Open Banking with Interdependent Payment and Credit Markets

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Abstract

We examine the joint pricing of loans and payment services under open banking when firms are subject to moral hazard and monitoring relies on payment information. Open banking is expected to improve consumer welfare by fostering competition and access to credit. By accounting for cross-market information spillovers we demonstrate that this need not be the case. We find that (i) banks respond to open banking by using their market power in the payments market to appropriate the value generated in the credit market indirectly, (ii) while open banking increases efficiency, it may end up hurting capital-constrained and capital-unconstrained firms alike. Our results underline the importance of accounting for information spillovers between data-producing and data-driven markets.

Keywords: Open banking, payments, credit markets, information, moral hazard.

JEL Classification: G01, G11, G21

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1 Introduction

Data is at the heart of banking business. On one hand, knowing more about your customer can alleviate information frictions between the bank and its borrowers and thus improve access to credit. On the other hand, information advantage over competitors gives rise to market power and economic rents for the incumbent, and ultimately reduce competition. The non-rivalrous nature of data naturally implies that data sharing can foster competition, efficiency and innovation. On this premise, led by a series of regulatory changes, an open data movement has emerged in the banking sector. Such "open banking" initiatives enable customers to share their payment data with third party entities through standardized and secured open API's (application programming interfaces).

Open banking is set to transform the banking industry as we know it today. However, its full impact remains difficult to predict. We argue that superficial commentary and analysis of open banking often overlook the potential spillover between *data-producing* and *data-driven* markets. A data-producing product or service may generate value in excess of its intrinsic utility insofar that it can improve the profitability of connected data-driven markets. Similarly, data-intensive services such as bank lending benefit from being jointly offered with a payment account as the latter feeds into the bank's information-intensive screening- and monitoring process.

This paper offers the first general equilibrium analysis of the economic impact of open banking that accounts for such information spillover. We specifically focus on payment services and the provision of business loans, though our analysis holds significance for other markets where similar information spillovers prevail. Our model involves firms with heterogeneous equity endowments that are subject to moral hazard. Banks provide both payment services and loans, and they are endowed with a monitoring technology that utilizes payment data. With the introduction of open banking, a firm's payment data becomes easily accessible for the competitor, so long as the firm uses a digital payment service within the banking sector, rather than cash, cryptocurrency, or other non-bank money provider.

We find that with the introduction of open banking, credit market indeed becomes more competitive, which decreases banks' profitability and increases firms' surplus from lending. This results in a downward shift in the supply of payment services and an upward shift in its demand among the firms that need monitoring to secure loans, thus increasing the price of the service. Firms with very low or high levels of wealth/equity - i.e. firms that are subject to either a too severe moral hazard effect or no such effect at all - lose from the introduction of open banking. While open banking decreases credit rationing and increases overall efficiency unambiguously, its impact on total surplus of firms and banks depends on the distribution of firm wealth/equity.

To sum up, our analysis provides three new insights. First, even though open banking levels the playing field in the credit market, banks may shift rent extraction to payment service market where they still hold market power. This reinforces the concern that has been raised by commentators and policy makers who envisage open banking as "the end of free banking". Second, open banking may have unintended consequences and may result in hurting consumer welfare when spillovers to all bank products are considered. Third, open banking may have unintended distributional effects among firms, and our framework provides a way to think about the potential trade-offs. Crucially, our study underlines the importance of accounting for information spillovers between different markets while evaluating the overall effect of data policies and regulations.

Open banking across the world. Open banking is gaining global traction. Collecting data on worldwide open banking initiatives, Babina et al. (2022) find that around half the countries have government-led open banking efforts at least at a nascent stage. In the EU, open banking has already become part of the regulatory framework in 2016 with the Revised Payment Services Directive (PSD2) and a regulatory framework for open finance (an expansion of the scope of open banking to all financial data) is expected to be in place by 2024 (EU Commission, 2020). In a parallel effort, the Data Act (EU Commission, 2022) includes measures to allow users to share the data generated by their connected devices while GDPR (General Data Protection Regulation) suggests a more direct consumer control over data in general.

Japan is another example to countries where open banking has matured. The revised Banking Act which requires banks to introduce open APIs within two years came into effect in 2018 with notable private collaborations to build joint payment systems preceding that. In Australia, open banking regulations took start with the Consumer Data Right (CDR) in 2020, gradually extending its scope of data and transforming into open finance by 2022. In the US, despite some display of government interest in promoting data-portability (the White House, 2021), open banking trend is primarily led by the private sector. Examples include the Financial Data Exchange, an industry-led initiative seeking to standardize API data.

Related Literature. Our study draws insights from the literature on banking activities with information spillover on lending. 'Checking account hypothesis' (Nakamura et al., 1992) claims that borrowers' checking accounts contain valuable information that can be leveraged for improved screening and monitoring. This hypothesis - with origins dating back to Black (1975) for household lending and Fama (1985) for commercial lending - is supported by more recent empirical studies. Norden and Weber (2010) find that observing abnormalities in borrowers' credit line usage, limit violations, and cash inflows can substantially improve default predictions, particularly for SMEs and individuals. Providing a similar result, Mester et al. (2007) claim that the value of transaction accounts lies in their capacity to provide high frequency information on loan collateral value. Puri et al. (2017), on the other hand, underline the value of historical data on account activity as it provides a baseline to evaluate borrowers' current status. Their findings suggest that observing potential borrowers' account activities prior to lending make lenders act differently in both screening and monitoring, and eventually reduce loan defaults. Lastly, subsequent to the rise of FinTech lending, several studies demonstrate the informational value of borrowers' digital footprints - including activities on e-commerce or social media platforms - in evaluating loan risk (Agarwal et al. (2020), Berg et al. (2020), Frost et al. (2019), Jagtiani and Lemieux (2019)).

Our study also relates to the literature on equilibrium credit rationing. Previous studies point out to various channels by which equilibrium rationing may arise in credit markets with imperfect information such as adverse selection (Stiglitz and Weiss (1981), Jaffee and Russell (1976)), moral hazard (Stiglitz and Weiss (1981), Holmstrom and Tirole (1997)) and costly state verification (Gale and Hellwig (1985), Williamson (1986)). Both Jaffee and Russell (1976) and Gale and Hellwig (1985) describe credit rationing as each borrower receiving funding at a smaller size than they would like. Alternatively, in Stiglitz and Weiss (1981) and Williamson (1986), credit rationing corresponds to the case where some firms are denied credit completely while other identical firms receive it. While these studies assume ex-ante identical borrowers, the analysis of Holmstrom and Tirole (1997) entails borrowers with heterogeneous wealth. Firm moral hazard, induced by unobservable firm effort, results in credit rationing, i.e. firms with less wealth than a threshold value are denied credit. Firm wealth helps alleviate moral hazard and wealth can be partially substituted by loan monitoring. Our model is largely inspired by Holmstrom and Tirole (1997) yet it diverges from it in several ways. Holmstrom and Tirole (1997) investigate the result of capital tightening - both on borrowers' and lenders' side – on credit allocation by assuming bank moral hazard and an elastic supply of funds. Our approach does not contain bank moral hazard and assumes an inelastic supply of funds. Most importantly, we introduce information spillovers from payment services to loan provision and use this framework to examine the implications of open banking.

Lastly, our study contributes to a growing literature studying welfare and efficiency implications of open banking. Building a banking model with maturity transformation, Goldstein et al. (2022) arrive at a conflicting result to ours, i.e. while open banking improves consumer welfare, it may deteriorate efficiency of allocation. Their results are driven by the feedback loop between bank financial cost and investment. He et al. (2023), on the other hand, point out to a potential risk from the borrowers' perspective by studying the effect of open banking on the competition between a FinTech lender and a traditional bank. They show that if the FinTech has superior screening technologies, levelling the playing field between the two lenders in terms of data access may result in transferring market power from the traditional bank to the FinTech lender - rather than eliminating it - and leave all borrowers worse off.

A few earlier studies precede our work in investigating the role of cross-market information spillovers in determining open-banking outcomes. Examining the 2016 Indian Demonetization on payments, Ghosh et al. (2021) find empirical evidence indicating that open banking improves the likelihood of loan approval and lending conditions in general and particularly more for low-risk borrowers. They also build a theoretical model to argue that this effect shifts demand for cashless payments upwards, creating a reinforcing feedback loop. Importantly, these results do not require consumers' demand for loans and payment services to be met by the same entities as consumers' choice between cash and digital payment methods can signal creditworthiness without necessarily disclosing payments.

Parlour et al. (2022) provide a theoretical welfare analysis of FinTech competition in payments where, similar to Ghosh et al. (2021), borrowers' choice of payment method constitutes a signal for creditworthiness. They show that, in the absence of data sharing, competition from Fintech payment providers disturbs the information spillover between banks' payment and credit services with an ambiguous effect on the loan market. They argue that open banking can harm consumers with more affinity towards banks' payment services than those of FinTechs by raising service fees. Similarly, low-risk borrowers may get hurt by open banking if data portability improves banks' screening capacity.

Babina et al. (2022) provide empirical findings in support of the argument that open banking mitigates adverse selection and barriers to entry in markets for financial services. They calibrate an IO model with consumer heterogeneity in marginal cost, willingness to pay and product customization needs and produce outcomes in line with their empirical findings. They also underline that open banking may hurt some consumers by improving screening and harm financial inclusion in the long run by eliminating incentives to provide data-producing services.

Our study diverges from these earlier works in several ways. First, in our model consumer heterogeneity derives from firm equity and each firm's equity is public knowledge, i.e. there are no ex-ante unobserved consumer types. Therefore, unlike the studies cited above which involve models with screening and adverse selection components, in our model choice of payment method does not signal borrowers' type and distributional outcomes do not arise from the change in lenders' screening capacity. Instead, our model identifies another channel for distributional outcomes, namely the heterogeneity in firm equity which determines to what extend firms' losses in the payment market (as a result of the price hike) is compensated by the enhanced competition in the loan market. Secondly, in contrast to Ghosh et al. (2021), in our model payments and loans are provided by the same entities. Moreover, open banking changes competitiveness in the loan market unlike Parlour et al. (2022) which entails a monopolistic borrower or Ghosh et al. (2021) which entails a perfectly competitive loan market. This framework enables us to examine how open banking alters incentives for both the supply and demand of payment services. Earlier analyses study either the effect of information spillovers in a partial equilibrium framework accounting either exclusively for demand-side effects (Ghosh et al. (2021),Parlour et al. (2022)) or exclusively for supply side effect (Babina et al., 2022). Therefore, our paper constitutes the first general equilibrium analysis of open banking with information spillovers to the best of our knowledge.

The remainder of the paper is organized as follows. Section 2 describes the model, section 3 model, section 4 solves the model with open banking and open data access and section 6 concludes.

2 Model setup

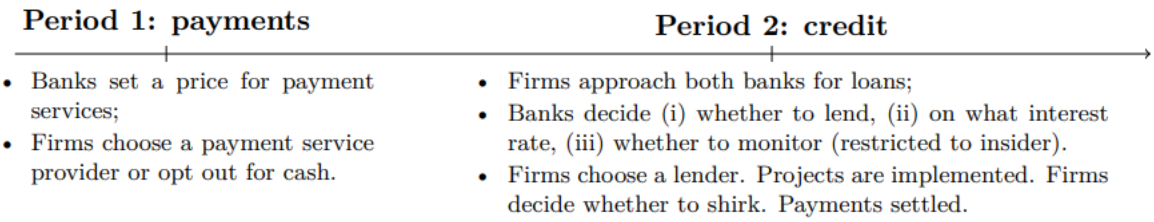
The model consists of two periods. In the first period, two banks, $j \in \{A, B\}$, offer differentiated digital payment services to a unit mass of firms with heterogeneous preferences in payments, each with a constant demand of one payment method. Bank and firm heterogeneity is captured with a Hotelling line on which firms are distributed uniformly and a bank is positioned on each end. Banks provide payment services at prices $\{p_A, p_B\}$ incurring a homogeneous marginal cost of ϕ. Firms may choose either bank's payment service and doing so receive a homogeneous utility, U, and incur a heterogeneous transaction cost, $\tau \times d_{ij}$, where τ is the Hotelling-parameter and d_{ij} is the firm's distance to the selected bank. Alternatively, firms can opt out for using cash, the utility of which is normalized to zero. Let the payment method choice of firm i be denoted by $\theta_i \in \{A, B, C\}$ where the first two letters represent the banks and C represents cash.

In the second period, each firm has access to an identical, indivisible project which requires a unit of funding. Firms are endowed with heterogeneous equities, $K_i < 1 \sim F(K)$, distributed independently from firm position. Thus, all firms need external funding to implement their projects. Projects yield $R > 1$ if they succeed and 0 if they fail. The probability of success depends on the effort exerted by the firm, $s_i \in \{0, 1\}$. If the firm exerts high effort (*'work'*, $s_i = 0$), the probability of success is ρ_H, whereas with low effort (*'shirk'*, $s_i = 1$), it is $\rho_L < \rho_H$. We assume that a project brings positive expected return if and only if the firm does not shirk, so $\rho_H R - 1 > 0 > \rho_L R - 1$. Shirking is unobservable to banks and brings private benefits to firms. The size of this benefit depends on the bank's monitoring decision as we explain below.

Banks offer identical loan products and there are no transportation costs to borrowing, i.e., there is no product differentiation in the credit market. Banks have deep pockets. For each firm, they decide simultaneously whether or not to offer a loan and if they do, what interest rate to charge (r_{ij}) and whether or not to monitor the firm. We denote the monitoring decision by $m_{ij}(\theta_i) \in \{0, 1\}$. Monitoring reduces firms' private benefits from shirking from b_0 to $b_m < b_0$. However it incurs a cost M to the bank, and it requires having access to the firm's transaction data.

We explore market outcomes under a varying set of rules for monitoring activity. The benchmark case represents a setting with no monitoring technology or, equivalently, a too costly technology to be optimally taken up, i.e. $\rho_H R - 1 - M > 0$. The second and third cases involve a more efficient monitoring technology where monitored projects bring positive social value, i.e. $\rho_H R - 1 - M < 0$, however they differ in terms of the rules regarding banks' access to transaction data. In the former case, a bank can access transaction data only when it is generated by its own payment services, thus banks can only monitor the firms that are their customers at the payment market. In the third case, both banks have access to all transaction data regardless of the bank generating it. Therefore, banks can monitor all firms which do no opt out for cash. The timeline of the game is summarized in Figure 1.

Figure 1: Timeline



3 No monitoring

We assume first that no loan monitoring technology is available or, equivalently, monitoring is prohibitively costly ($\rho_H R - 1 - M < 0$) and therefore not used by banks in equilibrium. In this case credit and payment market outcomes are independent from each other. Information asymmetry between borrowers and lenders (hereinafter referred to as *vertical information asymmetry*) in the credit market results in credit rationing. We present the symmetrical equilibrium results for both markets below.

3.1 Credit market equilibrium

We start with the equilibrium in the market for credit, and consider the firms' and the banks' decision problem in turn.

Firm's problem. The expected net profit of firm i when borrowing from bank j is:

$$\mathbb{E}[\Pi_{ij}^{t=2}] = (s_i \rho_L + (1 - s_i)\rho_H)(R - (1 - K_i)(1 + r_{ij})) - K_i + s_i b_0. \quad (1)$$

As the expected project return is negative when the firm shirks, a bank will fund a firm if and only if it can credibly commit to not shirking, i.e. if the firm's expected profit from not shirking is at least as high as its expected profit from doing so. This constitutes the firm's incentive compatibility (IC) constraint:

$$p_H \left(R - (1 - K_i)(1 + r_{ij})\right) - K_i \geq p_L \left(R - (1 - K_i)(1 - r_{ij}) - K_i + b_0\right)$$

Solving the IC for equality gives an upper threshold for loan interest rate conditional on firm equity, $r_0^{IC}(K_i)$:

$$r_0^{IC}(K_i) = \frac{R - \frac{b_0}{\Delta\rho}}{1 - K_i} - 1,$$

where $\Delta\rho = \rho_H - \rho_L$. A firm will demand funding at the interest rate r_{ij} if and only if its expected profit from borrowing without shirking. This constitutes the firm's individual rationality (IR) constraint

$$p_H \left(R - (1 - K_i)(1 + r_{ij})\right) - K_i \geq 0$$

Solving the IR for equality gives an upper threshold for loan interest rate conditional on firm equity, $r^{IR}(K_i)$,

$$r^{IR}(K_i) = \frac{R - \frac{K_i}{\rho_H}}{1 - K_i} - 1.$$

Bank's problem. The expected profit of bank j from lending to firm i at the interest rate r_{ij} is:

$$\mathbb{E}[\Omega_{ij}^{t=2}] = \rho_H(1 - K_i)(1 + r_{ij}) - (1 - K_i) \tag{2}$$

In order for bank j to supply funding to firm i, its expected profit from doing so should be non-negative. This constitutes the IR constraint for banks and translates into a lower threshold for loan interest rate, $r_0^{min}(K_i)$, defined as

$$r_0^{min}(K_i) = \frac{1}{\rho_H} - 1$$

Equilibrium. Any equilibrium $r^\star$ must be incentive-compatible for the firm and rational for both the bank and the firm. This implies

$$r_0^{min} \leq r^\star \leq \min\{r_0^{IC}(K), r^{IR}(K)\}$$

Because $p_h R > 1$, it's trivial to see that $r_0^{min} < r^{IR}$. Solving $r_0^{IC}(K) = r_0^{min}$ defines a threshold

$$\overline{K} = \frac{\rho_H b_0}{\Delta\rho} - (\rho_H R - 1) \tag{3}$$

Lending is feasible if and only if $K \in [\bar{K}, 1]$. Since credit market is perfectly competitive, firms in $[\overline{K}, 1]$ receive funding at a loan rate of r_0^{min}, which brings zero expected profit to the bank.

Firms with equity less than $\overline{K}$ do not have enough skin in the game and cannot credibly commit to not shirking at a profitable interest rate for banks. Consequently, they do not receive funding despite having access to projects with positive net value, and there is credit rationing.

The share of served firms is

$$Z = 1 - F(\overline{K})$$

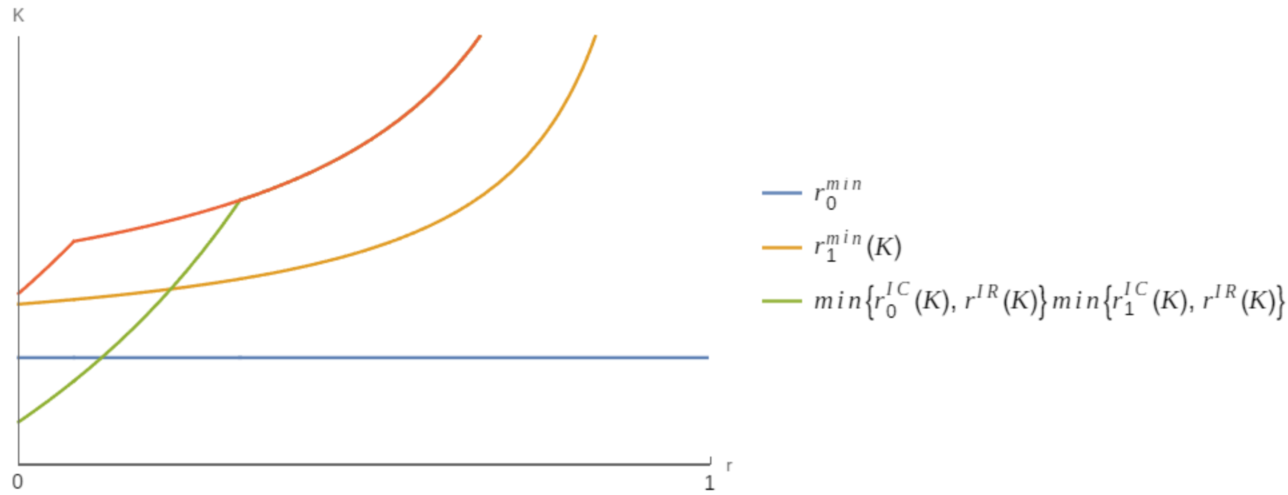
Credit rationing increases with private benefits to shirking while it decreases with expected project return (without shirking) and the effect of shirking on project success $(\rho_H - \rho_L)$. In equilibrium, banks make no profit in the credit market while total firm surplus in the profit market equals to

$$\sum_i \mathbb{E}[\Pi_i^{t=2}] = (\rho_H R - 1)(1 - F(\overline{K}))$$

We summarize these results in the following Lemma:

Lemma 1 *If monitoring is not possible, only firms with equity $K > \bar{K}$ are served where $\bar{K}$ is defined in Equation (3).* ***Proof.*** *Follows from above.* ■

Figure 2: Credit supply and demand



3.2 Payment Market

The expected profit of firm i in the payment market when it uses the payment service of bank j is

$$\mathbb{E}[\Pi_i^{t=1} | \theta_i = j] = U - p_j - \tau d_{ij} \tag{4}$$

We assume for simplicity that the market coverage is not perfect and at least some firms choose to use payment methods outside of the banking system. In the symmetrical equilibrium, a firm will always prefer the payment service of the closer bank to that of the farther. Therefore, the firm's binding choice is between cash and the payment service of the closer bank, and the bank de-facto can act a s a local monopolist. The distance between bank j and the firm that is indifferent between using cash or payment service gives the market share of bank j, x_j, and equals to

$$x_j = \frac{U - p_j}{\tau}$$

The expected profit of bank j in the payment market is

$$\mathbb{E}[\Omega_j^{t=1}] = \int_0^1 (p_j - \phi) x_j f(K) dK \tag{5}$$

Solving for the optimal price and market share is standard.

Lemma 2 *When payment markets are independent from credit markets due to lack of monitoring, the price of payment service is*

$$p = \frac{U + \phi}{2}$$

Each bank's market share is

$$x = \frac{U - \phi}{2\tau}$$

Bank surplus and firm surplus in the payment market are, respectively

$$S_B^{t=1} = \frac{(U - \phi)^2}{2\tau}$$
$$S_F^{t=1} = \frac{(U - \phi)^2}{4\tau}$$

Proof. *See Appendix A* ■

4 Monitoring without open banking

This section extends the benchmark case with a sufficiently cost efficient monitoring technology (i.e. $\rho_H R - 1 - M > 0$). Banks cannot access the transaction data generated by another bank's payment service, i.e. there is information asymmetry between banks in the credit market (hereinafter referred as *horizontal information asymmetry*). Consequently, a bank can only monitor the firms that use its own payment service. Let us refer such firms as *'insider borrowers'* of the bank and the remaining firms as its *'outsider borrowers'*.

4.1 Credit Market

Firm's problem. The expected profit of firm i borrowing from bank j becomes

$$\mathbb{E}[\Pi_{ij}^{t=2}] = (s_i\rho_L + (1-s_i)\rho_H)(R - (1-K_i)(1+r_{ij}) - K_i + s_i(m_{ij}b_m + (1-m_{ij}b_0) \quad (6)$$

Since private benefits from shirking decreases with monitoring, firms' IC constraint with monitoring implies a different upper threshold for loan interest rate compared to the case without and it is defined as

$$r_1^{IC}(K_i) = \frac{R - \frac{b_m}{\Delta\rho}}{1-K_i} - 1,$$

Firms' IR constraint is not affected by whether they are monitored or not. **Bank's problem.** The expected profit of bank j from lending to firm i becomes

$$\mathbb{E}[\Omega_{ij}^{t=2}] = \rho_H(1-K_i)(1+r_{ij}) - (1-K_i) - m_{ij}M \quad (7)$$

subject to

$$r_{ij} \leq min\{r_{m_{ij}}^{IC}(K_i), r^{IR}(K_i)\} \quad (8)$$

and

$$m_{ij} = 0 \text{ if } \theta_i \neq j \quad (9)$$

where equation 8 represents IC and IR constraints on the firm conditional on equity and monitoring decision while equation 9 represents banks' inability to monitor outsider borrowers. As monitoring is costly, banks' IR constraint with monitoring implies a different lower threshold for loan interest rate compared to the case without and it is defined as

$$r_1^{min}(K_i) = \frac{1}{\rho_H}\left(1 + \frac{M}{1-K_i}\right) - 1$$

Equilibrium. In figure 2, there is both supply and demand for loans with monitoring in the area the remains below both the r^{IR} and r_1^{IC} curves and above the r_1^{min} curve. Let us denote the firms with equities spanned by this area as $[\underline{K}, 1]$ where $\underline{\text{K}}$ is defined as

$$r_1^{IC}(\underline{K}) = r_1^{min} \iff \underline{K} = \frac{\rho_H b_m}{\Delta\rho} - (\rho_H R - 1 - M)$$

As previously discussed, firms in $[\overline{K}, 1]$ can also be funded without monitoring. Notice that the minimum profitable interest rate for banks to lend these firms is lower without monitoring than it is with monitoring, i.e.

$$r_0^{min} < r_1^{min}(K_i) \text{ for } K_i \in [0, 1]$$

Thus, competition drives loan interest rate again to $r_0^{min}(K_i)$ for $K_i \in [\overline{K}, 1]$, same as the benchmark case. Conversely, firms in $[\underline{K}, \overline{K}]$ can be funded only with monitoring, and therefore, only by their own bank. Banks act as monopolistic loan suppliers for their insider firms in this interval and charge the highest loan interest rate possible that does not induce moral hazard. As demonstrated in figure 2, for firms in $[\underline{K}, \hat{K}]$ this corresponds to $r_1^{IC}(K_i)$ while for firms in $[\hat{K}, \overline{K}]$ it corresponds to $r_1^{IR}(K_i)$ where $\hat{K}$ is defined as

$$r^{IR}(\hat{K}) = r_1^{IC}(\hat{K}) = \frac{R - b_m/\Delta\rho}{1 - \rho_H b_m/\Delta\rho} \iff \hat{K} = \frac{\rho_H b_m}{\Delta\rho}$$

For the firms in $[\hat{K}, \overline{K}]$, banks can set the interest rate such that they appropriate project return completely without inducing moral hazard. For firms with less equity than $\hat{K}$, however, banks have to decrease their own share from the project return to increase firms' skin in the game, otherwise firms will shirk. Therefore, loan interest rate decreases as firm equity decreases until $\underline{K}$ where firms appropriate the complete project return. Firms with less equity than $\underline{K}$ can not credibly commit to not shirking at a profitable interest rate for banks, with or without monitoring. Therefore, they do not receive funding regardless of their choice of payment method. Lemma 3 summarizes the equilibrium outcome in the credit market.

Lemma 3 *The expected profit of firms in the credit market conditional on firm equity and payment method choice is*

$$\mathbb{E}[\Pi^{t=2}(K_i, \theta_i)] = \begin{cases} \rho_H R - 1, & \text{if } K_i \geq \overline{K} \\ \frac{\rho_H b_m}{\Delta\rho} - K_i, & \text{if } \theta_i \neq C \;\; \& \;\; \hat{K}_1 \geq K_i > \underline{K} \\ 0, & \text{otherwise} \end{cases}$$

The expected profit of banks in the credit market from an insider borrower with equity K_i is

$$\mathbb{E}[\Omega^{t=2}(K_i)] = \begin{cases} \rho_H R - 1 - M, & \text{if } \overline{K} \geq K_i > \hat{K} \\ \rho_H R - 1 - M - \frac{\rho_H b_m}{\Delta\rho} + K_i, & \text{if } \hat{K} \geq K_i > \underline{K} \\ 0, & \text{otherwise} \end{cases}$$

Lemma 3 indicates that banks have market power on firms that need monitoring to receive funding which is a direct result of the horizontal information asymmetry in the credit market.

4.2 Payment Market

Firm's problem. With monitoring technology, choice of payment method becomes the determinant of the expected profit in the credit market for some firms. Thus, firms choose the payment method that maximizes their total expected profit across both markets. Total expected profit of firm i when it uses the payment service of bank j and when it opts out for cash are

$$\mathbb{E}[\Pi_i^{tot}|\theta_i = j] = U - p_j - \tau d_{ij} + \mathbb{E}[\Pi_i^{t=2}|\theta_i = j] \tag{10}$$

and

$$\mathbb{E}[\Pi_i^{tot}|\theta_i = C] = \mathbb{E}[\Pi_i^{t=2}|\theta_i = C] \tag{11}$$

respectively. The distance between bank j and the firm with equity K that is indifferent between the payment service of bank j and cash gives the market share of bank j conditional on firm equity and it is defined as

$$x_j(K) = \begin{cases} \frac{U - p_j + \rho_H b_m/\Delta\rho - K}{\tau}, & \text{if } \hat{K}_1 > K \geq \underline{K} \\ \frac{U - p_j}{\tau}, & \text{otherwise} \end{cases}$$

Bank's problem. With monitoring technology, payment service price becomes the determinant of banks' expected profit in both markets. Thus, banks will choose the payment service maximizing their total expected profit across both markets. Total expected profit of bank j is

$$\mathbb{E}[\Omega_j^{tot}] = \int_0^1 (p_j - \phi + \mathbb{E}[\Omega_j^{t=2}(K)])x_j(K)f(K)dK$$

Equilibrium. Equilibrium price and banks' market share in the payment market is presented in Lemma 4.

Lemma 4 *Equilibrium payment service price and the market share of each bank are, respectively,*

$$p = \frac{U + \phi - (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) + 2\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho} - K)f(K)dK}{2}$$

$$x(K) = \begin{cases} \frac{U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-2\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK+2(\rho_H b_m/\Delta\rho-K)}{2\tau}, & \textit{if } \hat{K}_1 > K \geq \underline{K} \\ \frac{U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-2\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK}{2\tau}, & \textit{otherwise} \end{cases}$$

Proof. *See Appendix B* ■

4.3 Welfare effects of a loan monitoring technology without open banking

Lemma 4 shows that credit and payment market outcomes become interdependent in the existence of a monitoring technology utilizing transaction data. Securing a higher share in the payment market among the firms in $[\underline{K}, \overline{K}]$ increases banks' expected profit in the credit market. Banks subsidize their payment services to attract these firms. Simultaneously, demand for payment service increases among the firms whose expected profit from the credit market becomes positive conditional on using a payment service, i.e. $[\underline{K}, \hat{K}]$, exerting a counteracting effect on price. The dominating effect depends on the distribution of firm equity. Payment service is subsidized if the share of firms in $[\underline{K}, \hat{K}]$ is sufficiently smaller than the share of firms in $[\hat{K}, \overline{K}]$ (see appendix C).

The share of payment service customers among firms in $[\underline{K}, \hat{K}]$ increases regardless of the direction of price change as some of these firms will choose to use a payment service despite making a negative profit from it in order to increase their overall expected profit. The share of payment service users among other firms, whose expected credit market profit does not depend on their choice of payment method, is determined by the direction of the change in price. Proposition 1 summarizes the effect of introducing a loan monitoring technology in both markets.

Proposition 1 *When banks* ***cannot*** *access the transaction data generated by other banks' payment services and a loan monitoring technology utilizing transaction data becomes available*

- *payment service price may increase or decrease depending on firm equity distribution.*
- *if price decreases, total expected profit increases for all firms regardless of their equity.*
- *if price increases, total expected profit increases only for the firms which benefit from monitoring and have equities below a certain threshold.*
- *the share of firms that use digital payment services increases.*
- *credit rationing decreases.*

- *total firm surplus increases.*

- *total bank surplus increases.*

Proof. *See Appendix C* ■

Loan monitoring alleviates credit rationing by allowing some firms which previously could not receive funding due to moral hazard to overcome this problem if they become payment service users. Less credit rationing translates into a higher total surplus in the credit market both for firms and for banks. Total payment market surplus may increase or decrease, both for firms and for banks as well as in total, depending on firm equity distribution and the relation between the social values of projects and payment services. Regardless of the payment market outcome, total surplus across both markets increase both for firms and for banks.

Loan monitoring technology has distributional effects if it results in a higher equilibrium payment service price. A higher price implies less surplus in the payment market for all firms which were payment service users in the benchmark case. In return, the expected profit in the credit market increases only for the firms in $[\underline{K}, \hat{K}]$ which remain payment service users. The lower the firm equity is the higher becomes the expected profit in the credit market and it eventually dominates the profit decrease in the payment market for a fraction of firms at the lower end of $[\underline{K}, \hat{K}]$. Total expected profit decreases for all other firms.

5 Open banking

Our next extension is to introduce *open banking*, i.e. allowing banks to access the data of all firms that use a digital payment service regardless of the bank providing it.

5.1 Credit Market

Firms' problem is identical to the one in section 4.1. Banks' problem, on the other hand, changes since horizontal information asymmetry is eliminated under open banking regime. The prerequisite for monitoring a firm is no longer that the firm uses the bank's *own* payment service but it uses *any* payment service. The corresponding model update is to change equation 9 to

$$m_{ij}(\theta_i) = 0 \text{ if } \theta_i = C$$

Equilibrium. Open banking does not change the credit market outcome for the firms in $[0, \underline{K}]$ and $[\overline{K}, 1]$ as loan supply for these firms does not depend on banks' access to transaction data. Conversely, for the firms that need monitoring to receive funding, i.e. $[\underline{K}, \overline{K}]$, open banking facilitates a perfectly competitive credit market, unlike the case without open banking. Competition drives loan interest rate offered to these firms to $r_1^{min}(K_i)$. Equilibrium credit market outcomes are summarized in Lemma 5

Lemma 5 *If banks can monitor any firm which uses a digital payment service, banks make no profit from lending while the expected profit of firms in the credit market conditional on firm equity and payment method choice is*

$$\mathbb{E}[\Pi^{t=2}(K_i, \theta_i)] = \begin{cases} \rho_H R - 1, & \textit{if } K_i \geq \overline{K} \\ p_H R - 1 - M, & \textit{if } \theta_i \neq C \ \ \& \ \ \overline{K} \geq K_i > \underline{K} \\ 0, & \textit{otherwise} \end{cases}$$

Lemma 5 shows that with open banking, i.e. without horizontal information asymmetry, banks have no market power in the credit market and all borrowing firms appropriate project return completely while banks make no profit.

5.2 Payment Market

Both banks' and firms' problems are identical to that in section 4.2. Plugging in the conditional firm profits in the credit market in lemma 5 into equations 10 and 11, we find banks' conditional payment market share under open banking as

$$x_j(K) = \begin{cases} \frac{U - p_j + \rho_H R - 1 - M}{\tau}, & \text{if } \overline{K} > K \geq \underline{K} \\ \frac{U - p_j}{\tau}, & \text{otherwise} \end{cases}$$

Equilibrium outcomes in the payment market is presented in Lemma 6.

Lemma 6 *Equilibrium payment service price and the market share of each bank are*

$$p = \frac{U + \phi + (\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))}{2}$$

$$x(K) = \begin{cases} \frac{U-\phi+(\rho_H R-1-M)(2-(F(\overline{K})-F(\underline{K})))}{2\tau}, & \text{if } \overline{K} > K \geq \underline{K} \\ \frac{U-\phi-(\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))}{2\tau}, & \text{otherwise} \end{cases}$$

Proof. *See Appendix D* ■

5.3 Welfare effects of loan monitoring technology and open banking implemented together

The increase in expected profit from borrowing for firms in $[\underline{K}, \overline{K}]$ shifts the demand for payment service upward, increasing the share of payment service users among these firms and the equilibrium payment service price. For the other firms, expected profit from borrowing does not change with open banking or availability of a monitoring technology. The share of payment service users among these firms decrease as a result of the increase in price. The total share of firms using a payment service increases. Proposition 2 summarizes the effect of introducing a loan monitoring technology under open banking regime on both markets.

Proposition 2 *When banks* ***can*** *access the transaction data generated by other banks' payment services and a loan monitoring technology utilizing transaction data is available*

- *credit rationing decreases,*
- *total firm surplus increases, and*
- *total bank surplus increases*

Proof. *See Appendix E* ■

As in the previous case, loan monitoring alleviates credit rationing and increases credit market surplus. As the credit market becomes perfectly competitive under open banking regime, all surplus appropriates to firms while banks make no profit in the credit market. However, banks can recuperate some of the surplus created in the credit market by increasing the price of their payment services. In other words, when regulation eliminates banks' market power in the credit market, they shift profits to the payment market where they still hold some market power due to product differentiation.

Loan monitoring technology combined with open banking regime leads to distributional outcomes as well. Total profit decreases for firms whose credit market outcome do not depend on payment market choice, i.e. those in $[0, \underline{K}]$ or $[\overline{K}, 1]$, as a result of a higher payment service price. For other firms, the increase in expected profit in the credit market dominates the former effect and total profit increases.

5.4 Welfare effects of introducing open banking regime when a loan monitoring technology already exists

Under open banking regime, demand for payment services increase among the firms in $[\underline{K}, \overline{K}]$, as a result of the increasing expected profit from borrowing for firms. This increases equilibrium payment service price. Proposition 3 summarizes the effect of introducing open banking regime on both markets when a loan monitoring technology already exists.

Proposition 3 *Assuming a loan monitoring technology utilizing transaction data already exists, when open banking is introduced*

- *firm surplus in the payment market decreases while firm surplus in the credit market increases, the change in total firm surplus is ambiguous.*
- *bank surplus in the payment market increases while bank surplus in the credit market decreases, the change in total bank surplus is ambiguous.*
- *total surplus across both markets increases*

Proof. *See Appendix F* ■

Open banking eliminates all bank profit in the credit market due to competition. However, banks increase their profit in the payment market where they still have market power. Since firms that need monitoring to overcome moral hazard have to use a payment service in order to secure loans, banks can charge them indirectly in the payment market. Since banks have to set a single payment service price, this leads to distributional effects on firms. A higher price implies less surplus in the payment market for all firms which were initially payment service users. In return, the expected profit in the credit market increases for the firms in $[\underline{K}, \overline{K}]$ if they remain payment service users. This increase is heterogeneous as firms received different shares from project return in the absence of open banking regime. Firms in $[\hat{K}, \overline{K}]$ - which received no profit in the absence of open banking - experience the highest increase which dominates their loss in the payment market and increase their total expected profit. For the firms in $[\underline{K}, \hat{K}]$, the increase becomes less substantial as firm equity decreases until the decrease in payment market profit starts to dominate for a fraction of firms at the lower end of this interval.

6 Conclusion

Data portability is advocated as having the potential to increase competition and consumer welfare in financial services. Accordingly, initiatives for enabling customers to share their financial data with third party entities, i.e. open banking/finance, is gaining global traction. With data being a key component of modern banking and finance, open banking is undoubtedly set to transform these sectors. Nevertheless, the full scope of its effect across different markets and market participants are not yet well understood. Our study contributes to the emerging literature aimed at improving such understanding.

We examine the joint pricing of loans and payment services under open banking when firms are subject to moral hazard and monitoring relies on payment information. Our model shows that, in the existence of cross-market information spillovers, open banking does not necessarily improve consumer welfare. We find that (i) banks respond to open banking by using their market power in the payments market to appropriate the value generated in the credit market indirectly, (ii) while open banking increases efficiency, it may end up hurting capital-constrained firms and capital-unconstrained firms alike.

To the best of our knowledge, our study provides the first theoretical welfare analysis of open banking that accounts for such spillovers and, while it focuses on payment services and loans in particular, it holds significance for all financial services and products displaying cross-market information spillovers. Overall, our results underline the importance of accounting for the information flow between data-producing and data-driven markets in evaluating data regulations and policies.

Appendices

A Proof of Lemma 2

Total firm surplus in the payment market is

$$
\begin{aligned}
S_F^1 &= 2\int_0^{\frac{U-\phi}{2\tau}} \left(U - \frac{U+\phi}{2} - \tau x\right) f(x)dx \\
&= \frac{(U-\phi)^2}{4\tau}
\end{aligned}
$$

Total bank surplus in the payment market is

$$
\begin{aligned}
S_B^1 &= 2\frac{U-\phi}{2\tau}(\frac{U+\phi}{2} - \phi) \\
&= \frac{(U-\phi)^2}{2\tau}
\end{aligned}
$$

B Proof of Lemma 4

Total expected profit of each bank is

$$
\begin{aligned}
\mathbb{E}[\Omega^{tot}] &= \int_0^1 (p - \phi + \mathbb{E}[\Omega_{ij}^{t=2} | K_i = K \ \ \& \ \ \theta_i = j])x(K)f(K)dK \\
&= \int_{\overline{K}}^1 (\rho - \phi)\frac{U-p}{\tau} f(K)dK + \int_{\hat{K}_1}^{\overline{K}} (p - \phi + \rho_H R - 1 - M)\frac{U-p}{\tau} f(K)dK \\
&+ \int_{\underline{K}}^{\hat{K}_1} (p - \phi + \rho_H R - 1 - M - \rho_H b_m/\Delta\rho + K)(\frac{U - p + \rho_H b_m/\Delta\rho - K}{\tau}) f(K)dK \\
&+ \int_0^{\underline{K}} (\rho - \phi)\frac{U-p}{\tau} f(K)dK
\end{aligned}
$$

By setting

$$
\frac{\partial \mathbb{E}[\Omega^{tot}]}{\partial dp} = \frac{U - 2p + \phi - (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) + \int_{\underline{K}}^{\hat{K}_1} 2(\frac{\rho_H b_M}{\Delta\rho} - K) f(K)dK}{\tau} = 0
$$

we find the payment service price and the market share of each bank in equilibrium as

$$
p = \frac{U + \phi - (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) + 2\int_{\underline{K}}^{\hat{K}_1} (\frac{\rho_H b_M}{\Delta\rho} - K) f(K)dK}{2}
$$

$$
x(K) = \begin{cases} \frac{U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) - 2\int_{\underline{K}}^{\hat{K}} (\frac{\rho_H b_M}{\Delta\rho} - K) f(K)dK + 2(\rho_H b_m/\Delta\rho - K)}{2\tau}, & \text{if } \hat{K} > K \geq \underline{K} \\ \frac{U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) - 2\int_{\underline{K}}^{\hat{K}} (\frac{\rho_H b_M}{\Delta\rho} - K) f(K)dK}{2\tau}, & \text{otherwise} \end{cases}
$$

C Proof of Proposition 1

The change in payment market price compared to the benchmark case is

$$
\Delta p_{01} = \frac{2\int_{\underline{K}}^{\hat{K}} (\frac{\rho_H b_M}{\Delta\rho} - K) f(K)dK - (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2}
$$

Payment services are subsidized if

$$(F(\hat{K}) - F(\underline{K}))[\frac{2\frac{\rho_H b_m}{\Delta\rho}}{\rho_H R - 1 - M} - 1] - \frac{2}{\rho_H R - 1 - M}\int_{\underline{K}}^{\hat{K}} Kf(K)dK < F(\overline{K}) - F(\hat{K})$$

Unconditional market share of a bank in the payment market is

$$X = \frac{U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau}$$

The change in the unconditional market share of a bank in the payment market compared to the benchmark case is

$$\Delta X_{01} = \frac{(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau} > 0,$$

i.e. the share of firms that use digital payment services increases. The rate of firms served by banks in the credit market is

$$\begin{aligned} Z &= 1 - F(\overline{K}) \\ &+ \frac{2(1 - (F(\overline{K}) - F(\underline{K}))) \int_{\underline{K}}^{\hat{K}} (\frac{\rho_H b_m}{\Delta\rho} - K) f(K)dK}{\tau} \\ &+ \frac{(F(\overline{K}) - F(\underline{K}))(U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))}{\tau} \end{aligned}$$

The change in the rate of served firms compared to the benchmark is

$$\begin{aligned} \Delta Z_{01} &= \frac{2(1 - (F(\overline{K}) - F(\underline{K}))) \int_{\underline{K}}^{\hat{K}} (\frac{\rho_H b_m}{\Delta\rho} - K) f(K)dK}{\tau} \\ &+ \frac{(F(\overline{K}) - F(\underline{K}))(U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))}{\tau} > 0, \end{aligned}$$

i.e. credit rationing decreases. Total firm surplus in the credit market is

$$\begin{aligned} S_F^2 &= \int_{\overline{K}}^{1} \mathbb{E}[\Pi_{ij}^{t=2} | K_i = K](K) f(K)dK + 2\int_0^{\overline{K}} \mathbb{E}[\Pi_{ij}^{t=2} | K_i = K] x_j(K) f(K)dK \\ &= (1 - F(\overline{K}))(\rho_H R - 1) \\ &+ \frac{[U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)] \int_{\underline{K}}^{\hat{K}} \frac{\rho_H b_m}{\Delta\rho} - Kf(K)dK}{\tau} \\ &+ \frac{2Var(K | \hat{K} > K > \underline{K})}{\tau} \end{aligned}$$

The change in total firm surplus in the credit market compared to the benchmark is

$$\Delta S^2_{F01} = \frac{[U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)]\int_{\underline{K}}^{\hat{K}} \frac{\rho_H b_m}{\Delta\rho} - Kf(K)dK}{\tau} + \frac{2Var(K|\hat{K}>K>\underline{K})}{\tau} > 0$$

Total bank surplus in the credit market is

$$S^2_B = \frac{[U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-2\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK](\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))}{\tau} - \frac{[U-\phi-(2-(F(\overline{K})-F(\underline{K})))(\rho_H R-1-M)]\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho}-K)f(K)dK}{\tau} - \frac{2Var(K|\hat{K}>K>\underline{K})}{\tau}$$

The change in total bank surplus in the credit market compared to the benchmark is

$$\Delta S^2_{B01} = S^2_B > 0$$

Total firm surplus in the payment market is

$$S^1_F = 2X(U-p-\tau\frac{X}{2}) = \frac{\left(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)\right)\left(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-4\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK\right)}{4\tau}$$

The change in total firm surplus in the payment market compared to the benchmark case is

$$\Delta S^1_{F01} = \frac{\left(2(U-\phi)+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-4\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK\right)(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)}{4\tau} - \frac{4(U-\phi)\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK}{4\tau}$$

The direction of change is ambiguous. Total bank surplus in the payment market is

$$S^1_B = 2X(p-\phi) = \frac{(U-\phi)^2-((F(\overline{K})-F(\underline{K}))(\rho_H R-1-M))^2+2\left(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)\right)\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK}{2\tau}$$

The change in the total bank surplus in the payment market compared to the benchmark case is

$$\Delta S^1_{B01} = \frac{2\left(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)\right)\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK-((F(\overline{K})-F(\underline{K}))(\rho_H R-1-M))^2}{2\tau}$$

The direction of change is ambiguous. Total firm surplus across both markets is

$$\begin{aligned} S_F^{tot} &= (1 - F(\overline{K}))(\rho_H R - 1) \\ &+ \frac{(U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))^2}{4\tau} \\ &+ \frac{8Var(K|\hat{K} > K > \underline{K})}{4\tau} \end{aligned}$$

while total firm surplus across both markets in the benchmark case is

$$\underline{S}_F^{tot} = \frac{(U - \phi)^2}{4\tau} + (\rho_H R - 1)(1 - F(\overline{K}))$$

The change in total firm surplus across both markets compared to the benchmark case is

$$\begin{aligned} \Delta S_{F01}^{tot} &= \frac{(2(U - \phi) + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{4\tau} \\ &+ \frac{8Var(K|\hat{K} \geq K \geq \underline{K})}{4\tau} > 0 \end{aligned}$$

Total bank surplus across both markets is

$$\begin{aligned} S_B^{tot} &= \frac{(U - \phi)^2 + 2(U - \phi)(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau} \\ &+ \frac{((F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) - 2\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)f(K)dK)^2}{2\tau} \\ &+ \frac{4\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)(\rho_H R - 1 - M - (\frac{\rho_H b_m}{\Delta\rho} - K))f(K)dK}{2\tau} \end{aligned}$$

while the total bank surplus across both markets in the benchmark case is

$$\underline{S}_B^{tot} = \frac{(U - \phi)^2}{2\tau}$$

The change in total bank surplus across both markets compared to the benchmark case is

$$\begin{aligned} \Delta S_{B01}^{tot} &= \frac{((F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) - 2\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)f(K)dK)^2}{2\tau} \\ &+ \frac{2(U - \phi)(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau} \\ &+ \frac{4\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)(\rho_H R - 1 - M - (\frac{\rho_H b_m}{\Delta\rho} - K))f(K)dK}{2\tau} > 0 \end{aligned}$$

D Proof of Lemma 6

By setting

$$\mathbb{E}[\Pi_i^{tot}|\theta_i = j] = \mathbb{E}[\Pi_i^{tot}|\theta_i = C],$$

we find payment market share of bank j conditional on firm with equity as

$$x_j(K) = \begin{cases} \frac{U-p_j+\rho_H R-1-M}{\tau}, & \text{if } \overline{K} > K \geq \underline{K} \\ \frac{U-p_j}{\tau}, & \text{otherwise} \end{cases}$$

Total expected profit of a bank under open banking regime becomes

$$\begin{aligned} \mathbb{E}[\Omega^{tot}] &= \int_0^1 (p-\phi)x(K)f(K)dK \\ &= \frac{p-\phi}{\tau}\big(U - p + (\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))\big) \end{aligned}$$

By setting

$$\frac{\partial \mathbb{E}[\Omega^{tot}]}{\partial dp} = \frac{U + \phi - 2p + (\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K})}{\tau} = 0$$

we find equilibrium payment service price and market share as

$$p = \frac{U + \phi + (\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))}{2}$$

and

$$x(K) = \begin{cases} \frac{U-\phi+(\rho_H R-1-M)(2-(F(\overline{K})-F(\underline{K})))}{2\tau}, & \text{if } \overline{K} > K \geq \underline{K} \\ \frac{U-\phi-(\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))}{2\tau}, & \text{otherwise} \end{cases}$$

E Proof of Proposition 2

The change in payment market price compared to the benchmark case is

$$\Delta p_{02} = \frac{(\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))}{2} > 0$$

Unconditional market share of a bank in the payment market is

$$X = \frac{U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau}$$

The change the unconditional market share of a bank in the payment market compared to benchmark is

$$\Delta X_{02} = \frac{(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau} > 0$$

The rate of firms served by banks in the credit market is

$$Z = 1 - F(\overline{K}) + \frac{(F(\overline{K}) - F(\underline{K}))(U - \phi + (\rho_H R - 1 - M)(2 - (F(\overline{K}) - F(\underline{K}))))}{\tau}$$

The change in the rate of firms served by banks in the credit market compared to the benchmark is

$$\Delta Z_{02} = \frac{(F(\overline{K}) - F(\underline{K}))(U - \phi + (\rho_H R - 1 - M)(2 - (F(\overline{K}) - F(\underline{K}))))}{\tau} < 0$$

Total firm surplus in the credit market is

$$S_F^2 = \frac{(\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))(U - \phi + (\rho_H R - 1 - M)(2 - (F(\overline{K}) - F(\underline{K}))))}{\tau} + (\rho_H R - 1)(1 - F(\overline{K}))$$

The change in total firm surplus in the credit market compared to the benchmark is

$$\Delta S_{F02}^2 = \frac{(\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K}))(U - \phi + (\rho_H R - 1 - M)(2 - (F(\overline{K}) - F(\underline{K})))}{\tau} > 0$$

Total bank surplus in the credit market is zero. The change in total bank surplus in the credit market compared to the benchmark case is zero as well. Total firm surplus in the payment market is

$$\begin{aligned} S_F^1 &= 2X(U - p - \tau\frac{X}{2}) \\ &= \frac{(U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))(U - \phi - 3(\rho_H R - 1 - M)(F(\overline{K}) - F(\underline{K})))}{4\tau} \end{aligned}$$

The change in total firm surplus in the payment market compared to benchmark is

$$\Delta S_{F02}^1 = \frac{-(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)(2(U - \phi) + 3(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M))}{4\tau} < 0$$

Total bank surplus in the payment market is

$$\begin{aligned} S_B^1 &= 2X(p - \phi) \\ &= \frac{\big(U - \phi + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)\big)^2}{2\tau} \end{aligned}$$

The change in total bank surplus in the payment market compared to benchmark is

$$\Delta S_{B02}^1 = \frac{\big(2(U - \phi) + (F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)\big)\,(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M)}{2\tau} > 0$$

Total firm surplus across both markets is

$$
\begin{aligned}
S_F^{tot} = &\frac{(U-\phi+(\rho_H R-1-M)(F(\overline{K})-F(\underline{K})))^2}{4\tau} \\
&+\frac{8(\rho_H R-1-M)^2(F(\overline{K})-F(\underline{K}))(1-(F(\overline{K})-F(\underline{K})))}{4\tau} \\
&+(\rho_H R-1)(1-F(\overline{K}))
\end{aligned}
$$

The change in total firm surplus across both markets compared to benchmark is

$$
\begin{aligned}
\Delta S_{F02}^{tot} = &\frac{(2(U-\phi)+(\rho_H R-1-M)(F(\overline{K})-F(\underline{K})))(\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))}{4\tau} \\
&+\frac{8(\rho_H R-1-M)^2(F(\overline{K})-F(\underline{K}))(1-(F(\overline{K})-F(\underline{K})))}{4\tau} > 0
\end{aligned}
$$

Total bank surplus across both markets is

$$
S_B^{tot} = \frac{\big(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)\big)^2}{2\tau}
$$

The change in total bank surplus across both markets compared to benchmark is

$$
\Delta S_{B02}^{tot} = \frac{(2(U-\phi)+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M))(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)}{2\tau} > 0
$$

Total welfare is

$$
\begin{aligned}
W = &(\rho_H R-1)(1-F(\overline{K})) \\
&+\frac{3(U-\phi+(\rho_H R-1-M)(F(\overline{K})-F(\underline{K})))^2}{4\tau} \\
&+\frac{8(\rho_H R-1-M)^2(F(\overline{K})-F(\underline{K}))(1-(F(\overline{K})-F(\underline{K})))}{4\tau}
\end{aligned}
$$

The change in total welfare compared to benchmark is

$$
\begin{aligned}
\Delta W_{02} = &\frac{3(\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))(2(U-\phi)+(\rho_H R-1-M)(F(\overline{K})-F(\underline{K})))}{4\tau} \\
&+\frac{8(\rho_H R-1-M)^2(F(\overline{K})-F(\underline{K}))(1-(F(\overline{K})-F(\underline{K})))}{4\tau} > 0
\end{aligned}
$$

F Proof of Proposition 3

The change in payment market price compared to the case with no open banking is

$$
\Delta p_{12} = (\rho_H R-1-M)(F(\overline{K})-F(\underline{K})) - \int_{\underline{K}}^{\hat{K}_1} (\frac{\rho_H b_M}{\Delta\rho} - K) f(K) dK > 0
$$

The change the unconditional market share of a bank in the payment market compared to the case with no open banking is

$$\Delta X_{12} = 0$$

The change in the rate of firms served by banks in the credit market compared to the case with no open banking

$$\Delta Z_{12} = \frac{-2(1-(F(\overline{K})-F(\underline{K})))((F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-\int_{\underline{K}}^{\hat{K}} \frac{\rho_H b_m}{\Delta\rho}-Kf(K)dK)}{\tau} < 0$$

The change in total firm surplus in the credit market compared to the case with no open banking is

$$\begin{aligned}\Delta S_{F12}^2 = & \frac{(U-\phi)((\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))-\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho}-K)f(K)dK)}{\tau} \\ & + \frac{(\rho_H R-1-M)(F(\overline{K})-F(\underline{K}))((\rho_H R-1-M)(2-(F(\overline{K})-F(\underline{K})))-\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho}-K)f(K)dK)}{\tau} \\ & - \frac{2Var(K|\hat{K}>K>\underline{K})}{\tau}\end{aligned}$$

The direction of change is ambiguous. The change in total bank surplus in the credit market compared to the case with no open banking is

$$\begin{aligned}\Delta S_{B12}^2 = & \frac{[U-\phi-(2-(F(\overline{K})-F(\underline{K})))(\rho_H R-1-M)]\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho}-K)f(K)dK}{\tau} \\ & + \frac{2Var(K|\hat{K}>K>\underline{K})}{\tau} \\ & - \frac{[U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-2\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK](\rho_H R-1-M)(F(\overline{K})-F(\underline{K}}{\tau}\end{aligned}$$

The change in total firm surplus in the payment market compared to the case with no open banking is

$$\Delta S_{F12}^1 = \frac{(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M))(\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK-(\rho_H R-1-M)(F(\overline{K})-F(\underline{K})))}{\tau} < 0$$

The change in total bank surplus in the payment market compared to the case with no open banking is

$$\Delta S_{B12}^1 = \frac{\left(U-\phi+(F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)\right)\left((F(\overline{K})-F(\underline{K}))(\rho_H R-1-M)-\int_{\underline{K}}^{\hat{K}_1}(\frac{\rho_H b_M}{\Delta\rho}-K)f(K)dK\right)}{\tau} > 0$$

The change in total firm surplus across both markets compared to the case with no open banking is

$$\Delta S^{tot}_{F12} = \frac{2((\rho_H R - 1 - M)^2(F(\overline{K}) - F(\underline{K}))(1 - (F(\overline{K}) - F(\underline{K}))) - Var(K|\hat{K} \geq K \geq \underline{K}))}{\tau}$$

The direction of change is ambiguous. The change in total bank surplus across both markets compared to the case with no open banking is

$$\Delta S^{tot}_{B12} = \frac{2(Var(K|\hat{K} > K > \underline{K}) - (1 - (F(\overline{K}) - F(\underline{K})))(\rho_H R - 1 - M)\int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)f(K)dK)}{\tau}$$

The direction of change is ambiguous. The change in total welfare compared to the case with no open banking is

$$\Delta W_{12} = \frac{2(\rho_H R - 1 - M)(1 - (F(\overline{K}) - F(\underline{K})))[(F(\overline{K}) - F(\underline{K}))(\rho_H R - 1 - M) - \int_{\underline{K}}^{\hat{K}}(\frac{\rho_H b_m}{\Delta\rho} - K)f(K)dK)]}{\tau} > 0$$