payments leaves them with a relatively small share of this surplus. By contrast, offline distribution generates less surplus, but the privacy brought about by cash guarantees that sellers can appropriate a larger share of it. If the benefits of more efficient sales outweigh the loss of informational rents associated with privacy, sellers distribute online.

While online distribution is efficient, there are two inefficiencies when sellers choose to stay offline. First, offline distribution generates a low level of sales.

[4] For example, privacy has been named as number one concern in the Eurosystem's public consultation on a digital euro (European Central Bank, 2021).

Second, the lender may find it too costly to elicit all information through contractual terms. In this case, only some, but not all H-sellers will be re-financed, and additional output is lost.

Our benchmark case of perfectly informative payment flows is inspired by traditional payments systems that are centered around bank deposits which constitute a significant source of information for banks.[5] We then extend the model to speak to recent developments that pose significant challenges to this status quo, for example through changes in the competitive landscape, the rise of new technologies, or regulation.

First, we study the equilibrium when the design of digital money includes privacy-preserving features (called $\mathcal{P}$-money). This is inspired by the gravitation of payments data outside the banking sector (via non-bank PSPs), as well as a potential future role of cryptocurrencies and CBDCs. In the context of our model, this means that the lender no longer gets a signal from payments. Then $\mathcal{P}$-money 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. This raises welfare in two ways. It increases the incentives for sellers to distribute online, and induces the lender to always elicit full information about sellers' type, so that her refinancing decisions are efficient. However, $\mathcal{P}$-money does not fully crowd out cash because the latter can generate higher informational rents for sellers under some conditions.

Second, we analyze the case where users have control over the data generated by the payments they receive. Such a design of digital payments reflects a broader notion of privacy (Hughes, 1993; Acquisti et al., 2016), and is consistent with initiatives aimed at increasing end-user control over the data they help generate, such as "open banking" regulations or infrastructure projects such as "India Stack". More precisely in our model, with this new type of money ($\mathcal{C}$-money), sellers can

[5]For example, the consultancy firm PwC argues that "payments generate roughly 90% of banks' useful customer data". See "Navigating the payments matrix–Payments 2025 & beyond", available at `https://www.pwc.com/gx/en/industries/financial-services/publications/financial-services-in-2025/payments-in-2025.html`.

decide whether the lender receives a signal, and at what time. In equilibrium, sellers choose to reveal a perfect signal after repaying the first loan, which prevents the lender from extracting any rents on the first loan and guarantees the first-best outcome in which sellers always distribute online.

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 the privacy design of digital payments.

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.[6] 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 arise from lower sales due to inefficient offline distribution.

Our paper builds on work studying the interaction of payments and lending. A large empirical literature (see, e.g., Black, 1975; Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017; Ouyang, 2023; Ghosh et al., 2024) suggests that payment flows are informative about borrower quality. Parlour et al. (2022) study a screening model where banks face competition for payment flows by FinTechs.[7] While this may improve financial inclusion, it affects lending and payment pricing by threatening the information flow to banks. Relative to their contribution, we

[6] Kang (2024) uses a similar idea, although in his set up data helps to improve the matching of goods and customers' preferences.

[7] Cheng and Izumi (2024) also study a screening problem where the choice of payment infrastructure reveals information about types.

explicitly model the link between the signal and payments data. As a result, we show that the bank may prefer a contract that does not lead to full separation, which gives rise to other types of inefficiencies. Moreover, we study a broader definition of end-user control over payments data that includes the ability to time the possible data release.

He et al. (2023) study competition between banks and Fintech in lending markets with consumer data sharing. They find that open banking can hurt borrowers when lenders have different abilities to analyze the data shared by the borrower. In this case, there is a winner's curse that can discourage participation of the lender with the worse data-analysis technology. Rather, we find that a digital payment technology with data-sharing features is unequivocally good because it enables an "informational level-playing field" among lenders, as empirically documented by Babina et al. (2024). Finally, Agur et al. (2023) study the privacy policy and data sales decisions of a "BigTech" digital payments provider. Unlike in our model, privacy is a fully exogenous cost to end-users in their setting.

Finally, our paper is related to the fast-growing literature on CBDC.[8] 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. And in Keister and Monnet (2022), real-time information from the payment system improve the efficacy of bank resolution in crisis times.

Structure. The paper proceeds as follows. We introduce the basic model with cash and deposits in Section 2, and solve for the equilibrium with digital payment in Section 3. We then introduce alternative payment arrangements in section 4, followed by a discussion of two model extensions in Section 5. Section 6 concludes. All proofs are found in Appendix A, and additional results are described

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

in the Online Appendix.

2 The basic model

There are four dates $t = 0, 1, 2, 3$ with no discounting and two sets of risk-neutral agents: a lender (she) and a continuum of sellers (he/they) with unit mass. There is a single good each period.

Sellers. Sellers can be of two types. A fraction $q \in (0, 1)$ is of high type (H-sellers) and the remaining $1 - q$ are of low type (L-sellers). L-sellers produce a good of low quality at $t = 1$ and nothing at $t = 3$. By contrast, H-sellers produce a good of high quality at $t = 1$, and output worth $\theta > 1$ at $t = 3$. Production in t requires the investment of one unit of the good in $t - 1$ that must be raised from the lender. Production is indivisible, and sellers privately learn their type at the beginning of $t = 1$.

Goods distribution. Sellers can distribute their goods via two different venues. They can either sell offline (F) via a brick-and-mortar store, or online (O) over the internet. Since their production is indivisible, they can only choose one of the two venues and they must do so at $t = 0$, i.e. before learning their type.[9]

We assume that online distribution yields a relatively high level of sales. In particular, it guarantees that H-sellers generates sales of p_H. By contrast, offline distribution is less efficient. Specifically, high-quality goods generate sales of p_H only with probability α, and are sold for $p_L < p_H$ with probability $1 - \alpha$. We refer to H-sellers with high sales p_H as HH-sellers, and H-sellers with low sales p_L as HL-sellers. For simplicity, we assume that low-quality goods generate sales of p_L independently of the distribution venue. We show how to endogenize this price

[9] We think of distribution decisions as long-term, which sellers have to make before knowing the (entire) demand for their goods. Hence, they cannot condition the trading venue on their own quality.

structure using search frictions and Nash bargaining in Section 5.2.

To make matters interesting, we assume that the payoff on the continuation project θ exceeds p_L, but at the same time is smaller than p_H.

Assumption 1. $p_H \geq \theta > p_L$.

This assumption ensures that the lender can extract the full continuation surplus from HH-sellers but not from HL-sellers. Accordingly, she faces a non-trivial choice among different types of contract menus when sellers distribute their goods offline.[10]

Payments. Offline sales can be settled with physical currency ("cash"). This is too cumbersome for online sales, which therefore must be settled via a digital means of payment. However, unlike cash, such transactions create a digital footprint. In line with existing theoretical and empirical literature (Black, 1975; Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017; Parlour et al., 2022; Ouyang, 2023; Ghosh et al., 2024), we assume that digital payment flows are informative about borrowers' income. More precisely, when the digital payment for an online sale is processed, it generates a signal $\sigma(p)$ to the lender with $p \in \{p_H, p_L\}$ such that

$$\sigma(p) = \begin{cases} p & \text{with prob. } x \\ p' & \text{with prob. } 1-x, \quad p' \neq p, \end{cases}$$

where $x \geq 1/2$ denotes the precision of the signal. Note that the lender observes a signal about the revenue and tries to infer both sellers' type and their true revenue (more on this below). Since the exchange of physical currency does not leave any trace, offline transactions settled in cash do not generate any signal.[11]

[10] Alternatively, such a trade-off for the lender arises when prices are the result of Nash bargaining between sellers and prospective buyers. In this case, a feedback effect from continuation investment to sales prices creates variation in the informational rents that sellers can appropriate (see Section 5.2 for details).

[11] Since digital payments do not entail a benefit for offline sales, assuming that they are settled in cash is without loss of generality.

Lender. The monopolistic lender is endowed with one unit of the good at $t = 0$ and $t = 2$. She derives utility 1 from consuming one unit of the good, which is also her opportunity cost. The lender can neither commit to long-term contracts, nor to not renegotiating the loan terms. Hence, it is as if she could set the interest rates at $t = 1$ and $t = 3$, respectively.

While the lender makes take-it-or-leave it offers, sellers can always abscond with a fraction $\lambda \in (0, 1)$ of their sales or loaned good. When they choose to abscond, sellers must disrupt the signal generated by digital payments in a way that renders it completely uninformative.[12] Finally, to simplify the analysis, we assume that the initial loan is always profitable, i.e. $(1 - \lambda)p_L > 1$.

Timing and Equilibrium definition. The timing is as follows. At $t = 0$, sellers borrow one unit from the lender and choose their distribution venue $v \in \{O, F\}$.[13] At $t = 1$, sellers learn their type $\tau \in \{H, L\}$ and generate sales p. The pair $\pi = (\tau, p) \in \{H, L\} \times \{p_L, p_H\}$ is the seller's profile. The lender learns the signal $\sigma \in \{p_H, p_L, \emptyset\}$, where $\sigma = \emptyset$ whenever the seller trades offline or absconds. Given the signal σ, the lender offers a contract menu $\{r_\sigma(\pi), k_\sigma(\pi)\}_{\sigma,\pi}$, where $r_\sigma(\pi)$ is the repayment of the initial loan and $k_\sigma(\pi) \in \{0, 1\}$ is an indicator whether a continuation loan is granted at $t = 2$, when a seller reports profile π. The lender also chooses the repayment R on the continuation loan at $t = 3$. H-sellers who have received a continuation loan produce θ and repay R, or abscond with the production to obtain a payoff $\lambda\theta$. L-sellers who have received a loan abscond with it to obtain a payoff λ. Our equilibrium definition is as follows.

Definition 1. *An equilibrium consists of a menu of contracts* $\{r_\sigma(\pi), k_\sigma(\pi)\}_{\sigma,\pi}$*, a repayment for the second loan* R*, a venue choice* $v \in \{O, F\}$*, and a reporting strategy* $\hat{\pi} \in \{H, L\} \times \{p_L, p_H\}$ *such that:*

[12] This is akin to the seller diverting cash flows through offshore accounts and complex accounting procedures, which prevents the lender from having real-time access to sellers' digital payment records. It ensures that a digital transaction leaves as little a trace as possible, and the seller can abscond successfully.

[13] The first loan is always profitable so that the lender is always willing to provide funds.

1. *the lender chooses the contract menu* $\{r_\sigma(\pi), k_\sigma(\pi)\}_{\sigma,\pi}$ *as well as repayment on the second loan* R *to maximize expected profits, taking sellers venue choice and reporting strategy as given;*

2. *sellers choose the venue* v *and reporting strategy* $\hat{\pi}$ *to maximize expected profits, taking* $\{r_\sigma(\pi), k_\sigma(\pi)\}_{\sigma,\pi}$ *and* R *as given.*

As is standard, sellers report a profile that maps into a contract of repayment and a refinancing choice. It is as if sellers were choosing that contract and this is how we will think about the sellers report going forward.

Welfare. There are three potential inefficiencies that can arise in equilibrium. First, offline distribution is inefficient because it generates lower sales, as a fraction $1-\alpha$ of H-sellers only generates revenue p_L. Second, the net present value of the continuation loan is positive if and only if the borrower is of type H. And third, contracts where some sellers do not repay and abscond with a share λ of the funds destroy resources because the remaining fraction $1-\lambda$ of output is lost. Therefore, welfare is maximized whenever (i) all sellers distribute their goods online; (ii) the lender grants a second loan to all H-sellers but not to L-sellers; and (iii) all sellers repay the initial loan. This full-information benchmark is useful as we turn to the economy with asymmetric information.

3 Benchmark: Transparent digital payments

In this section, we solve for the equilibrium in the case where digital payments provide a signal with high precision to the lender. We believe this benchmark is useful because of the structure of traditional payment systems. These are centered around banks and their ability to create deposits (or "commercial bank money") used as means to pay. As providers of both means of payment and payment rails, banks derive a substantial amount of information from processing customer payment flows. This does not only include the amount and timing of payments, but also information on the parties involved and the purpose of the transaction. It is well-known that these data can then be used to assess and monitor borrower credit quality (Black, 1975; Mester et al., 2007; Norden and Weber, 2010; Puri et al., 2017; Parlour et al., 2022; Ouyang, 2023; Ghosh et al., 2024).[14]

We therefore associate digital payment means with a high level of signal precision x to bank deposits or, more generally, to related payment instruments that leave a trace observable to lenders. We henceforth refer to such payment means as $\mathcal{D}$-money (short for deposits). For simplicity, we assume that the signal is perfect, $x = 1$. The intuition developed here and in the next section carries over to the general case in which x can take any value in the interval $[\frac{1}{2}, 1]$, which we study in Section 5.1.

To solve for the equilibrium, we proceed backwards. We start with the lender's decision to extend a continuation loan. We then solve for the optimal menu of contracts for the repayment of the initial loan. Finally, we study the seller's choice of trading venue.

3.1 Lender refinancing choice

Since not all sellers produce output at $t = 3$, the lender's decision at $t = 2$ depends on whether she is informed about sellers' type. When she is informed, L-sellers do not receive a continuation loan because they will produce nothing and abscond with the loan. By contrast, H-sellers are granted financing because the lender knows that she will be able to recover her unit cost of investment. Given that the lender is a monopolist, she sets the repayment on the second loan to

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

[14]The informational value of payment flows also provides incentives for lenders to tie the provision of credit to the use of its payment services, e.g. by requiring borrowers to open a checking account. Such tying or bundling of loans and deposit services is legal in the United States under the "Traditional bank product exception" of the anti-tying provisions of 12 U.S.C. 1972(1), see https://www.occ.treas.gov/news-issuances/bulletins/1995/bulletin-1995-20.html. It is, however, illegal in at least other jurisdictions, see https://www.pymnts.com/news/banking/2022/cma-cracks-down-bundling-rules-breach-top-united-kingdom-banks.

so that H-sellers just obtain their outside option $\lambda\theta$.

By contrast, a lender that does not know sellers' type faces adverse selection. We assume that the share of H-sellers in the overall population is sufficiently low to ensure that an uninformed lender does not find it profitable to provide re-financing at $t = 2$.

Assumption 2. $q < \bar{q} \equiv \min\{\frac{1}{(1-\lambda)\theta}, \frac{p_L}{p_H}\}$.

In addition to simplifying the analysis, Assumption 2 also facilitates the exposition by reducing the number of contract menus that the lender will offer in equilibrium.

3.2 Loan repayment

In this subsection, we study the lender's choice of repayment of the initial loan at $t = 1$. We separately study the cases of online and offline distribution because the lender's information set depends on the selected distribution venue.

Repayment with online distribution. When sellers distribute online and accept $\mathcal{D}$-money, the signal generated by the payment system reveals their type to the lender. This is because i) the signal is perfect ($x = 1$), and ii) sales and types are perfectly correlated with online distribution. As a consequence, the repayments do not have to satisfy any incentive constraints for truthful reporting, they are fully pinned down by the respective seller's participation constraint. Moreover, since the lender is perfectly informed, all H-sellers get refinanced at $t = 2$.

Lemma 1. *Suppose that sellers choose online distribution with $\mathcal{D}$-money. Then, the lender sets repayments $r_L^{\mathcal{D}} = (1-\lambda)p_L$ and $r_H^{\mathcal{D}} = (1-\lambda)p_H + \lambda\theta$.*

In essence, the information from payment flows enables the lender to condition the contract terms on the signal. She can therefore extract the maximum possible surplus, which leaves sellers with nothing but their reservation value.

Repayment with offline distribution. Under offline distribution with cash payments, the lender receives no signal. Accordingly, she must elicit information by offering an appropriate menu of contracts. Ideally, the lender wants to learn sellers' full profile. Knowledge of the type allows her to choose refinancing appropriately, while knowledge of the level of sales enables her to set the repayment as high as possible. However, the fact that H-sellers sometimes realize low sales complicates the lender's inference problem and prevents her from acquiring all this information.

In choosing the optimal contract, the lender faces the following trade-off. She can either offer a *separating contract* $\{r_H^S, r_L^S\}$ that identifies all H-sellers, or alternatively a *partial pooling* contract $\{r_H^P, r_L^P\}$ that only singles out HH-sellers, and pools the remaining HL-sellers with L-sellers. While the first contract menu generates more information, it requires the lender to leave additional informational rents to sellers by lowering some of the repayments on the initial loan. Lemma 2 characterizes the lender's optimal choice.

Lemma 2. *Suppose that sellers choose offline distribution. Then, the lender offers a separating contract (S) whenever*

$$q(1-\alpha)(\theta-1) \geq q\lambda(\theta-p_L), \tag{2}$$

and a partial pooling contract (P) otherwise. The respective repayments are $r_L^S = (1-\lambda)p_L$, $r_H^S = p_L$, *and* $r_L^P = (1-\lambda)p_L$, $r_H^P = (1-\lambda)p_L + \lambda\theta$.

As usual under monopolistic screening (Bolton and Dewatripont, 2004), the low repayment r_L is pinned down by L-sellers' participation constraint, who just earn their outside option λp_L. The spread between the high and the low repayment is determined by the incentive constraint of HH-sellers for the partial pooling contract, and the feasibility constraint of HL-sellers for the separating contract.

Inequality (2) captures the trade-off inherent in the lender's screening problem. With full separation, the lender can distinguish HL-sellers from L-sellers.

This allows for more efficient re-financing, so that the continuation surplus $\theta - 1$ is not only generated by HH-sellers, but also the fraction $q(1-\alpha)$ of HL-sellers. At the same time, the lender must ensure that HL-sellers can afford the high repayment. To do so, she must lower the "spread" between high and low repayments from $\lambda\theta$ to λp_L. In essence, she cedes a part of the continuation surplus to all H-sellers, with measure q.

While other contracts are possible, they imply lower expected profits for the lender. A *pooling* contract with a unique repayment for all sellers is never optimal because it generates a lower income and no information at all. The lender can also opt for a *partial participation* contract that foregoes repayment by L-sellers in order to extract additional surplus from H-sellers. However, the low share of H-sellers (see Assumption 2) implies that this contract is dominated by the separating contract.

3.3 Sellers' choice of distribution venue

We can now determine sellers' choice of distribution venue at $t = 0$. At this stage, sellers take the contracts derived in the previous section as given. With offline distribution, they will face the separating contract (r^S, k^S) or the partially pooling contract (r^P, k^P), depending on parameters. By contrast, online distribution implies that they will face the contract $(r^{\mathcal{D}}, k^{\mathcal{D}})$.

Let $M = \{S, P, \mathcal{D}\}$ denote the set of contract menus that sellers can possibly face at $t = 1$, with individual elements indexed by m. Sellers' expected profits for a given venue v and contract menu m are then given by expected sales minus loan repayment plus the gains from the continuation project. This expectation is taken over all possible profiles $\pi = (\tau, p) \in \{H, L\} \times \{p_H, p_L\}$ for this particular venue.[15]

$$\mathcal{S}_v^m = E_{\pi|v}\left[p - r^m(\pi) + k^m(\pi)\lambda\theta\right], \tag{3}$$

To build intuition, it is useful to decompose the profits for a given contract menu

[15] For example, $\pi|O \in \{(H, p_H), (L, p_L)\}$.

into sellers' outside option, λp, plus an informational rent. With offline distribution and the partial pooling contract, only HH-sellers (with mass αq) are refinanced. Then, sellers' expected profit is

$$\mathcal{S}_F^P = \alpha q[\lambda p_H + (1-\lambda)(p_H - p_L)] + (1-\alpha q)\lambda p_L. \tag{4}$$

In this case, only HH-sellers earn a rent equal to $(1-\lambda)(p_H - p_L)$, while all other sellers just obtain their reservation utility.

With offline distribution and the separating contract, all H-sellers are refinanced, and sellers' expect profits are

$$\begin{aligned} \mathcal{S}_F^S \; &= \alpha q[\lambda p_H + (1-\lambda)(p_H - p_L) + \lambda(\theta - p_L)] \\ &+ (1-\alpha)q[\lambda p_L + \lambda(\theta - p_L)] + (1-q)\lambda p_L. \end{aligned} \tag{5}$$

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

Turning to online distribution with payments settled in $\mathcal{D}$-money, sellers' expected profits are

$$\mathcal{S}_O^{\mathcal{D}} = q\lambda p_H + (1-q)\lambda p_L. \tag{6}$$

In this case, all sellers receive exactly their reservation utility. However, since online distribution is efficient, all H-sellers now generate p_H. Combining equations (4)-(6) with Lemma 2 allows us to characterize the equilibrium.

Proposition 1. ***(Equilibrium in the baseline model.)***
1. For $(1-\alpha)(\theta-1) < \lambda(\theta - p_L)$, the lender offers a partial pooling contract to offline sellers. Sellers distribute online if $\lambda \geq \alpha$, and offline otherwise.
2. For $(1-\alpha)(\theta-1) > \lambda(\theta - p_L)$, the lender offers a separating contract to offline sellers. Sellers distribute online if $\lambda \geq \alpha\frac{p_H - p_L}{p_H - \theta}$, and offline otherwise.

3. All online sales are settled with $\mathcal{D}$-money (by assumption).

Figure 1 illustrates the equilibrium in the (λ, α)-space. The downward-sloping solid line is $\lambda = (1-\alpha)\frac{\theta-1}{\theta-p_L}$, which represents inequality (2) in Lemma 2. It delineates the parameter combinations for which the lender offers a partially pooling contract (to the right) and a separating contract (to the left) under offline distribution. The two upward-sloping dotted lines represent sellers' indifference curves regarding the choice of trading venue. For parameter combinations above (below), sellers choose online (offline) distribution.

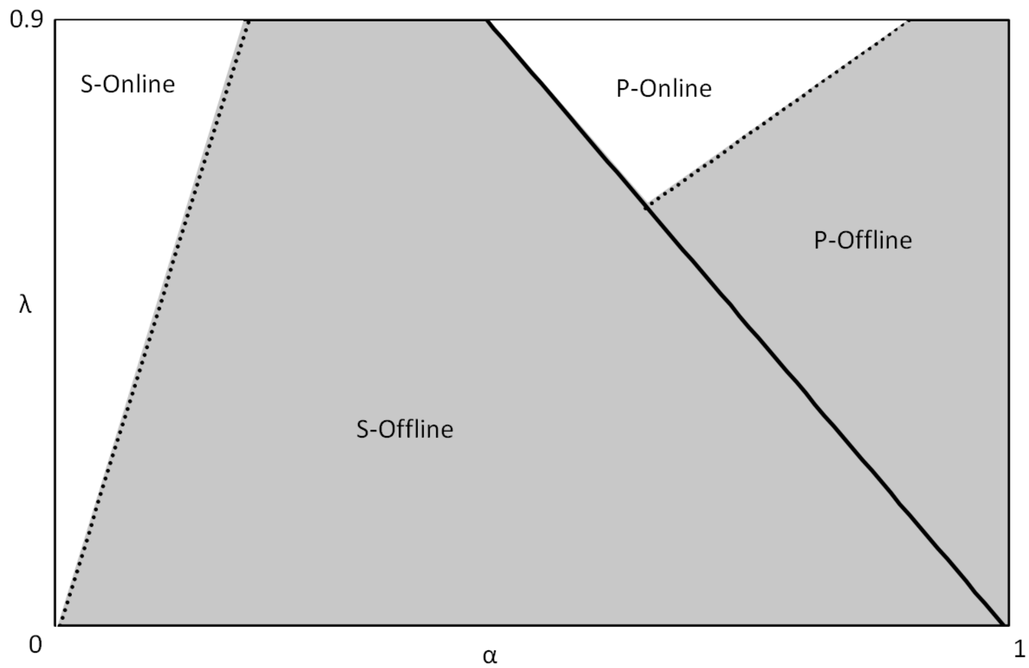

Figure 1: **Equilibrium Map with $\mathcal{D}$-money in (λ, α)-space.** Parameter values are: $p_H = 28$, $p_L = 10$, $\theta = 24$, $q = 0.2$. The y-axis is truncated at $\lambda = \frac{p_L-1}{p_L} = 0.9$. Labels indicate i) the type of contract menu offered by the lender conditional on sellers choosing offline distribution, and ii) sellers' equilibrium venue choice. For example, the label "S-Online" indicates that the lender offers a separating contract under offline distribution, and sellers choose to distribute online in equilibrium.

When choosing among trading schemes, sellers trade off the efficiency gains from online distribution with the informational rents arising from the anonymity of offline sales settled in cash. Intuitively, a high value of λ means that sellers obtain a large share of the efficiency gains associated with online distribution, which increases their willingness to choose this venue. By contrast, a high value of α means that the efficiency gains from online distribution are relatively small, so sellers are less willing to sacrifice the informational rents from using cash with offline trade.

To understand how this trade-off depends on the model's parameters, it is most instructive to look at the case in which the lender offers a partial pooling contract under offline distribution (i.e. to the right of the solid line). Using equations (4) and (6), we can write

$$\mathcal{S}_O^D - \mathcal{S}_F^P = \lambda(1-\alpha)q(p_H - p_L) - \alpha q(1-\lambda)(p_H - p_L). \tag{7}$$

The first term of (7) represents the efficiency gains from online distribution that accrues to sellers. Relative to offline distribution, the overall surplus increases by $(1-\alpha)q(p_H - p_L)$ because all H-sellers generate sales p_H (instead of only a fraction α). Since the lender is a monopolist, she extracts the maximum surplus possible, which means that sellers are left with a share λ of these gains.

The second term of (7) is the cost of online distribution due to a loss of anonymity. Since the lender obtains a perfect signal, HH-sellers (with mass αq) no longer earn an information rent of $(1-\lambda)(p_H - p_L)$. Cancelling terms, it is straightforward to deduce that the seller distributes online if and only if $\lambda > \alpha$, which is the dotted line in Figure 1 to the right of the solid line.

The intuition for the case in which the lender offers the separating contract with offline distribution (to the left of the solid line) is the same. However, the indifference curve is steeper because sellers earn more information rents under this contract. Hence, they must be able to extract a relatively higher share of the efficiency gains from online distribution (captured by λ) to give up the anonymity that cash allows.

The grey-shaded areas in Figure 1 highlight the parameter space for which the equilibrium is inefficient. There are two inefficiencies. First, the equilibrium is inefficient whenever goods are distributed offline because HL-sellers generate low revenues. This implies a welfare loss of $\alpha q(p_H - p_L)$. Second, an additional inefficiency arises when the lender uses the partial pooling contract. In this case, she 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. This generates a welfare loss of $\alpha q(\theta - 1)$.

4 Alternative arrangements

In this section, we study two deviations from the benchmark model. These are motivated by recent developments such as the rise of non-bank payment service providers (PSPs), the advent of new technologies (e.g. blockchain), regulatory initiatives like "open banking", and the ongoing debate on central bank digital currency (CBDC). First, we study the case of privacy-preserving digital payments that prevent the lender from extracting information from payment flows. Second, we analyze a model where end-users have control over the data generated by payment systems, and can decide whether and with whom to share them.

4.1 Privacy-preserving digital payments

First, we consider digital payments with privacy-preserving features that limit the signal's informativeness. This setting is motivated by recent developments in the economics of payments.

The past two decades have seen the rapid rise of non-bank PSPs, including firms like Paypal (United States), Wise (United Kingdom), WeChat Pay and Ali-Pay (China). While payments continue to be settled in commercial bank money held in segregated accounts, these entities provide the customer interface for an increasing number of transactions. This implies that they are in control over the data that is being generated through individual payments. Accordingly, banks merely provide the payment rails and often only observe netted payment flows after individual transactions have been internalized within the PSPs' systems. Moreover, these transactions frequently come without information on their ultimate origin and purpose. Taken together, the growth of non-bank PSPs implies a significant loss on banks' ability to derive information from payment flows.

The rise of cryptocurrencies is another development that may diminish banks' ability to derive information from payments data going forward. The central premise of distributed ledger technology (DLT) is the decentralized settlement of transactions in the digital space. By definition, this aims to eliminate the creation of an informative digital footprint. While cryptocurrencies are currently not widely adopted as means of payment, DLT has the potential to further disrupt the information flows to banks and other lenders.

Finally, central banks around the world are examining the case for retail CBDC. Several major central banks have made pledges to incorporate privacy-preserving features into their CBDC designs, which is likely to reduce the informational content of payment flows relative to the status quo with $\mathcal{D}$-money.[16] The People's Bank of China (PBOC) has already rolled out its e-CNY across several major cities, and its privacy provisions imply a drastic loss of access to information for banks. Duffie and Economy (2022) provide a detailed description, and write (p.32): "Within the e-CNY system, operating institutions cannot directly see who is paying whom or even how much is being paid because the PBOC's authentication center verifies the authenticity of circulating e-CNY, not the operating institutions".

With these developments in mind, we modify our benchmark model and henceforth assume that digital payments are based on privacy-preserving technology. We henceforth refer to this as $\mathcal{P}$-money. Again for simplicity, we assume that

[16] For example, the Bank of Canada has stated that it "could engineer a CBDC system with higher levels of privacy than commercial products can offer" (Darbha and Arora, 2023). Similarly, the Bank of England recently launched a new consultation paper, according to which CBDC users would be able to "vary their privacy preferences to suit their privacy needs" (Bank of England, 2023b). Moreover, the European Central Bank announced that data related to online CBDC payments "would be limited to what is necessary to perform basic digital euro services" (European Central Bank, 2023).

such payments generate a completely uninformative signal, so $x = \frac{1}{2}$. Recall that Section 5.1 considers the case with general $x \in [\frac{1}{2}, 1]$.

Whenever sellers distribute online and allow sales to be settled in $\mathcal{P}$-money, the lender faces a similar problem as with offline sales settled in cash.[17] Since the signal is uninformative, she must elicit information by setting the appropriate contractual terms on the initial loan. However, since online distribution is efficient, all H-sellers generate high sales, p_H. This simplifies the lender's inference problem.

Lemma 3. *Suppose that sellers choose online distribution and settlement in $\mathcal{P}$-money. Then, the lender always offers a separating contract with repayments $r_H^{\mathcal{P}} = (1-\lambda)p_L + \lambda\theta$ and $r_L^{\mathcal{P}} = (1-\lambda)p_L$.*

Then, sellers' expected payoff is

$$\mathcal{S}_O^{\mathcal{P}} = q\left[\lambda p_H + (1-\lambda)(p_H - p_L)\right] + (1-q)\lambda p_L. \tag{8}$$

Comparison with Equation (6) shows that $\mathcal{S}_O^{\mathcal{P}} > \mathcal{S}_O^{D}$, and hence $\mathcal{P}$-money fully displaces $\mathcal{D}$-money. Since the lender uses a separating contract, she can appropriate the entire continuation surplus, but must leave all the gains from more efficient matching to sellers. With $\mathcal{D}$-money, some of these gains also go to the lender, so that sellers are strictly better off with $\mathcal{P}$-money. Further comparison of equations (4) and (8) leads to the following result.

Proposition 2. ***(Equilibrium with $\mathcal{P}$-money)***

1. For $(1-\alpha)(\theta-1) > \lambda(\theta - p_L)$, the lender offers a separating contract to offline sellers. Then, sellers distribute online if $(1-\alpha)\frac{p_H - p_L}{\theta - p_L} \geq \lambda$, and offline otherwise.

2. For $(1-\alpha)(\theta-1) < \lambda(\theta - p_L)$, the lender offers a partial pooling contract to offline sellers. Sellers always distribute online.

3. All online sales are settled with $\mathcal{P}$-money.

Comparing Propositions 1 and 2 shows that the introduction of $\mathcal{P}$-money

[17] We do not consider the case of offline sales settled in $\mathcal{P}$-money because the only feature that distinguishes them from cash is their ability to settle online transactions.

leads to an increase in online sales. The effect is most pronounced in the parameter region where the lender offers a partial pooling contract with offline distribution, i.e. to the right of the solid line in Figure 2. In this case, sellers *always* opt for online distribution. Intuitively, $\mathcal{P}$-money enables sellers to capture the best of both worlds. They reap the efficiency gains of online distribution, and at the same time earn informational rents from remaining anonymous towards the lender.

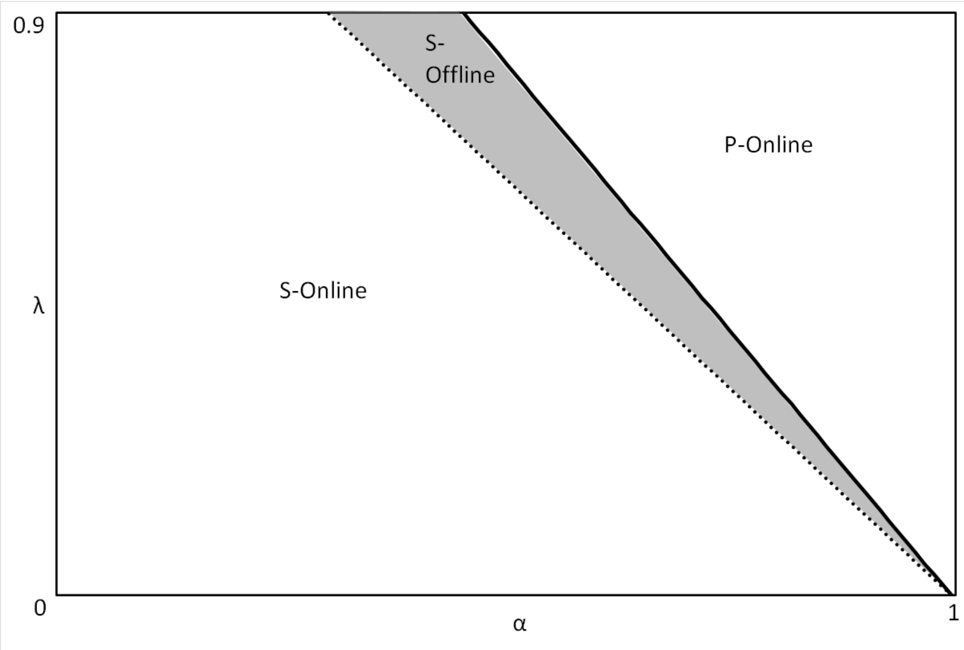

Figure 2: **Equilibrium Map with $\mathcal{P}$-money in (λ, α)-space.** Parameter values are: $p_H = 28$, $p_L = 10$, $\theta = 24$, $q = 0.2$. The y-axis is truncated at $\lambda = \frac{p_L - 1}{p_L} = 0.9$. Labels indicate i) the type of contract menu offered by the lender conditional on sellers choosing offline distribution, and ii) sellers' equilibrium venue choice. For example, the label "S-Online" indicates that the lender offers a separating contract under offline distribution, and sellers choose to distribute online in equilibrium.

However, physical cash is not always fully crowded out by $\mathcal{P}$-money. Whenever the lender offers a separating contract with offline distribution (to the left of the solid line in Figure 2), there are parameter combinations for which sellers prefer to remain offline. In this case, the informational rents from using cash are strictly higher than those earned with $\mathcal{P}$-money. Since HL-sellers generate lower sales offline (p_L instead of p_H), the lender can no longer extract the entire surplus generated from continuation financing. Hence, she must offer additional rents to elicit the same amount of information, and these may exceed the rents earned by sellers under the use of $\mathcal{P}$-money. In this case, sellers can be better off with cash.

Formally, Part 1 of Proposition 2 implies that cash may be used in equilibrium as long as $\theta - 1 > p_H - p_L$. In this case, the efficiency gains from online distribution are not sufficient to compensate sellers for the loss in informational rents obtained with cash.[18]

Interestingly, Figure 2 shows that sellers' indifference curve between online or offline distribution (the dotted line) no longer slopes upward when the lender offers the separating contract. The reason is that, unlike with $\mathcal{D}$-money, H-sellers earn an informational rent of $(1-\lambda)(p_H - p_L)$ with $\mathcal{P}$-money (see Equation (8)). Since this rent is decreasing in λ, it alters the trade-off between online and offline distribution in the (λ, α)-space, and the relative attractiveness of offline distribution becomes increasing in λ.

The introduction of $\mathcal{P}$-money raises welfare through two channels. First, the increase in online distribution implies higher sales by H-sellers, so the surplus p_H is reaped more frequently. Second, with $\mathcal{P}$-money, the lender always opts for full separation, and thus provides continuation financing to *all* H-sellers. This is not the case under offline sales with the partial pooling contract, where only HH-sellers are granted a second loan.

4.2 Digital payments with data-sharing/user-control

The previous section has shown that the introduction of $\mathcal{P}$-money can increase efficiency relative to a world with only cash and $\mathcal{D}$-money. However, the equilibrium is not always efficient because the informational rents associated with cash can be too large to induce sellers to switch to online distribution. In this section, we ask whether efficiency can be increased further by providing sellers with some

[18] To understand this condition, recall from Lemma 2 that the lender offers a separating contract if and only if the extra surplus from the continuation project is sufficiently attractive to warrant leaving the required informational rent to sellers, i.e. $(1-\alpha)(\theta - 1) > \lambda(\theta - p_L)$. However, these informational rents exceed the benefits from distributing goods online whenever $\lambda(\theta - p_L) > (1-\alpha)(p_H - p_L)$. Accordingly, whenever $\theta - 1 > p_H - p_L$, sellers may opt for offline sales with cash.

form of control over their payments data.

This idea is based on a host of regulatory initiatives known under the umbrella term "open banking" that have been implemented in a growing number of jurisdictions over the past decade. In a nutshell, open banking aims to empower users with the ability to share their payments data with third parties in order to enhance competition and innovation in the provision of financial services (He et al., 2023; Babina et al., 2024). However, this is still far from "full" control since these regulations do not prevent the original institution from observing the data when they are generated, thus still giving it a competitive (first-mover) advantage.

Recent advances in technology allow us to envisage a system where users are in complete control of their data. One concrete example is "India Stack", an infrastructure project that is transforming the payment ecosystem in India. It comprises digital ID, interoperable digital payments, and user consent.[19] The last element (consent) is guaranteed by the existence of so-called "fiduciaries" that intermediate the flow of financial data between individuals and financial firms. These fiduciaries are responsible for managing personal data, and must obtain an individual's consent before processing personal data. They may not access or store shared data, but can charge a fee for their services (see Carriere-Swallow et al., 2021).

Similarly, the design of future CBDCs may include significant elements of end-user control. Several major central banks have made statements in this direction. In particular, they emphasize that user consent will likely be a prerequisite for intermediaries to obtain access to payments data, or the purposes it can be used for.[20]

[19] See `https://indiastack.org` for details.

[20] For example, a recent report by the European Central Bank states: "Digital euro users would have full control over how their own personal data are used. This includes an opt-in rather than an opt-out for allowing PSPs to process a user's personal data for commercial purposes or to provide additional services." (European Central Bank, 2023). The Bank of England has communicated: "Digital pound users will be able to make choices about the way their data is used. We are supportive of, and encourage, firms to offer services that enable holders to opt for enhanced privacy functionality and exert greater user control of personal data." (Bank of England, 2023a)

Given these developments, we study the implications of digital payments with end-user control in our model. 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."[21] We refer to such payments as $\mathcal{C}$-money (where $\mathcal{C}$ refers to user "control"). Specifically, we assume that sellers can choose whether they want the lender to receive a signal (i.e. they choose $x \in \{\frac{1}{2}, 1\}$), and whether this signal is revealed *before* or *after* the repayment of the initial loan. This extent of user-control implies that sellers can avoid being monitored in real-time in case they choose to disclose it after repayment. Accordingly, we also assume that the signal does not lose its informational content in case sellers decide to abscond.

The ability to exert data control via $\mathcal{C}$-money has profound consequences for the equilibrium in the lending market at $t = 1$. Sellers have no incentive to reveal their type before the repayment of the first loan because the lender cannot commit to the contract terms. However, they have an incentive to reveal their type after the repayment because this will enable the best of them to obtain a continuation loan. Formally, if the lender uses a separating contract $(r_H^{\mathcal{C}}, r_L^{\mathcal{C}})$, the ICs read

$$p_H - r_H^{\mathcal{C}} + \lambda\theta \geq p_H - r_L^{\mathcal{C}} + \lambda\theta \tag{9}$$

$$p_L - r_L^{\mathcal{C}} \geq p_L - r_H^{\mathcal{C}} + \lambda. \tag{10}$$

In essence, $\mathcal{C}$-money enables H-sellers to obtain a share of the surplus of the second loan even upon absconding. These constraints imply $0 \geq r_H^{\mathcal{C}} - r_L^{\mathcal{C}} \geq \lambda$, a contradiction. Hence a separating contract is infeasible, and the lender can only offer a pooling contract with the interest rate $\bar{r}^{\mathcal{C}} = (1 - \lambda)p_L$. Therefore, sellers' ex-ante expected payoff is given by

$$\mathcal{S}_O^{\mathcal{C}} = q[\lambda p_H + (1 - \lambda)(p_H - p_L) + \lambda\theta] + (1 - q)\lambda p_L, \tag{11}$$

where $\mathcal{S}_O^{\mathcal{C}}$ indicates the use of $\mathcal{C}$-money with online distribution. Comparison with

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

(5) and (8) reveals that $\mathcal{S}_O^{\mathcal{C}} > \max\{\mathcal{S}_F^S, \mathcal{S}_O^{\mathcal{P}}\}$, so we conclude the following.

Proposition 3. ***(Equilibrium with $\mathcal{C}$-money)***

Sellers always distribute online and all online sales are settled with $\mathcal{C}$-money. The equilibrium is efficient.

The use of $\mathcal{C}$-money enables sellers to separate the bright and the dark side of informative payment flows. Since they can delay the release of the signal until after the initial repayment, the bank is no longer able to extract the full continuation surplus through the first loan. Once the repayment is carried out, sellers are happy to reveal the signal in order to reap a share λ of the additional surplus generated by the continuation loan.

The equilibrium allocation with $\mathcal{C}$-money always reaches the first best. Recall that there are three dimensions of efficiency, all satisfied here. First, sellers choose online distribution, so there is no loss associated with offline distribution and inefficient matching (low sales of high-type seller). Second, all H-sellers are refinanced. Third, all types repay the initial loan, so there is no inefficiency associated with partial participation.

It is worth noting that the equilibrium allocation with $\mathcal{C}$-money is first-best despite the lack of competition for continuation finance. While the lender reaps a surplus $(1-\lambda)\theta - 1 > 0$ from the second loan, this does not impede the efficiency of sellers' choice, but only the division of the surplus across agents. In this sense, entry by a second lender (in addition to data-sharing) would alter the distribution of surplus towards the seller, but would not affect overall efficiency.

5 Extensions

This section provides an overview of two model extensions. For brevity, we only highlight the main insights, and relegate the details to the Online Appendix.

5.1 General signal precision

So far we have studied the case in which the signal is either perfectly informative ($x = 1$) or totally uninformative ($x = \frac{1}{2}$). In this section, we summarize the main insights from the general case in which $x \in [\frac{1}{2}, 1]$. The detailed analysis in contained in Online Appendix OA.1.

Since the lender receives the signal before setting the repayment on the initial loan, she can use the underlying information to adjust the contract terms in a way that maximizes her profits. In fact, this is precisely what the lender does in the case where $\mathcal{D}$-money delivers a perfect signal (Section 3.2). Whenever the signal indicates the presence of a H-seller (L-seller), the bank demands a high (low) repayment and thus extracts the entire surplus (Lemma 1). By contrast, when there is no signal, the contract terms are fixed. The lender must therefore take into account incentive compatibility, which gives rise to informational rents for sellers (as e.g. in Lemma 2).

This intuition carries over to the general case when the signal is informative, but imperfect, $x \in (\frac{1}{2}, 1)$. However, since the signal can be wrong (with probability $1 - x$), contract tailoring gives rise to an additional inefficiency. Intuitively, if the lender receives a high signal and therefore decides to demand a high repayment, the subsequent arrival of an L-seller will lead to default/absconding, so that some output is lost.

More specifically, if the signal precision associated with $\mathcal{D}$-money is sufficiently high ($x > \bar{x}$), the lender optimally offers a partial participation (PP) contract upon receiving a high signal ($\sigma = p_H$), and a separating contract upon a low signal ($\sigma = p_L$). The PP contract entails a single repayment $r^{PP} = (1-\lambda)p_H + \lambda\theta$ that extracts H-sellers' entire surplus. However, it exceeds the funds available to L-sellers. Therefore, they find it optimal to abscond with a fraction of their sales, λp_L, while the remaining output of $(1 - \lambda)p_L$ is lost.[22] This effect diminishes as

[22] Formally, this contract ignores L-sellers' participation constraint. This enables the lender to charge a higher repayment from H-sellers compared to a contract with full participation.

the signal becomes perfect (as in our baseline model).

A more informative signal enables the lender to extract more surplus by tailoring the contract terms. In equilibrium, sellers take this into account when choosing their trading venue, so that a more precise signal increases their incentives to stay offline, all else equal.

Whenever the signal is too noisy ($x < \bar{x}$), the equilibrium is identical to the one for the extreme case $x = \frac{1}{2}$ from the baseline model. The lender does not find it profitable to condition the contract terms on the signal because the risk of default is too large. She therefore always offers a separating contract when sellers choose online distribution with $\mathcal{D}$-money.

5.2 Endogenous prices

So far, our analysis has taken the price structure as given. Here, we describe an extension in which prices result from Nash bargaining between sellers and their customers (buyers). Besides providing micro-founded prices, this setting also gives rise to a feedback effect of the lender's refinancing decision on sales prices. This ensures that the lender faces a non-trivial choice between different contract menus even when she can extract the entire continuation surplus from HL-sellers. This allows us to relax Assumption 1. However, these desirable features come at the cost of added complexity. We here discuss the resulting intuition, and relegate the analysis and derivations to Online Appendix OA.2.

As before, we assume that a measure q of sellers produces a high quality good (H-sellers), while the remaining $1 - q$ L-sellers produce a low quality good. Unlike in the baseline model, there is also a continuum of heterogeneous buyers with deep pockets. A measure q of H-buyers 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 $u_H > u_L \geq 1$. The remaining $1 - q$ L-buyers obtain utility u_L from consuming either good.

Let $m = (s, b)$ denote a meeting of a seller with type s and a buyer of type b. We assume that online distribution gives rise to perfect matching where all H-sellers are matched with H-buyers (who desire high-quality goods). By contrast, matching is imperfect with offline distribution. In this case, we assume that a measure α of H-buyers is matched with H-sellers, and the rest with L-sellers. For consistency, we then assume that L-sellers meet H-buyers with probability $1 - \alpha_L = \frac{q(1-\alpha)}{1-q}$, and L-buyers with probability α_L.[23]

With Nash bargaining, prices are such that buyers and sellers split the joint surplus from trade according to their bargaining power. We assume that buyers have bargaining power η, and that their outside option is to consume the investment good and obtain utility λ. Crucially, the joint surplus depends on the lender's decision at $t = 2$ because H-sellers will generate an additional payoff $\theta - 1$ for the lender/seller coalition whenever a continuation loan is granted. Define $u(m) = u_H$ for $m = (H, H)$ and $u(m) = u_L$ otherwise. Then, the bilateral price in meeting m *conditional on the lender's future lending decision* $k \in \{0, 1\}$ is

$$p(m, k) = (1 - \eta)u(m) + \eta\lambda - \eta\Delta(m, k), \tag{12}$$

where $\Delta(m, k) = \theta - 1$ for $(m, k) = ((H, b), 1)$, and zero otherwise, is the surplus generated by financing a H-seller for the second round of production.

The first two terms are standard and imply that buyers pay higher prices for goods they value more. The last term, which depends on both the meeting m and the lender's decision k, represents the feedback effect from re-financing decisions to prices. Buyers' bargaining power enables them to extract a fraction η of the continuation surplus $\Delta(m, k)$ whenever H-sellers receive re-financing at $t = 2$. Intuitively, the H-seller/lender coalition is willing to cede part of this surplus because it cannot be generated when trade breaks down.

[23]Together, this implies that the measure of (H, H) meetings is $q\alpha$, the measure of (H, L) meetings is $q(1 - \alpha)$, the measure of (L, H) meetings is $(1 - \alpha)q$ and the measure of (L, L) meetings is $1 - 2q + \alpha q$. Random matching corresponds to the case $\alpha = q$, while perfect matching (as in online meetings) is $\alpha = 1$.

This feedback effect gives rise to a trade-off for the lender. With a separating contract, she becomes fully informed and can reap the maximum benefits from informed lending at $t = 2$. However, in this case, HL-sellers will generate lower sales than L-sellers because they must cede part of the benefits from continuation financing to buyers. The resulting price dispersion increases sellers' informational rents at the lender's expense. With a partial pooling contract, this effect is absent: HL-sellers are not refinanced and generate the same sales as L-sellers, which limits price dispersion and informational rents. However, since the lender is no longer fully informed, continuation investment is inefficiently low in this case.

Finally, notice that when buyers have no bargaining power, $\eta = 0$, the price in meeting m is given by

$$p_m = u_m, \tag{13}$$

which yields the price structure that we have used in the main text.

6 Conclusion

Our model provides a tractable 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: digital payments facilitate the efficient distribution of goods via online channels, but they entail a costly loss in privacy because they leave a 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, digital payment means that preserve privacy or allow for end-user control over their data improve welfare because they enable sellers to get the best of both worlds. They can remain anonymous when it matters, reveal their type when they need it, and still reap the benefits of distributing goods online.

Our paper has important implications for the regulation of payment systems and the design of CBDCs going forward. Our findings suggest that laissez-faire is likely to entail welfare losses. Regulations such as "open banking" can help to alleviate privacy concerns because they help to level the playing field. However, further steps towards "full" user control are likely to generate additional benefits, in particular in situations where competition is difficult to introduce.

Similarly, our work encourages central banks to make privacy a key design feature of possible future CBDCs. Importantly, they may be able to generate welfare gains by being more ambitious than simply aiming to mimic cash as closely as possible. As we show, there are benefits from enabling end-user control and data portability.

Most of the discussion on privacy and payments focuses on customers, but our paper places a novel emphasis on the privacy of merchants. As our paper exemplifies, there are good reasons to think this is also an important aspect of payment system design that regulators and central banks should consider seriously.[24]

For brevity, we have not studied the case where different lenders compete at $t = 2$. However, we have seen that the equilibrium allocation is already efficient in the presence of $\mathcal{C}$-money. Accordingly, competition at $t = 2$ will not increase efficiency, but only the distribution of the surplus between borrowers and lenders. We have also left unspecified the details of how lenders can learn from the inspection of payment flows. Further investigation in this direction may provide interesting insights. Similarly, we have not considered how payments data may be used to improve future sales. These are important topics left for future research.

[24]Several central banks, such as the European Central Bank and the Bank of England have floated the idea of holding limits for CBDCs (see, e.g. European Central Bank, 2023; Bank of England, 2023b). Transactions exceeding these limits would be transferred automatically (or "swept") into ordinary bank accounts. Low holding limits would imply that the payment flows observable to banks remain relatively informative, so that not all welfare benefits from enhanced privacy are realized.

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A Proofs

A.1 Proof of Lemma 1

When $\mathcal{D}$-money (deposits) is used under online distribution, the lender receives a perfect signal about actual sales, which directly reveals sellers' types. Thus, no ICs are needed and the relevant PCs are

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

where we have used the fact that absconding requires a scrambling of the payment signal, so that the lender cannot extend a continuation loan to a H-seller who absconds because uninformed lending is unprofitable (Assumption 2). Profit maximization implies that each of these PCs bind, resulting in the repayment stated in the Lemma. Feasibility is ensured by Assumption 1. The lender's expected profit is

$$
\begin{aligned}
\mathcal{L}_O^{\mathcal{D}} &= q(r_H^{\mathcal{D}} - 1) + (1-q)(r_L^{\mathcal{D}} - 1) + q\left[(1-\lambda)\theta - 1\right] \\
&= (1-\lambda)p_L - 1 + q(\theta - 1) + q(1-\lambda)(p_H - p_L). \qquad (14)
\end{aligned}
$$

A.2 Proof of Lemma 2

First, consider the *separating contract*. Since the lender provides re-financing to all H-sellers, incentive compatibility requires that they both choose the high repayment r_H^S. Hence, the contract must satisfy the following simplified ICs:

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

because pretending to have high sales by paying r_H^S yields a continuation loan, which is worth λ to an L-seller (who can abscond with the loan at $t = 2$).

Uninformed lending is unprofitable (Assumption 2), so a seller that absconds does not obtain a loan. Hence, the participation constraints (PCs) are

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

The first PC must be slack as the second PC is more restrictive. Moreover, feasibility requires that sellers have enough funds for repayment at $t = 1$,

$$p_H \geq r_H^S, \quad p_L \geq r_H^S, \quad p_L \geq r_L^S.$$

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

Under profit maximization, the last PC binds, $r_L^S = (1-\lambda)p_L$. Substitution into either of the first two ICs or the second PC (they have identical implications) yields $\lambda\theta + (1-\lambda)p_L \geq r_H^S$. By Assumption 1, we have $\theta > p_L$. Hence, all these three constraints are slack, so that the second feasibility constraint must bind, and we have $r_H^S = p_L$. Note that the third IC is also satisfied because $p_L > 1$. The lender earns

$$\begin{aligned} \mathcal{L}_F^S &= q(r_H^S - 1) + (1-q)(r_L^S - 1) + q\left[(1-\lambda)\theta - 1\right] \\ &= (1-\lambda)p_L - 1 + q(\theta - 1) - q\lambda(\theta - p_L). \end{aligned} \tag{15}$$

Second, consider the *partial pooling contract*, under which the lender only extends continuation finance to HH-sellers (H-sellers with high sales). Since HL-sellers do not obtain re-financing, they must optimally choose the low repayment r_L^P. Hence, the simplified ICs read

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

Pretending to have high sales by paying r_H^P 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 $r_H^P = r_L^P + \lambda\theta$. The contract must also satisfy the following PCs.

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

Profit maximization yields $r_L^P = (1-\lambda)p_L$, so $r_H^P = (1-\lambda)p_L + \lambda\theta$. Assumption 1 ensures that the contract is feasible. Lender profits under partial pooling are

$$
\begin{aligned}
\mathcal{L}_F^P &= \alpha q(r_H^P - 1) + (1-\alpha q)(r_L^P - 1) + \alpha q\left[(1-\lambda)\theta - 1\right]\\
&= (1-\lambda)p_L - 1 + \alpha q(\theta - 1).
\end{aligned} \tag{16}
$$

Comparing Equations (15) and (16) yields the inequality in Lemma 2.

A (fully) *pooling contract* would imply a repayment $\bar{r} = (1-\lambda)p_L$ for all sellers and thus yield strictly lower lender profits than the contracts characterized above. Intuitively, the lender learns nothing under full pooling, so a continuation loan is never granted and the lender never reaps future surplus.

Finally, consider a *partial participation contracts*, whereby L-sellers default but the seller can extract more surplus from H-sellers. There are two cases: (a) only HH-sellers participate and HL-sellers also default; and (b) all H-sellers participate. We consider these cases in turn and show that they yield a lower expected profit to the lender than at least one of the previous contracts (separation or partial pooling). A single repayment is offered under partial participation, so there are no ICs.

In case (a), the PC of HH-sellers binds, so $r^{PP,a} = (1-\lambda)p_H + \lambda\theta$, which is feasible because of Assumption 1. Since the share of HH-sellers is αq, the expected profit of the lender is $\alpha q[r^{PP,a} + (1-\lambda)\theta - 1] - 1 = \alpha q(1-\lambda)p_H - 1 + \alpha q(\theta - 1) < \mathcal{L}_F^P$ by Assumption 2 and $\alpha < 1$.

In case (b), the PC of HL-sellers is more restrictive than the PC of HH-sellers. Because of Assumption 1, the feasibility constraint of HL-sellers is even more restrictive and binds, so $r^{PP,b} = p_L$. Since the share of H-sellers is q, the expected profit of the lender is $q[r^{PP,b} + (1-\lambda)\theta - 1] - 1 = qp_L - 1 + q[(1-\lambda)\theta - 1] < \mathcal{L}_F^S$ because of $q < 1$.

A.3 Proof of Lemma 3

Since there are only two types of matches with online sales, the lender's choice under online distribution is either a separating, a fully pooling, or a partial participation contract. (Partial pooling does not apply with two matches m.)

Consider the *separating contract* first. As usual, the PC of L-sellers binds, $r_L^{\mathcal{P}} = (1-\lambda)p_L$, where the superscript indicates that trades are settled in $\mathcal{P}$-money. The ICs are

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

which together with profit-maximization yield $r_H^{\mathcal{P}} = r_L^{\mathcal{P}} + \lambda\theta$. Feasibility is ensured by Assumption 1. The lender's expected profits under separation are

$$\begin{aligned} \mathcal{L}_O^S &= q\left[r_H^{\mathcal{P}} + (1-\lambda)\theta - 1\right] + (1-q)r_L^{\mathcal{P}} - 1 \\ &= (1-\lambda)p_L + q(\theta - 1) - 1. \end{aligned}$$

A *pooling contract* has no ICs and the more restrictive PC is that of L-sellers, which binds and yields $\bar{r} = (1 - \lambda)p_L$. Hence, the expected lender profits are $(1-\lambda)p_L - 1$, which is strictly lower than under separation, as the lender learns nothing under the pooling contract and, therefore, does not extend a second loan.

Finally, a *partial participation contract* sets a single repayment r^{PP}, so no ICs are required. The repayment is set for the PC of H-sellers to bind, so $r^{PP} = (1 - \lambda)p_H + \lambda\theta$, which is feasible by Assumption 1. While L-sellers default on the initial loan and the lender receives nothing from them, the partial participation contract allows the lender to extract more surplus from H-sellers. The expected lender profits is $q(1 - \lambda)p_H - 1 + q(\theta - 1)$, which is lower than the expected profit under separation because of the low share of high types (Assumption 2).

Payments and privacy in the digital economy

Online Appendix – not for publication

OA.1 The general case

In this section, we solve the model for the general case in which $x \in [\frac{1}{2}, 1]$. While the intuition from the polar cases $x = 1$ ($\mathcal{D}$-money) and $x = \frac{1}{2}$ ($\mathcal{P}$-money) carries through, it gives rise to additional effects. To solve the model, we proceed backwards as before, starting with the lender's contract choice.

OA.1.1 Loan contract

Offline distribution. Since no signal is generated whenever sellers distribute online, this case is identical to the benchmark model. Hence, the lender's optimal decision is fully characterized by Lemma 2.

Online distribution. Let q_σ denote the lender's posterior belief about the probability that the seller is of type H, with $\sigma \in \{p_H, p_L\}$. Using Bayes' rule, we get

$$q_{p_H} = \frac{xq}{1 - x + q(2x - 1)} \tag{OA.1}$$

$$q_{p_L} = 1 - \frac{x(1-q)}{x - q(2x - 1)} \tag{OA.2}$$

Suppose the lender offers the separating contract with repayments r_L^S and r_H^S given in Lemma 3. Given belief q_σ, her expected profits are

$$\mathcal{L}_O^S(\sigma) = (1 - \lambda)p_L + q_\sigma(\theta - 1) - 1. \tag{OA.3}$$

However, this is not the only possible contract. Since she receives an informative signal, the lender can also offer a contract with partial participation (PP), which specifies a single repayment $r^{PP} = (1-\lambda)p_H + \lambda\theta$ that extracts H-sellers' entire surplus. Faced with these demands, L-sellers will choose to abscond with λp_L, since it leaves them strictly better off than repaying r^{PP}. The partial participation contract merely needs to satisfy H-sellers' participation constraint. Since L-sellers do not participate, there is no need to enforce incentive compatibility. This enables the lender to increase H-sellers' repayment relative to a contract with full participation. In this case, the lender's expected profits are

$$\mathcal{L}_O^{PP}(\sigma) = q_\sigma[(1-\lambda)p_H + (\theta - 1)] - 1. \tag{OA.4}$$

Comparing equations (OA.3) and (OA.4) highlights the lender's trade-off between these two contracts. With separation, all sellers participate. While this depresses the repayment that the lender can charge vis-a-vis L-sellers' participation constraint, it is earned with probability 1. By contrast, partial participation enables the lender to extract more from H-sellers, but incurs losses whenever L-sellers cannot repay and abscond. It is easy to see that the lender prefers partial participation over separation if and only if $q_\sigma \leq \frac{p_L}{p_H}$. Using equations (OA.1) and (OA.2) together with the fact that $q < \frac{p_L}{p_H}$ (Assumption 2), we can conclude the following:

Lemma 4. *Suppose sellers distribute online and define* $\bar{x} \equiv \frac{p_L(1-q)}{q(p_H - p_L) + (1-q)p_L}$. *Then, for* $x \geq \bar{x}$*, the lender offers a contract with partial participation upon receiving signal* p_H*, and a separating contract upon receiving signal* p_L*. For* $x < \bar{x}$*, the lender always offers a separating contract.*

Intuitively, a sufficiently precise signal enables the lender to increase the potential for rent extraction by "tailoring" the contract terms. When the signal is sufficiently precise, a good signal implies that the seller is likely to be of high type. In this case, she is better off by opting for full rent extraction from H-sellers, since the risk that the seller is of low type is small. Conversely, when the signal is low, the lender can be confident to meet an L-seller, so that partial participation is too costly in terms of foregone revenue. By contrast, such contract tailoring is not sufficiently profitable when the signal is noisy, so the lender always opts for the separating contract.

OA.1.2 Sellers' choice of trading venue

We can now determine sellers' choice of trading venue. As before, their payoff is given by expected sales revenue minus expected loan repayment plus any benefits from continuation financing. Since offline distribution does not generate any signal, seller's payoffs are unchanged relative to the benchmark model. Depending on which contract the bank offers, they are given by equations (4) and (5).

Next, we turn to the case when sellers choose to trade online. Consider first the case of a precise signal, $x \geq \bar{x}$. We let $\mathcal{S}_O^S(\sigma)$ and $\mathcal{S}_O^{PP}(\sigma)$ denote sellers' expected payoffs conditional on the signal realization under the separating and partial participation contract, respectively. Then, their expected payoff under online distribution with a precise signal is given by

$$\begin{aligned} \mathcal{S}_O^{x\geq\bar{x}} &= Pr(\sigma = p_H)\,\mathcal{S}_O^{PP}(p_H) + Pr(\sigma = p_L)\,\mathcal{S}_O^{S}(p_L) \\ &= q[\lambda p_H + (1-x)(1-\lambda)(p_H - p_L)] + (1-q)\lambda p_L. \end{aligned} \tag{OA.5}$$

This expression shows that sellers' expected profits is decreasing in the signal precision x. This is due to the lender's use of the partial participation contract, which enables her to extract the entire surplus from all sellers. Accordingly, H-sellers earn the information rent $(1-\lambda)(p_H - p_L)$ only with probability $1-x$, i.e. in the case where the lender gets a wrong signal. As $x \to 1$, this effect diminishes and the lender gets to extract everything. Hence, her payoff converges to the case with full precision in equation equation (6).

Finally, consider the case of an imprecise signal, $x < \bar{x}$. Since the lender offers the separating contract for any signal, sellers' payoff is the same as with

$\mathcal{P}$-money, i.e.

$$\mathcal{S}_O^{x<\bar{x}} = q\left[\lambda p_H + (1-\lambda)(p_H - p_L)\right] + (1-q)\lambda p_L. \tag{OA.6}$$

In this case, H-sellers always earn the informational rent. Combining equations (4), (5), (OA.5) and (OA.6) with Lemma 4 then allows us to conclude the following.

Proposition 4. ***(Equilibrium with an imperfect signal.)*** *Define $\bar{\alpha} = \lambda\frac{\theta - p_L}{\theta - 1}$, $\alpha^*(x) \equiv 1 - x(1-\lambda)$, $\alpha^{**} \equiv 1 - \lambda\frac{\theta - p_L}{p_H - p_L}$ and $\alpha^{***}(x) \equiv 1 - x(1-\lambda) - \lambda\frac{\theta - p_L}{p_H - p_L}$. Then,*

1. *For $x < \bar{x}$, sellers distribute offline if $\alpha \in [\alpha^{**}, \bar{\alpha}]$, and online otherwise.*
2. *for $x \geq \bar{x}$ and $\alpha > \bar{\alpha}$, sellers distribute offline if $\alpha > \alpha^*(x)$, and online otherwise.*
3. *for $x \geq \bar{x}$ and $\alpha \leq \bar{\alpha}$, sellers distribute offline if $\alpha > \alpha^{***}(x)$, and online otherwise.*

Figure A.1 illustrates the equilibrium in the space (α, x). When the signal is imprecise, $x < \bar{x}$, the equilibrium is the same as the one with $\mathcal{P}$-money described in Section 4.1. Since the signal is imprecise, digital money enables online distribution, but at the same time preserves informational rents. Accordingly, sellers only opt for offline distribution (with a separating contract) when the rents associated with cash exceed the efficiency gains that arise from online sales. This is the case whenever $\alpha \in [\alpha^{**}, \bar{\alpha}]$, i.e. α is sufficiently low to rule out a partial participation contract, but sufficiently high to avoid online distribution. As detailed in Section 4.1, this interval collapses whenever the efficiency gains from online distribution exceed the social value of the continuation project, i.e. for $p_H - p_L > \theta - 1$.

The equilibrium with a precise signal ($x \geq \bar{x}$) is somewhat more complex. Since the lender optimally varies the contract terms on the realization of the signal (Lemma 4), sellers' payoff with online distribution depends with the signal precision x (see equation OA.5). Hence, consistent with the analysis in Section 3, it is possible to obtain an equilibrium with offline distribution for $\alpha > \bar{\alpha}$, i.e. when the lender offers a partial participation contract. In Figure A.1, this is not

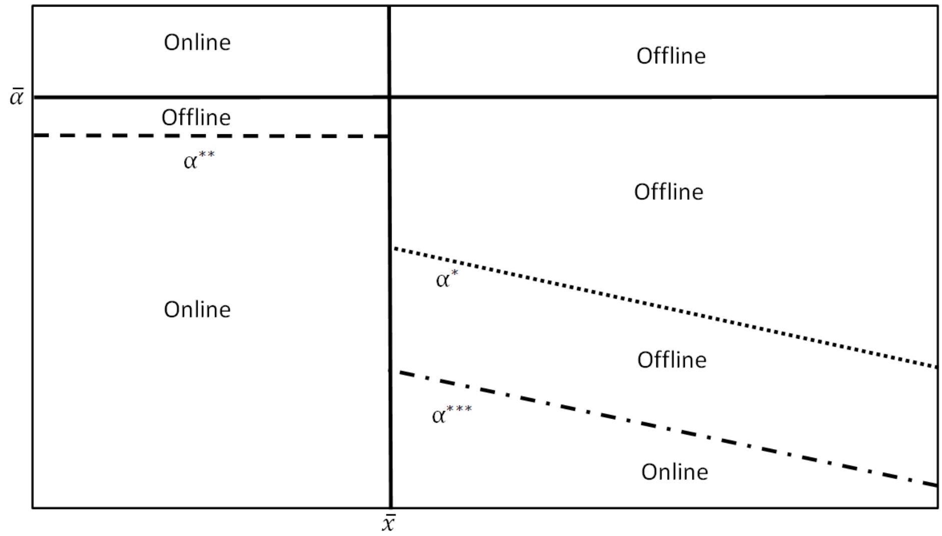

Figure A.1: Equilibrium Map in the (α, x)-space. Parameter values are: $p_H = 28$, $p_L = 10$, $\theta = 24$, $\lambda = 0.3$, $q = 0.2$. The y-axis is truncated at $\lambda = \frac{p_L - 1}{p_L} = 0.9$. The labels indicate sellers' equilibrium venue choice ("Online" or "Offline").

the case because λ is relatively low ($\lambda = 0.3$). Accordingly, sellers opt for online distribution whenever $\alpha > \alpha^{***}(x)$.

While the equilibrium for the general case shares the key features of the extreme cases with full and no precision, there is one noteworthy extra feature. Whenever the lender uses an imperfect signal for tailoring the lending contract (i.e. whenever $x \in (\bar{x}, 1)$), L-sellers abscond in equilibrium with sales p_L. This generates a deadweight loss of $(1-x)(1-q)(1-\lambda)p_L$. This additional inefficiency is not present in the previously analyzed cases because contract tailoring cannot arise when the signal is useless ($x = \frac{1}{2}$), and the deadweight loss is zero when the signal is perfect ($x = 1$).

The two inefficiencies previously analyzed continue to operate in the general case. Whenever sellers distribute offline, some output is lost relative to the case of online sales. Moreover, offline distribution with a partial pooling contract generates inefficient continuation investment because HL-sellers are not refinanced. We conclude the following.

Proposition 5 (Welfare). *The economy is efficient if*

1. *For $x < \bar{x}$, the economy is inefficient for $\alpha \in [\alpha^{**}, \bar{\alpha}]$, and efficient otherwise. In particular, for $p_H - p_L > \theta - 1$, the economy is always efficient.*
2. *For $\bar{x} < x < 1$, the economy is always inefficient.*
3. *For $x = 1$, the economy is inefficient for $\alpha \in [0, \alpha^{***}(1)] \cup [\bar{\alpha}, \lambda]$, and efficient otherwise.*

Taken together, a low signal precision can only give rise to an inefficient equilibrium for intermediate values of α. In this case, cash is not fully crowded out, and sellers distribute offline with a separating contract. This is inefficient because some potential sales are lost. Whenever $p_H - p_L > \theta - 1$, this inefficiency disappears.

If the signal is sufficiently precise $\bar{x} < x$, the equilibrium can only be efficient when the signal is perfect ($x = 1$) and sellers opt for online distribution. Otherwise, contract tailoring yields a deadweight loss. In addition, whenever sellers stay offline, sales and continuation investment can be inefficiently low.

OA.2 Endogenous prices

In the main text, the price structure is given exogenously. In this section, we show how to endogenize this price structure. To this end, we introduce buyers and assume that prices are determined by Nash bargaining. We denote buyers' bargaining power by η. While this approach does not change our main results, it delivers further insights. The logic of the analysis follows that of the main text, so we only sketch the key results here.

OA.2.1 Nash bargaining

In solving for the bargaining solution between buyers and sellers, we treat sellers and lenders as a coalition, following Petrosky-Nadeau and Wasmer (2017). Once the negotiation is concluded, sellers and lenders decide on how to share the joint surplus. Recall that we sellers can abscond with a fraction λ of production or the initial loan. We assume that they exit if bargaining fails.

To determine the joint surplus from trade, we need to consider not only the meeting $m \in (s,b)$, but additionally condition on lender's refinancing decision, $k \in \{0,1\}$. Whenever a loan is extended, H-sellers will generate an additional payoff $\theta - 1$ for the lender/seller coalition. Since any repayment r splits the surplus between the lender and the seller, it does not enter the bargaining solution between the coalition and the buyer.

If the buyer and seller agree to trade at $p(m,k)$, the seller/lender coalition earns $p(m,k) - 1 + \Delta(m,k)$, where

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

Without trade, the seller walks away with his outside option and obtains λ. Since the lender's investment of 1 is sunk, the the joint payoff for the lender/seller coalition is $\lambda - 1$. Combining the previous two equations, the joint surplus from trade for the seller/lender coalition is $p(m,k) - \lambda + \Delta(m,k)$. Since buyers have deep pockets, their surplus from trade is $u(m) - p(m,k)$, where $u(m) = u_H$ for $m = (H,H)$ and $u(m) = u_L$ otherwise. The bilateral price $p(m,k)$ is given by[25]

$$p(m,k) = (1-\eta)u(m) + \eta\lambda - \eta\Delta(m,k). \tag{OA.7}$$

For ease of notation, we define the following

$$p(m,k) = \begin{cases} p_{HH} \equiv (1-\eta)u_H + \eta\lambda - \eta(\theta - 1) & \text{if } (m,k) = ((H,H),1), \\ p_{HL} \equiv (1-\eta)u_L + \eta\lambda - \eta(\theta - 1) & \text{if } (m,k) = ((H,L),1), \\ \tilde{p}_{HL} \equiv (1-\eta)u_L + \eta\lambda & \text{if } (m,k) = ((H,L),0), \\ p_L \equiv (1-\eta)u_L + \eta\lambda & \text{if } (m,k) = ((L,b),0). \end{cases} \tag{OA.8}$$

[25]Formally, it solves $\max_p \left[u(m) - p(m,k)\right]^{\eta} \left[p(m,k) - \lambda + \Delta(m,k)\right]^{1-\eta}$.

Whenever H-sellers obtain a second loan, $k = 1$, they generate the extra surplus $\theta - 1$ and buyers can extract a share η thereof. This implies that HL-sellers generate lower sales than L-sellers in case they are refinanced ($p_L > p_{HL}$). This increases price dispersion relative to our baseline model. Importantly, this increase in dispersion is conditional on the lender's refinancing choice. Henceforth, we impose the following parametric assumption

Assumption 3. $\theta \leq \overline{\theta} \equiv min\{\frac{(1-\eta)(u_H-u_L)+\eta}{\eta}, \frac{(1-\eta)u_L+\eta(1+\lambda)}{1+\eta}\}$.

This assumption guarantees that the price ordering $p_{HH} > p_L$ is always satisfied. Moreover, it ensures that all contracts studied below are feasible. It is a weaker version of Assumption 1 in the main text. Thanks to the feedback effect from refinancing decisions to prices, the model with Nash bargaining can generate a non-trivial contract choice for the lender without a lower bound for θ.

OA.2.2 Loan repayment

We study the contracts with online and offline distribution separately. As in the main text, we assume that q is sufficiently low to render uninformed lending profitable and rule out the use of a partial participation contract. Specifically, we assume the following

Assumption 4. $q < \bar{q} \equiv \min\{\frac{1}{(1-\lambda)\theta}, \frac{(1-\eta)u_L+\eta\lambda-\eta(\theta-1)}{(1-\eta)u_H+\eta\lambda-\eta(\theta-1)}\}$.

Online distribution. When sellers choose online distribution with $\mathcal{D}$-money, the lender infers their type perfectly and the relevant sales prices are p_{HH} (all H-sellers generate high sales and are refinanced) and p_L. Binding participation constraints yield loan repayment $r_H^{\mathcal{D}} = (1-\lambda)p_{HH} + \lambda\theta$ and $r_L^{\mathcal{D}} = (1-\lambda)p_L$. Feasibility, $r_H^{\mathcal{D}} \leq p_{HH}$, is ensured by Assumption 3. Sellers' expected payoff is

$$\mathcal{S}_O^{\mathcal{D}} = q\lambda p_{HH} + (1-q)\lambda p_L. \tag{OA.9}$$

Offline distribution. Now suppose sellers distribute offline. When the lender offers a separating contract, she can infer sellers' type perfectly. Hence, in this case, the relevant sales prices are p_{HH}, p_{HL}, and p_L. The usual steps lead to a binding PC of HL-sellers, who has the lowest sales (recall $p_L > p_{HL}$), and a binding IC of HH-sellers, so $r_H^S = (1-\lambda)p_{HL} + \lambda\theta$ and $r_L^S = (1-\lambda)p_{HL}$. Feasibility is satisfied by Assumption 3. The expected profits are

$$\mathcal{L}_F^S = (1-\lambda)p_{HL} - 1 + q(\theta - 1), \tag{OA.10}$$

$$\begin{aligned}\mathcal{S}_F^S &= \alpha q[\lambda p_{HH} + (1-\lambda)(p_{HH} - p_{HL})] + (1-\alpha)q\lambda p_{HL} \\ &\quad + (1-q)[\lambda p_L + (1-\lambda)(p_L - p_{HL})].\end{aligned} \tag{OA.11}$$

Under this contract, HH-sellers and L-sellers receive an informational rent.

Now consider the partial pooling contract. Since the lender can only identify HH-sellers, HL-seller are not refinanced. Because of the feedback via Nash bargaining, the relevant sales prices are p_{HH}, $\tilde{p}_{HL}$, and p_L. The usual steps lead to a binding PC of L-sellers and HL-sellers (they generate the same sales as $\tilde{p}_{HL} = p_L$) and a binding IC of HH-sellers, so $r_H^S = (1-\lambda)p_L + \lambda\theta$ and $r_L^S = (1-\lambda)p_L$. Feasibility follows from Assumption 3. The expected profits for the lender and sellers are

$$\mathcal{L}_F^P = (1-\lambda)p_L - 1 + \alpha q(\theta - 1), \tag{OA.12}$$

$$\mathcal{S}_F^P = \alpha q[\lambda p_{HH} + (1-\lambda)(p_{HH} - p_L)] + (1-\alpha q)\lambda p_L. \tag{OA.13}$$

In contrast to the separating contract, only HH-sellers receives an informational rent.

As in the main text, it is straightforward to deduce that neither a full pooling contract nor a partial participation contract is optimal for the lender. Comparing the lender's expected payoffs, we reach the following result.

Lemma 5. *Suppose that sellers choose offline distribution. Then, the lender offers* *a separating contract (S) whenever*

$$(1-\alpha)q \geq \eta(1-\lambda),$$

and a partial pooling (P) contract otherwise.

As in the main text, this condition represents the trade-off between the benefits and costs of full separation versus partial pooling. With full separation, the lender is always informed, so the probability that the surplus $\theta - 1$ is reaped increases by $(1-\alpha)q$ (from αq to q). However, this requires her to increase in sellers' informational rents relative to the partial pooling contract by $(1-\lambda)(p_L - p_{HL}) = (1-\lambda)\eta(\theta-1)$. Intuitively, the separating contract reduces HL-sellers' sales from $\tilde{p}_{HL} = p_L$ to p_{HL} because buyers can appropriate $\eta(\theta - 1)$. This forces the lender to offer a lower repayment to ensure HL-sellers' participation, resulting in higher informational rents for the remaining sellers.

OA.2.3 Sellers' choice of distribution venue.

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, the informational rents are additionally affected by buyers' bargaining power η, but the underlying economic mechanism is the same. The following Proposition characterizes the equilibrium with Nash bargaining.

Proposition 6. ***(Equilibrium with Nash bargaining.)***
1. For $\eta(1-\lambda) \geq q(1-\alpha)$, lenders offer the partial pooling contract under offline trade. Sellers distribute their goods online if $\lambda \geq \alpha$, and offline otherwise.
2. For $\eta(1-\lambda) < q(1-\alpha)$, lenders offer the separation contract under offline trade. Sellers distribute their goods online if $q(\lambda-\alpha)(1-\eta)(u_H - u_L) \geq (1-q)(1-\lambda)\eta(\theta-1)$, and offline otherwise.

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