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Mobile Payments and Interoperability: Insights from the Academic Literature*

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Abstract

We connect various streams of academic literature to analyze how alternative competition and regulatory policies may affect the development of digital financial services, and particularly of mobile payments. Our main objective is to highlight the extent to which existing models, often coming from related industries (such as telecom, payments, and banking) can be applied to study the effects of mobile money interoperability. We focus on four dimensions of interoperability. First, we consider mobile network interoperability (whether clients of one telecom can access another telecom's payment services) in connection with the IO literature on tying. Second, we discuss platform level interoperability (the ability to send money off-network) in light of the literature on compatibility. We also build on the behavioral IO literature to suggest how the effects of interoperability may be very heterogeneous across various types of firms and consumers, or even backfire. Third, we consider interoperability in the cash-in-cash-out agent network, in light of the literature on co-investment in network industries, and of more specific studies on ATMs' interoperability. Fourth, we discuss how the literature in banking and on data ownership can be used to understand interoperability of data. We conclude with some broader remarks on policy implications and on possible directions for future research.

Keywords: Mobile Payments, Interoperability, Financial Inclusion, Competition Policy.

JEL codes: L51; L96; G23; G28; O16.

1 Introduction

Digital financial services are often viewed as a key tool towards financial inclusion (Demirguc-Kunt, Klapper, Singer and Ansar (2018)). New technologies can significantly decrease transaction costs, which allows reaching consumers who have been traditionally under-served (Goldfarb and Tucker (2019)). Moreover, the use of digital financial services generates data, which may be used to expand the set of services households can have access to.

A key step, often the first key step, in this direction is to move out from a fully cash-based economy and increase the use of digital payments. While giving access to a bank account has been shown to improve financial capabilities (Ashraf, Karlan and Yin (2006), Dupas and Robinson (2013)), a substantial fraction of the world population remains unbanked. At the same time, many of the unbanked have a mobile phone. Accessing digital money though mobile network is then an important way to decrease the reliance on cash, and a natural stepping-stone towards accessing other financial services such as credit and insurance (Demirguc-Kunt et al. (2018)).

In this paper, we connect various streams of academic literature to shed light on how alternative competition and regulatory policies may affect the development of digital financial services, and particularly of mobile payments. Following Hoernig and Bourreau (2016), these are defined as payments that use mobile money, a form of digital money held in accounts offered by mobile phone operators. We wish to study in particular the effects of interoperability of mobile payment networks, which can be broadly viewed as "the ability for mass users to perform specific transactions between accounts at different providers" (Arabehety, Chen, Cook and McKay (2016)).

Our main objective is to highlight the extent to which existing models, often coming from related industries (such as telecom, payments, banking) can be applied in the context of mobile money. While some of these models have been derived in the context of developed economies, their insights can be useful to inform current debates in developing countries. We attempt to focus on somewhat general economic principles, perhaps at the cost of abstracting from (possibly very important) institutional specificities. We believe that highlighting these connections can be helpful both from a research perspective, as a way to identify which areas appear under-explored, and from a policy perspective, as a way to leverage previous regulatory experiences.

Our discussion is motivated by some fundamental questions. As an industry characterized by network externalities, market forces may lead to the emergence of a dominant player. At the same time, a well-functioning payment network requires significant investments in infrastructures that often have a public good component. A key question is then how to strike a balance between competition and cooperation between service providers. A second question concerns the governance of the key assets, such as data and infrastructures, highlighting whether and how regulatory authorities should intervene. A third question is on welfare implications, which may be highly heterogeneous across various market participants and which may also include access to broader financial services.

Interoperability can be viewed, in the terminology of Beck and De La Torre (2007), as a *market enabling* policy, possibly allowing the financial sector to expand its capacity. As such, it intersects the above-mentioned questions in many ways. Is interoperability an effective way to promote entry and competition? How does interoperability affect platforms' incentives to invest in possibly common infrastructures? Should interoperability be mandated by a public authority, or would it emerge from decentralized platforms' agreements? How does interoperability influence the use of data and the access to other financial services? The answers to these questions appear of first order importance to assess the ultimate effects of digital payments and in particular their welfare implications on the various market participants.

The relationship between interoperability, competition, and consumer welfare is far from obvious. First, interoperability does not directly imply that competition will be fierce. In the telecom industry, for example, providers can offer differentiated services, and design pricing and bundling strategies so as to take advantage of network interconnections. Moreover, if consumers can join more than one network at the same time, interoperability does not necessarily promote entry (Bourreau and Kraemer (2022)). Second, the intensity of competition may not be the only relevant dimension for consumer welfare, which also depends on providers' incentives to invest in network quality and product innovation (Valletti and Cambini (2005)).[1] Finally, promoting competition does not necessarily lead to improved access to financial services. As argued in Croxson, Frost, Gambacorta and Valletti (2022) platforms by themselves are unlikely to promote financial inclusion without appropriate regulation.

We organize our discussion by identifying four key dimensions of interoperability. We start by considering interoperability at the mobile network level, which refers to the extent to which the subscribers of the phone (basic) service by one telecom can use the payment (ancillary) service of any other telecom. As we discuss in Section 2, the lack of interoperability at the mobile network level echoes what the literature on competition policy calls tying, whereby a typically dominant firm in one market makes the sale of its main product conditional upon the purchaser also buying another product (here, mobile payment) from it. We then consider interoperability at the platform level, which refers to the ability of users of one provider to make transfers to those of another provider. In Section 3, we argue that interoperability at the platform level is parallel to what the literature on competition policy calls compatibility.

The fact that most countries exhibit non-interoperable payment services at the mobile network level is surprising in light of the traditional Chicago School argument (reviewed below) positing that tying only occurs when it is harmless. Similarly, the Coase Theorem suggests that interoperability at the platform level should occur provided "property rights" are duly defined over the user bases of different providers. Yet, this form of

[1] We refer to Jullien and Sand-Zantman (2021) for a recent overview of the multiple ways by which the link between competition and consumer surplus is more complex and subtle in markets with network externalities.

interoperability is not widespread. We highlight how lessons from the competition policy literature may be used to illuminate these somewhat puzzling market outcomes.

In Section 4, we build on the literature in behavioral IO to consider the possibility that, in the case of mobile money, participants may have different degrees of experience or understanding of the market.[2] This literature emphasizes how standard effects of pro-competitive measures can be considerably weakened, or even reversed, once one takes into account that a fraction of consumers face for example search costs, limited attention, or limited understanding of the various fee structures. This literature is also particularly useful to highlight how market forces may often lead to cross-subsidization between different groups of consumers, thereby speaking directly to how interoperability may affect various market participants in a highly heterogeneous way.

Our third key dimension refers to interoperability of cash-in-cash-out agents. These agents are a central component of the mobile network infrastructure as they ensure the possibility of transforming cash into mobile money and mobile money into cash, which is essential in any economy in which households still largely rely on cash, and bank branches or ATMs are not easily accessible. In Section 5, we discuss how interoperability of mobile-money agents can be analyzed building on the literature on interoperability for ATMs, focusing in particular on the effects of various forms of interchange fees between banks and of surcharges to customers. We also discuss the relation with the literature on co-investment in network industries, highlighting how potential free-riding may severely impede investments in agent networks and how different pricing and co-investment policies may alleviate these concerns and improve the network's coverage.

Our fourth key dimension concerns data interoperability. As mentioned earlier, the use of mobile payment is often viewed as a first step towards a broader access to financial services. Data interoperability is key in this process, as it refers to the extent to which the data generated when dealing with one service provider can be transferred and used by other service providers. This is clearly connected to issues of ownership of data and of privacy regulation. As we emphasize in Section 6, data interoperability can be understood building on two important streams of literature. First, the standard literature in banking that highlights the complementarity between payment and lending, as controlling the former creates an informational advantage in screening and monitoring lenders. Under this view, data interoperability can improve the functioning of credit markets while also potentially bringing important distributional effects both across borrowers and across lenders. Second, the literature on data control rights and on the efficient use of information, discussing how gaining access to the data can promote entry in the payment market and what the optimal level of information sharing is.

As mentioned before, our main purpose is to highlight how existing insights from related industries can be useful for the debate on mobile money development. In this exercise, we have selected some representative contributions, in particular from the IO and finance literature, without aiming at being comprehensive. Our work should be viewed as complementary to other contributions which are more directly focused on the effects of alternative regulatory practices (Bourreau and Valletti (2015), Croxson et al.

[2]Throughout the article, IO refers to industrial organization.

(2022)), on how interoperability can be implemented in practice (Hoernig and Bourreau (2016)), on interoperability in cross-border payments (Boar, Claessens, Kosse, Leckow and Rice (2021)), and on institutional evidence from different countries (Arabehety et al. (2016), Hoernig and Bourreau (2016), Naji (2020)).

2 Mobile Network Interoperability

Mobile payment services in many developing countries are offered by telecom service providers (TSP's).[3] Moreover, it often happens that each payment service provider (PSP) is offered exclusively by one single telecom operator. Accordingly, the subscribers of the phone (basic) service by one telecom cannot adopt any payment (ancillary) service other than the one offered by their own telecom operator. In more technical parlance, mobile payments lack interoperability *at the mobile network level* (Bourreau and Valletti (2015)).

In turn, interoperability *at the platform level*, as defined by Bourreau and Valletti (2015), refers to the ability of consumers of one service to make transfers to those of another service. When payment services are non-interoperable at both the mobile network *and* platform levels, consumers are essentially constrained to make/receive transfers from those consumers from the same telecom operator (unless they pay the cost of multi-homing on telecom services).

In many developing nations, payment services remain non-interoperable at the network level, although interoperability at the platform level is now commonly mandated by regulators. In Kenya, for instance, M-Pesa is offered solely to subscribers of Safaricom, MTN Mobile Money solely to subscribers of MTN, Airtel Money to solely subscribers of Airtel.[4] These payment services were not fully interoperable at the platform level until as recently as 2022 (as only peer-to-peer, but not peer-to-merchant, transfers were possible), and were not interoperable at all at the platform level until 2018.

The lack of interoperability at either (or both) levels may serve to extend the mobile market dominance enjoyed by the telecom operator to the payments market. This concern is particularly acute in developing countries with low levels of bankarization, as financial inclusion depends to a large extent on the use of mobile phones. Beyond the effects of market power on the prices of financial and payment services, it is often argued that dominant closed-loop payment schemes lack the incentives to innovate and expand the array of financial services available to consumers. By stifling innovation and

[3]To serve the unbanked population, telecoms typically constitute a subsidiary payment institution with a license to issue electronic money through pre-paid transactional accounts. E-money issuers cannot lend the funds from these accounts, being required to either keep the funds as reserves at the central bank, or buy short-term public debt, or deposit the funds in sound financial institutions. To more easily serve the banked population, telecoms sometimes enter into agreements with financial institutions to connect the bank and e-money accounts of their joint customers.

[4]A similar pattern can be observed in several markets, such as Tanzania, the Philippines, Rwanda and Madagascar, among others. A notable exceptions is Nigeria, where payment service providers (PSP's) are independent from telecom services, whose only role is to provide a platform to PSP's. See Hoernig and Bourreau (2016) for a comprehensive cross-country comparison.

rendering the payments market uncontested, the lack of interoperability may severely hinder financial inclusion.

Regulators around the globe adopted diverse strategies regarding interoperability (or the lack thereof). One possibility is to mandate interoperability at the mobile network level, obliging telecoms to open their mobile services to PSP's other than their own. Nigeria is an early adopter of this approach, which has also been championed by developed countries (e.g., Germany with its Lex Apple Pay of 2020, obliging Apple to let digital wallets other than Apple Pay to be installed in the iPhone and use its NFC capability).[5] Another approach encourages (or possibly mandates) interoperability at the platform level, even if the latter is absent at the mobile network level. This approach, followed notably by Tanzania in 2016 and more recently by Kenya, hinges on the belief that, by eliminating network effects, effective competition between telecom operators induces low prices and greater efficiency. The next section develops a careful discussion of why telecoms may lack the incentives to willingly adopt this form of interoperability, and describes the effects of mandating it. Finally, in some instances, central banks and/or consortium of commercial banks created payment schemes open to all financial and payment institutions (including those owned by telecom operators). This approach, followed notably in Brazil, India and West Africa,[6] although successful in many cases, relies on the entrepreneurial ability of the public (or private) sector to establish a new payment scheme and develop its infrastructure. In countries with low bankarization and/or a weak government, the most natural path may be to rely on large telecom operators to offer payment services.

The lack of interoperability at the mobile network level is allusive of what the literature on competition policy calls *tying*, whereby a (typically dominant) firm in one market (here, telecom) makes the sale (or price) of its main product conditional upon the purchaser also buying another product (here, mobile payment) from it.

In this section, we investigate the incentives that telecom operators have (or lack) to willingly implement interoperability at the mobile network level. In doing so, we assume that interoperability at the platform level is already in place, which is the case in most jurisdictions. By enjoying the same network effects, PSP's may only differ in the user experience they provide to consumers.

That most countries exhibit non-interoperable payment services at the mobile network level may look surprising in light of the traditional Chicago School argument (reviewed below), which posits that tying only occurs when it is harmless for firms and society. As we argue next, this logic fails when two conditions hold. First, the payment service provider enjoys externalities from consumer data. Second, prices cannot be negative. The latter restriction captures the idea that consumers could fraud the platform if they were paid to use it, which is a natural assumption in developing countries (where

[5]More recently, at the European level, the Digital Markets Act of 2022 determines that third-party providers should be able to offer payment services in multi-purpose platforms under conditions similar to those of the platform.

[6]For a careful description of the recent experience in Brazil, see Duarte, Frost, Gambacorta, Koo Wilkens and Shin (2022); in India, see Alonso, Bhojwani, Hanedar, Prihardini, Uña and Zhabska (2023); and in West Africa, see https://www.gim-uemoa.org/.

most accounts are pre-paid and monitoring of consumers imperfect). That payment service providers value payments data is increasingly a truism (see Section 6). Indeed, payment data can be used to better tailor telecom/retail offers to consumers (Accenture (2022)), to sell other financial products such as credit and insurance (STLPartners (2021)), or to improve the revenues from advertising (Forbes (2022)).

We start by reviewing the Chicago School argument, to then appreciate why it fails in the presence of data externalities and non-negative prices.

2.1 The Chicago School argument

Consider two telecom providers offering phone services worth v_a and v_b to consumers at zero marginal cost. Each telecom provider also offers payment services worth u_a and u_b, again at zero marginal cost (for simplicity). Suppose firm a is a superior telecom provider, in that $v_a > v_b$, but an inferior payment provider, in that $u_a < u_b$. Moreover, suppose firm a is "overall" better, in that $v_a + u_a > v_b + u_b$.

Let us now consider the following two modes of competition. In the first, there is no interoperability at the mobile network level. Accordingly, firms compete by offering bundles of telecom and payment services, so that consumers cannot use the telecom service from one firm but the payment service from another. For brevity, we will use the word "tying" to describe this case. In the second mode of competition, firms offer telecom and payment services on a stand-alone basis and consumers can mix and match across stand-alone products. Again for brevity, we say "untied competition" rather than "competition with services interoperable at the mobile network level".

Under tied competition, firm a corners the market for the bundle by charging the price $v_a - v_b - (u_b - u_a) > 0$. In turn, under untied competition, firm a conquers the telecom market, charging the price $v_a - v_b > 0$, while firm b conquers the payments market, charging the price $u_b - u_a > 0$. Clearly, untied competition makes both firms better off.

Only when $u_a \geq u_b$, which is contrary to the assumed above, would tying *not* be harmful for firm a. In this case, firm a offers better telecom and payment products, conquering both markets regardless of there being interoperability or not (and obtaining the same profit in both cases). In conclusion, non-interoperability at the mobile network level can only occur when it is harmless for both firms and society.

The "single monopoly profit" argument described above (which dates back to Posner (1979)) highlights the idea that the non-interoperability of mobile networks erodes the profits of the firm that is "overall" better. This suggests that mobile network interoperability should not be a concern to competition policy, as banning it is unprofitable whenever it is consequential for equilibrium outcomes.

For long, economists have been putting into question the assumptions behind the Chicago School argument. One notable critique is that of Whinston (1990), according to which tying may work as a commitment device by the incumbent firm to compete aggressively for the ancillary good market (on which the incumbent is less efficient). By inducing the entrant to stay out of payments, tying constitutes a strategic foreclosure strategy. Another notable theory is that of Carlton and Waldman (2002), according to which tying by the incumbent prevents the entrant from competing on the basic good market. However, none of these theories explains why a telecom operator would like to keep services tied even *after* the entry of a second (or even third) telecom/mobile payment system, as indeed occurred in most markets. That non-interoperability can be profitable as an *in-the-market* competitive tool is a major virtue from the theory of Choi and Jeon (2021), which we present next.[7]

2.2 Data externalities and the zero lower bound

Let us know assume that the prices of telecom and mobile payments are non-negative and introduce data externalities (enjoyed by the provider of payment services). Namely, assume that payments data can be monetized at a rate $\beta > u_b - u_a$ per transaction. We maintain the same assumptions on parameters v_a, v_b, u_a, u_b as in the subsection above.

Under untied competition, firm a charges $v_a - v_b$ for the telecom service and 0 for the payment service. In turn, firm b charges v_b for telecom and $u_b - u_a$ for payments. Firm a conquers the telecom market, obtaining the profit $v_a - v_b$, while firm b conquers the payment market, obtaining the profit $u_b - u_a + \beta$.

Under tied competition, firm a charges $v_a - v_b + (u_a - u_b)$ for the bundled services, while firm b charges zero. Firm a's profit is $v_a - v_b + (u_a - u_b) + \beta$ and b is excluded.

Clearly, firm a is better-off when mobile networks are not interoperable! Intuitively, the zero lower bound renders the foreclosed firm b less aggressive in equilibrium. To appreciate this point, note that, absent interoperability, firm b would be happy to hand in to consumers β dollars just for switching providers. Crucially, this mode of competition is more likely to occur (therefore decreasing welfare relative to the interoperable case) when payments produce sufficiently large data externalities.

2.3 Conclusion

The theory above debunks the Chicago School argument by appealing to the presence of data externalities, which are a natural feature of payments. However, in this theory, competition is always "all-or-nothing," preventing the co-existence of more than one service operating, which occurs in most markets. The next section relaxes this restrictive feature by considering the possibility that payments can be made across payment services.[8] Specifically, it investigates the incentives of telecom operators to interoperate at the platform level, and reveals under what conditions regulation mandating this form of interconnection is needed (and warranted).

[7] See Amelio and Jullien (2012) for an illustration of how tying can relax the zero-lower bound constraint in a monopoly setting.

[8] Relatedly, another relaxation that may also prevent market tipping is rendering consumer data interoperable across platforms, as discussed in section 6.

3 Platform Interoperability

To simplify the analysis, in this section, we abstract from the "telecom" aspect of mobile payments. Rather, we focus on how the network effects present on payment services affects firms' decision to be interoperable at the platform level (or compatible, for short).

To this end, consider two payment providers, a and b, and assume for the moment that these services are not compatible. Consumers differ on their tastes for each provider, described by their position $x \in [0, 1]$ uniformly distributed in the Hotelling segment. Consumers also may differ on their valuation $\beta \geq 0$ for network size. Accordingly, the net utility of a consumer with valuation β located at x when she adopts provider $i \in \{a, b\}$ is

$$U_i(x, \beta, N_i) = \beta N_i - p_i - t_i(x),$$

where N_i represents the total number of provider i's customers, and p_i is i's price. We choose labels such that $t_a(x) = tx$ and $t_b(x) = t(1 - x)$, where $t \geq 0$ measures the intensity of brand preferences. We focus on the case where the market is fully covered (i.e., every consumer joins at least one provider).

If the consumer adopts both providers (multi-homes), her net utility is

$$U_{ab}(x, \beta, N_a, N_b) = \beta - p_a - p_b - t.$$

In turn, if services a and b are compatible, the net utility of a consumer with valuation b located at $x \in [0, 1]$ when she adopts provider $i \in \{a, b\}$ is rather

$$\tilde{U}_i(x, \beta, N_i) = \beta - p_i - t_i(x).$$

Accordingly, compatibility destroys network effects, in that each consumer can reach the same set of other consumers by joining either platform. Obviously, no consumer would multi-home in this case.

We assume that providers, first, simultaneously take compatibility decisions. Services are compatible if and only if both providers decide accordingly, in which case each pays a fixed cost F. Secondly, knowing the outcome of the first stage, firms simultaneously choose prices. We will describe equilibria of the game above assuming consumers can/not multi-home, and considering the cases where the magnitude of network effects (captured by β) fares large/small relative to brand tastes (captured by t). We impose the natural restriction that all prices have to be non-negative. Marginals costs are zero.

3.1 Strong network effects: Market tipping

Consider first the case where network effects are stronger than brand tastes, in that all consumer share the same valuation $\beta > 0$ and $t = 0$ (for simplicity). This captures situations where payment systems constitute homogeneous independent products (not inheriting the brand tastes of other elements of the same eco-system), and where payments are often "non-local." The latter means that agents are likely to transfer money to non-neighbors chosen arbitrarily, so that "global" network effects (i.e., considering the overall population) are important. This is to be opposed to the case where payments are local (within village members, for instance), so that coordination among few individuals is enough to generate maximal value to consumers. Local payments are better captured by assuming that the strength of network effects β is small relative to the intensity of brand preferences, captured by t. This case is treated in the next subsection.

We analyze first the situation where consumers single-home. We select equilibrium assuming beliefs are favorable in the sense of Caillaud and Jullien (2001) and Caillaud and Jullien (2003), meaning that consumers coordinate on a given platform and only migrate to the competitor if doing so is a dominant strategy.

In this environment, choose labels such that provider a is the winning payment service. If services are not compatible, equilibrium prices are then $p_a = \beta$ and $p_b = 0$, following which all consumers join provider a. By contrast, were services compatible, equilibrium prices would be $p_a = p_b = 0$. Obviously, the winning payment provider would oppose compatibility. Because we analyze the extreme case where $t = 0$, imposing compatibility does not raise welfare (although it would were t small but positive). However, imposing compatibility does shift rents from the winning platform to consumers.

Consider now the situation where consumers can seamlessly multi-home (but lexicographically prefer not doing so), and construct equilibrium beliefs such that a consumer would multi-home only if doing so is a strictly dominant strategy. In the absence of compatibility, equilibrium again involves $p_a = \beta$ and $p_b = 0$, following which all consumers single-home at provider a. Again, compatibility would produce a Bertrand race leading to $p_a = p_b = 0$. So, similarly to the single-homing case, compatibility would be opposed by the dominant provider.

These rather extreme modeling assumptions are chosen to illustrate the idea that, in the absence of product differentiation, under full market coverage, firms will have insufficient incentives to make services compatible, regardless of whether consumers can/not multi-home. This idea is well established in the literature, dating back to Katz and Shapiro (1985).[9] The analysis is more nuanced when "global" network effects are less important, so that brand tastes are enough to guarantee that the market does not "tip," in that a single provider attracts all consumers.

3.2 Moderate network effects: Market sharing

We now analyze the market sharing scenario, where more than one payment provider operates. This is the likely outcome of economies where payments occur within small geographic areas, so that local coordination (at the village level, for instance) is enough to generate all network gains. In this case, it is useful to think that market power stems more from brand tastes than from network externalities. Accordingly, we assume in this subsection that $t > \mathbb{E}(\beta)$, where $\mathbb{E}(\beta)$ is the average network valuation across agents. For simplicity, we assume that β takes two values, β^l and β^h, with $\beta^l < \beta^h$, in which case $\mathbb{E}(\beta) = \lambda\beta^h + (1-\lambda)\beta^l$, where λ is the fraction of high-valuation consumers (distributed iid across agents, and independently of the brand taste x).

[9] For a more recent treatment, see Doganoglu and Wright (2006) and Farrell and Klemperer (2007).

We consider first the case where consumer cannot multi-home, having to choose a single payment provider. This assumption approximates reality when, for instance, dual-sim phones are very expensive or simply unavailable to consumers.

3.2.1 Single-homing consumers

Let us denote by N_a^l (resp., N_a^h) the share of low-valuation (resp., high-valuation) consumers joining firm a (and define N_b^l and N_b^h analogously for firm b). Clearly, $N_a = \lambda N_a^h + (1-\lambda)N_a^l$.

In the absence of compatibility, each consumer picks the provider that maximizes her net utility. It is then straightforward to derive the following linear demand system:

$$N_a^h = \frac{1}{2} + \frac{p_b - p_a}{2t} + \frac{\beta^h(p_b - p_a)}{2t(t - \mathbb{E}(\beta))} \qquad \text{and} \qquad N_a^l = \frac{1}{2} + \frac{p_b - p_a}{2t} + \frac{\beta^l(p_b - p_a)}{2t(t - \mathbb{E}(\beta))}. \quad (1)$$

Each provider maximizes profits, as given by $p_i N_i$. In the unique symmetric equilibrium, $p_a = p_b = t - \mathbb{E}(\beta)$, both firms share the market, and each obtains a profit of $\frac{1}{2}(t - \mathbb{E}(\beta))$. Direct computation reveals that the equilibrium welfare is

$$W = \frac{\mathbb{E}(\beta)}{2} - \frac{t}{4}.$$

By contrast, consider the case where payment services are compatible. The absence of network effects brings us back the standard Hotelling demands:

$$N_a^h = \frac{1}{2} + \frac{p_b - p_a}{2t} \qquad \text{and} \qquad N_a^l = \frac{1}{2} + \frac{p_b - p_a}{2t}.$$

The equilibrium is therefore $p_a = p_b = t$, both firms share the market, and each obtains a profit of $\frac{t}{2} - F$, where, recall, F is the fixed cost that each provider has to pay to render his service compatible. Equilibrium welfare is then

$$\tilde{W} = \mathbb{E}(\beta) - \frac{t}{4} - 2F.$$

Therefore, compatibility is socially optimal if and only if

$$\tilde{W} \geq W \qquad \Longleftrightarrow \qquad F \leq \frac{\mathbb{E}(\beta)}{4}.$$

In turn, compatibility is privately optimal (for payment providers) if and only if

$$\frac{t}{2} - F \geq \frac{1}{2}(t - \mathbb{E}(\beta)) \qquad \Longleftrightarrow \qquad F \leq \frac{\mathbb{E}(\beta)}{2}.$$

It then follows that "symmetric" payment providers (i.e., with similar market shares) have an excessive incentive to be compatible relative to the social optimum. The reason is that network effects render demands, in the absence of compatibility, more elastic, which decreases equilibrium prices.

This result has been established under different forms in the literature. The formulation above follows Doganoglu and Wright (2006). An alternative treatment is offered by Crémer, Rey and Tirole (2000), who assume that firms compete in capacity and prices clear demand (i.e., Cournot competition). In the latter paper, besides reducing demand elasticities, compatibility renders services more attractive relative to the outside option, thus expanding the market. In turn, Chen, Doraszelski and Harrington (2009) investigate a dynamic extension where firms' past purchases improve the product's quality over time (a form of data-enabled learning). Random taste shocks may however render the market asymmetric. The authors then show that the dynamic adjustment of prices helps to avoid market tipping, preserving the incentives to offer compatible services. Finally, Malueg and Schwartz (2006) consider an asymmetric market structure where a dominant firms faces a set of small competitors. The authors show that it is a dominant strategy for the small competitors to be interoperable. In equilibrium, the market may tip towards the smaller firms, as intra-network competition assures consumers of low prices.

3.2.2 Multi-homing consumers

So far, we have seen that market tipping has the effect of rendering compatibility (more often) undesirable for the dominant operator, but socially desirable under moderate brand tastes by consumers. By contrast, market sharing often renders compatibility desirable for the competing operators (as it relaxes price competition), while sometimes being socially detrimental. As we will see next, the latter conclusion is sensitive to the assumption that consumers cannot multi-home.

Consider the equilibrium where high-valuation consumers multi-home, while low-valuation consumers single-home.[10] Under this configuration, in the absence of compatibility, firm a's total demand is given by

$$N_a = \frac{1}{2} + \frac{\lambda}{2} + \frac{(1-\lambda)(p_b - p_a)}{2(t-(1-\lambda)\beta^l)}, \tag{2}$$

and similarly for firm b (after changing indexes). Comparing (1) and (2), the total demand faced by firm a increases by $\frac{\lambda}{2}$ and its price sensitivity decreases. Not surprisingly, the equilibrium prices, given by

$$p_a = p_b = \left(\frac{1+\lambda}{1-\lambda}\right)(t-(1-\lambda)\beta^l), \tag{3}$$

are greater than their single-homing counterparts. Profits are also greater, as demands expand due to multi-homing.

[10] Clearly, no equilibrium where all consumer multi-home exists. As argued by Doganoglu and Wright (2006), considering equilibria where a fraction of high-valuation consumers single-home leads to similar qualitative results.

Because multi-homing is irrelevant under compatibility, the equilibrium under compatible services is identical to that derived when consumers single-home. Accordingly, firms set prices $p_a = p_b = t$ and enjoy the profit $\frac{t}{2} - F$.

We now assess the firms' incentives for compatibility under multi-homing. It is straightforward to see that, when β^l is small, the equilibrium prices in (3) exceed t. This implies that firms would remain incompatible even if the cost of achieving compatibility was zero! By contrast, the planner may favor compatibility (provided F is positive but low) in order to save duplication in transportation costs and to generate network effects for low-valuation consumers. As can be verified after some tedious algebra, under multi-homing and for β^l low, firms have an insufficient incentive to choose compatibility. Somewhat surprisingly, the ability of consumers to multi-home, by inducing firms to avoid compatibility, may reduce network effects in equilibrium.

3.3 Conclusion

The model of this section offers two explanations for why telecom/payment providers may fail to willingly inter-operate at the platform level (even when it is efficient to do so). The first applies to markets with one dominant firm, such as Kenya. The idea is that the dominant firm's market power stems from strong network externalities, which would disappear under compatibility. The second explanation applies to markets with multiple "symmetric" firms serving multi-homing consumers., such as Tanzania. In this case, compatibility shrinks the market (as multi-homing disappears) and makes demand more elastic (as consumers joining decisions are rival), reducing prices, sales and profits. In both cases, there is a case to mandate interoperability at the platform level, which would raise welfare and consumer surplus.

It is worth noting that the theory above compares two extreme outcomes; one with full-fledged platform interoperability (in the sense that all providers have free and unfettered access to each others' networks and consumers pay the same regardless of their share of on-net or off-net transactions), the other with no interoperability at all. Arguably, one could think of intermediate situations where firms and consumers face, respectively, interchange fees and different prices for on/off net transfers. It is expected that one such intermediate outcome would enable firms to achieve a Pareto improvement, as they would increase efficiency while selling each other access to their respective user bases. In accordance with this view, Tanzania implemented such a tariff-based interoperability, with additional tariffs to off-net transfers. Its success has been limited, however, probably because many consumers already held multiple accounts in different providers, a strategy that dates back to the times of no interoperability.

While agnostic on why tariff-based interoperability remains atypical, we believe it is an interesting topic of future research to study the optimal design of such a system (from both the firms' and the regulator's perspective). One novel element of this problem is that consumer multi-homing imposes a natural upper bound on the difference between on-net and off-net transfers that telecom/payment providers can charge each other. [11]

[11] Relatedly, consumer coordination is a key issue in environments where interoperability is partial;

4 Interoperability with Behavioral Consumers

Mobile money customers may exhibit behavioral biases and lack experience with financial products (see, e.g., Garz, Giné, Karlan, Mazer, Sanford and Zinman (2021)), or may not have the time and resources necessary to compare providers and find the best one (see, e.g., Shah, Mullainathan and Shafir (2012)). In this section, we argue that interoperability may exacerbate these problems, which in turn limits the potential benefits from interoperability. To illustrate, if consumers do not understand the fees for transferring money across networks, or if those fees are difficult to compare across providers, competition between providers will be weak, leading to high off-net fees and low off-net transaction volumes.[12] Moreover, anticipating high off-net fees, consumers may prefer to use incumbent providers with large installed bases, thus inhibiting entry of new players. Market interventions are then required to get the full benefits of interoperability.

While we focus our discussion on platform interoperability, the issues that we highlight in this section can also be applied to, e.g., mobile network or agent interoperability, where consumers again need to compare fees and services across providers.

4.1 Fees in practice

Different mobile money providers "frame" their fees in different ways. According to CGAP (2017) there are three common formats: i) "slab pricing", where all transactions within a given range have the same fixed fee (but fees differ across slabs, usually in a regressive way), ii) percentage-based pricing, where the fee is a fixed percentage of the amount transacted, and iii) consumers may even pay no fee to transact money. Providers also differ as to whether on- and off-net transactions incur the same fee. Different countries have adopted different regulatory stances on this—ranging from no restrictions, to policies that require fees to be the same regardless of the receiver's network (see, e.g., CGAP (2021)). Partly as a result of this, we observe different pricing models in different countries, as illustrated by the following examples (correct as of September 2023).

Example 1. In Kenya, Safaricom and Airtel both use slab pricing. However they use different transaction bands. Their pricing strategies are also qualitatively different: Safaricom charges positive fees for most on- and off-net transactions, whereas Airtel has a zero fee for on-net transactions but a positive fee for most off-net transactions.[13]

Example 2. In Ghana, MTN uses slab pricing for low and high transaction amounts, but charges a fixed percentage fee for intermediate amounts; however it does not discriminate between on- and off-net transactions. On the other hand, G-Money uses slab pricing for

and consumers multi-home. For a dynamic treatment of this question, see the recent contribution of Bourreau and Kraemer (2022).

[12]Consumers may respond to high off-net fees by multi-simming (GSMA (2012)) which may be inconvenient, or by transacting with cash which leads to travel and coordination costs (Aron (2018)).

[13]See here for Safaricom and here for Airtel. As mentioned earlier, fees are regressive. For example, on Safaricom, an on-net transfer of 101 Shillings attracts a fee of 7 Shillings, whereas a transfer of 150,000 Shillings attracts a fee of 108 Shillings.

on-net transactions, but a mix of slab pricing and percentage fees for off-net transactions; it also charges up to 10 times more for off- rather than on-net transactions.[14]

To summarize, in these first two examples there is "fee dispersion"—providers charge different fees, which are also presented using different "frames". Moreover some providers discriminate against off-net transactions. This contrasts with our final example:

Example 3. In Uganda, MTN and Airtel both use slab pricing. They use (essentially) the same transaction bands. Each provider recently revised its fees, and now charges the same fee for on- and off-net transactions (which was not the case beforehand). Moreover these fees are the same except for one band (where Airtel's fee is 5 times MTN's).[15]

4.2 Imperfect Information and Search costs

When providers introduce a new service such as off-net transactions, consumers are often poorly informed about how much different providers charge for this service. We first review how in theory this can result in high off-net fees and low consumer take-up, and discuss some policy interventions. We then provide evidence of imperfect information in mobile money (and other financial services), and discuss empirical work on the effects on giving consumers better information about the fees they incur.

Theory

Economic theory predicts that imperfect consumer information can lead to weak competition and high fees. To illustrate this, start with *no interoperability* and assume that consumers single-home. First, suppose consumers must incur a positive search cost to learn a provider's (on-net) transaction fee. It is well-known that in equilibrium all providers charge the same (high) monopoly fee; this is called the Diamond Paradox, after Diamond (1971). Intuitively, because consumers expect to be "ripped off" with high fees, they visit at most one provider, so providers do not compete with each other.[16] Second, now suppose that some consumers are well-informed about different providers' fees (e.g., because they enjoy shopping around). The Diamond Paradox fails because providers have an incentive to undercut each other to attract the well-informed consumers. Nevertheless the presence of some uninformed consumers prevents prices going to marginal cost, even if providers are homogeneous. Instead, Varian (1980) and Stahl (1989) show there is "fee dispersion"—some providers set a high fee to exploit consumers with search costs, and other providers set a low fee to compete for well-informed consumers.[17]

Continue to assume that consumers single-home, but now assume there is *interoperability* such that providers offer two services—one being on-net and the other being off-net transactions. Start again with the case where consumers must incur a positive

[14]See here for MTN and here for G-Money.

[15]See here for MTN and here for Airtel

[16]Similarly in a context with repeated purchases—as is true with mobile money—there is no incentive to search another provider if the one used in the past did not deviate from the expected (high) fee.

[17]Interestingly, fee dispersion is *not* necessarily a sign of weak competition: starting from the Diamond outcome, as more consumers become informed prices fall on average but become more dispersed.

search cost to learn a provider's fees. In equilibrium fees are higher than under perfect information, but somewhat lower than under no interoperability (Rhodes (2015)). Intuitively, adding off-net transactions expands the set of consumers that use mobile money; since these new consumers must have had relatively low valuations for providers' existing on-net services, it is optimal for providers to reduce their fees. If instead some consumers are informed about providers' fees, fees exceed marginal cost (even when providers are undifferentiated) and are again dispersed in such a way that a provider may have a low on-net fee but a high off-net fee (or vice versa) (see, e.g., Shelegia (2012)).

Since imperfect information leads to high fees and low (off-net) transactions, it limits the potential benefits of interoperability. We now turn to possible policy responses.

Possible Interventions

We briefly discuss three possible interventions: i) increasing competition, ii) caps on consumer fees, and iii) comparison sites and other ways to facilitate price transparency.

Economic theory suggests that increasing competition can have perverse consequences when consumers have search costs. If all consumers have strictly positive search costs, as in Diamond (1971), then encouraging more providers to enter the market has *no* effect on fees. Meanwhile, if some consumers are well-informed about fees, as in Stahl (1989) and Varian (1980), encouraging entry can even lead to higher fees on average, to the detriment of those consumers who have high search costs. This happens because, facing more competition for the well-informed consumers, providers find it optimal to focus more on exploiting consumers with high search costs via high fees.

Economic theory also provides mixed guidance on fee caps. In a setting like Diamond (1971) a cap unambiguously reduces fees and therefore benefits consumers. However Armstrong, Vickers and Zhou (2009) show that when some consumers are well-informed, fee caps can potentially reduce competition and harm consumers. The intuition is that a fee cap reduces, *ceteris paribus*, the amount of fee dispersion, reducing the incentives for consumers to become well-informed, potentially relaxing competition.

Price comparison sites display providers' fees in one centralized place. In terms of the models presented above, they increase the fraction of well-informed consumers and thus should lead to more competition (see, e.g., Baye and Morgan (2001)).[18]

Empirical Evidence

There is growing evidence that mobile money consumers are poorly-informed about fees. Annan (2020) writes that in Ghana "customers receive little to no information about M-Money's transaction tariffs and services when they sign up." The author also conducts surveys and finds that only 48% of consumers know the official fees they should pay to transfer money. A similar pattern emerges in other countries. In Uganda, for example,

[18] Price comparison sites may raise concerns about increased equilibrium obfuscation by providers (e.g., Ellison and Ellison (2009)), degradation of service quality (e.g., Yang (2021)), or higher fees once the commissions charged by the comparison site are taken into account (e.g., Ronayne (2021)). However these seem second-order for mobile money, especially if the comparison site is run by a regulator.

IPA (2021) reports that 83% of surveyed mobile money customers either did not know the fees charged by their provider, or their guess about the fees was off by more than 10 percent; only 10% of the surveyed customers exactly knew the fees. Moreover, 64% stated that they only learned how much they would pay for a transaction *after* they had carried it out, and 19% complained of unclear or unexpected charges.[19]

There is also evidence that this lack of information translates into higher fees. Annan (2020) looks at this in the context of overcharging (relative to official rates) by local mobile money agents. He shows that giving consumers more information about official rates leads to a 40% reduction in fees, and a substantial increase in transaction volumes.

There is also some evidence from other financial markets that providing (vulnerable) consumers with more information can lead to better outcomes. Ferman (2016) finds that, in Brazil, making credit card interest rates more prominent induces greater price-sensitivity from high-risk consumers (but not other consumers).[20] Meanwhile, in the US, measures which make fees more salient reduce the probability of incurring overdrafts (Stango and Zinman (2014)) or taking out payday loans (Bertrand and Morse (2011)); in both studies the effects are strongest for consumers with the lowest financial literacy. Nevertheless, returning to credit cards, Agarwal, Chomsisengphet, Mahoney and Stroebel (2015) find that in the US regulatory caps on fees are much more effective than providing consumers with information about fees, while Galenianos and Gavazza (2021) find that caps on interest rates would reduce market power and benefit consumers.

4.3 Complexity and Framing of fees

Even if consumers are informed about fees, they still need to compare them across providers. As we saw earlier, providers may "frame" their fees differently. This makes comparisons difficult. For example, if one provider uses "slab" pricing and the other charges percentage fees, it may be hard to compute which provider is cheaper, especially if a consumer plans to make several transfers of varying amounts. Moreover, interoperability may exacerbate this problem, because if a provider starts offering off-net transfers at a different fee to on-net transfers, this makes its overall "product" more complex.[21]

We first review how in theory firms can use complexity to raise fees, and then review empirical evidence on interventions that force fees to be displayed in a standardized way.

Theory

Economic theory suggests that firms may use complexity to exploit consumers. To illustrate, consider two symmetric mobile money providers which offer equally good

[19] IPA (2021) found qualitatively similar results for Kenya. Although consumers were better informed about fees, 72% still reported only learning how much they would pay after carrying out a transaction.

[20] However in Mexico, Ponce, Seira and Zamarripa (2017) find that consumers do not allocate spending optimally across credit cards with different interest rates, and making fees more salient does not change this. Seira, Elizondo and Laguna-Müggenburg (2017) report further "negative" evidence. One reason is that consumers may adjust slowly as, e.g., in the Karlan and Zinman (2018) study on microcredit.

[21] Specifically, if fees "are vectors rather than scalars, consumers have trouble choosing the best price" (Grubb (2015)).

services. Each provider chooses both fees and the complexity with which those fees are presented, as in Carlin (2009). Suppose some consumers get confused and choose a provider randomly, while other consumers choose the best provider; the fraction of confused consumers is increasing in the level of each firm's complexity. In equilibrium fees are dispersed. Moreover, if a provider has low fees it also chooses low complexity, whereas if it has high fees it also has high complexity. An increase in the feasible amount of complexity—for instance, because interoperability increases the number of possible fees—leads to more confusion and higher fees. Encouraging entry of a new provider can have perverse effects because, as in the search models considered earlier, existing providers are more likely to choose complex fees so as to target confused consumers.

Piccione and Spiegler (2012) and Chioveanu and Zhou (2013) microfound complexity via different providers using different frames. They find that sellers of a homogeneous good will generally randomize over different frames, leading to some consumers getting confused, which is then exploited via dispersed (and supra-competitive) prices. The first paper shows that policies which makes fees somewhat easier to compare—for example requiring all providers to use slab pricing—may backfire and harm consumers when providers have other ways to make fees complex—for example, by choosing different on- and off-net fees. The second paper shows that increased competition—for example, by encouraging more mobile money providers to enter—may harm consumers, by encouraging firms to make their frames more complex to soften competition.[22]

Possible Interventions

Three natural interventions are: i) increasing competition, ii) caps on fees, and iii) standardized presentation of fees.

As already discussed, Piccione and Spiegler (2012) and Chioveanu and Zhou (2013) show that increasing competition or (weak) caps on fees may backfire, by inducing firms to make their offerings more complex. These models suggest that the third intervention—making offerings as standardized and hence comparable as possible—may work best. We now discuss some suggestive evidence in favor of this.

Empirical Evidence

We are not aware of empirical studies that look at how mobile money consumers choose between (potentially very) complex offerings—and we think such a study would be very valuable. Nevertheless there is suggestive evidence from other settings that standardizing offerings leads to better consumer choices.

As discussed earlier, when mobile money providers become interoperable, their products have more "dimensions", and providers have more ways to frame their fees. In a laboratory study, Kalaycı and Potters (2011) assign participants as either buyers or sellers; sellers choose how many dimensions their products have, and buyers then choose

[22] As Gabaix, Laibson, Li, Li, Resnick and de Vries (2016) point out, consumers may alternatively make small errors when evaluating different products, leading them to act as in a discrete choice model. Depending on the distribution of the errors, greater competition can again increase prices.

which product to purchase. The authors find that when products have more dimensions, buyers are more likely to make suboptimal purchase decisions, and sellers exploit this by charging higher prices. Also in the lab, Huck and Wallace (2015) vary how the prices of homogeneous products are framed, and show this leads to worse choices by buyers compared to simple linear pricing (which corresponds to percentage fees in a mobile money context). Carvalho and Silverman (2022) argue that the way participants respond to complex fees is a form of rational inattention, due to the high cognitive effort that is needed. This suggests that policies which make offerings more standardized should lead to better consumer choices. Gine, Martinez Cuellar and Mazer (2017) test this using lab experiments in Mexico and Peru, in the context of loans and savings products. They find that when consumers are presented with simplified statements with "key facts" about products (rather than firms' marketing materials), the probability of choosing the cheapest loan increases from 42% to 65%, and the elasticity of demand for credit triples.

4.4 Add-on pricing

Even if consumers learn providers' fees and try to compare them, some fees may be more salient than others. Suppose providers initially compete with mobile telephony services and on-net mobile money services. If interoperability allows providers to add off-net transactions, the fees for those services may (at least initially) be less salient to consumers—e.g., because consumers do not pay attention, or do not envisage using those services very much. We first review how in theory this saliency affects fee competition, then we discuss potential interventions, before finally discussing some empirical evidence.

Theory

Following Ellison (2005) and Gabaix and Laibson (2006), telephony and on-net transaction services are "base goods", and newly-added off-net transactions are "add-on goods".

Gabaix and Laibson (2006) look at firms' incentives to make their add-on fees salient. To illustrate, suppose providers choose all fees simultaneously. The fees for the base good are salient and accounted for by all consumers. However providers can, if they wish, "shroud" their add-on price, meaning that consumers cannot observe it when choosing their provider. Some consumers are sophisticated: they account for add-ons when choosing a provider, and can exert effort to avoid paying add-on fees if they are (expected to be) excessive.[23] Other consumers are myopic: they completely neglect add-on fees when choosing a provider, unless one or more provider has unshrouded, in which case they become like sophisticated consumers. Gabaix and Laibson (2006) show that if enough consumers are myopic, all providers shroud. Intuitively, no provider wishes to unshroud, because this would educate myopic consumers, inducing them to buy from the provider with the lowest base good fee and take actions to avoid paying add-on fees. Add-on fees end up being very high, such that sophisticated consumers engage in socially costly activities to avoid paying them. As a result, off-net transactions are low.

[23] E.g., they could multi-sim or use cash instead of incurring high fees to transfer to another network.

In principle, providers may compete more fiercely on the base good, in the hope of attracting more myopic consumers who can be exploited later on with high add-on fees. Interoperability might therefore lead to lower on-net fees and thus higher *on-net* transactions.[24] However Ellison (2005) argues that in practice the degree of pass-through may be relatively small. To see why, suppose sophisticated consumers are more price-sensitive than myopic consumers on the base good. (E.g., sophisticated consumers are less influenced by providers' attempts to appear more differentiated.) If a provider reduces its base fee it attracts more consumers, but relatively many of them are sophisticated consumers, who are less profitable because they do not buy add-ons. Hence firms' incentive to undercut on the base good is reduced: interoperability induces only a small reduction in on-net fees, and thus only a small increase in on-net transactions.

Possible Interventions

Following Gabaix and Laibson (2006) there are again three natural policy interventions. Firstly, mobile money providers could be compelled to disclose all fees prominently, including those for off-net transactions. However as we saw earlier, if providers can frame fees as they wish, this may not help resolve the problem of high fees. Secondly, consumers might receive a warning about fees when signing up to a provider. However, as we also saw earlier, with search costs, a mere warning may not induce consumers to search and force providers to price more competitively. Thirdly, then, some form of caps may be required. Moreover, to the extent that some consumers may naively believe on- and off-net fees to be identical anyway, it might be beneficial to directly mandate this.

Empirical Evidence

Although we are not aware of empirical studies of add-on pricing in mobile money markets, there are studies for other financial markets markets. Ru and Schoar (2016) find that US credit card providers shroud unappealing contract terms using fine print or complex language, especially for consumers who appear to be less financially literate. Consistent with the above theory models, higher shrouded (add-on) fees are accompanied by lower unshrouded (base) fees. Meanwhile Alan, Cemalcilar, Karlan and Zinman (2018) provide evidence that firms lack incentives to unshroud. Specifically, in collaboration with a large Turkish bank, they find that promotional text messages offering a 50% discount off the usual APR for going overdrawn *reduced* overdraft usage by around 1.2 percentage points (from a baseline of around 30%); the interpretation is that this made the high fees more salient, and educated consumers to avoid them.

4.5 Conclusion

For interoperability to work well, off-net fees should be low so as to increase transaction volumes. In this section we reviewed several reasons why in practice those fees might

[24] Note that the benefits of interoperability would not be spread evenly—sophisticated consumers would benefit from lower on-net fees, but myopic consumers would be harmed due to high off-net fees.

not be low, and we also discussed various policy interventions to correct this. A common theme is that well-intentioned policy interventions can potentially backfire if attention is not paid to the underlying cause of high fees.

5 Agent Interoperability

One of the key features of digital payments and finance in developing countries is the prevalence of agent-based banking and mobile money. In most developing countries, cash remains the most preferred mean of transaction and traditionally, individuals rely on ATMs and bank branches for obtaining cash. In rural areas with low population density, it is often economically unfeasible for banks to have many branches or ATMs. Even consumers that use digital financial services like mobile money might need to rely on physical infrastructure to deposit and withdraw cash. The agent-based model of mobile money and payment platforms addresses precisely this gap in physical infrastructure.

Typically, mobile money agents facilitate cash-in/cash-out services in areas underserved by traditional banking. Apart from cash-in/cash-out, mobile money agents register customer, educate them provide person to person transfers, recharges for mobile airtime and bill payments. Depending on the country, agents may perform one or all of these functions (Davidson and Leishman (2012)).[25] The mobile money provider's main source of revenue is the fee charged to the consumer for every transaction, and the agent receives a part of this fee. The agent may receive training from the mobile money provider but typically bears the cost of operating herself.

The benefits of a large agent network (which may or may not be as a result of mandating agent interoperability) are well documented. Suri and Jack (2016) find that the key driver of adoption of mobile money services in Kenya are agent networks. In Niger, Aker, Prina and Welch (2020) finds that despite a relatively high demand for mobile money services, adoption remains limited because agent networks are sparse.

There can be many different forms of the relationship between agents and providers, leading to different types and extent of interoperability. Depending on the country, agents can either be exclusive to one mobile money provider or represent several providers. For example, an interoperable agent might provide cash-in services to customers of other providers with her agent account, but not cash out. An agent could also represent several companies but only by having multiple agent accounts (non-exclusivity). There could also be a full-interoperability regime where an agent can provide all its services to the customers of another service provider.

Some countries have already implemented interoperability of mobile money agents. As discussed in Hoernig and Bourreau (2016), in Kenya, regulation in 2014 mandated that the dominant provider, Safaricom, open its network of agents to rival mobile money providers. In Nigeria as well, agents can serve multiple banks/mobile money providers. In Tanzania, agent exclusivity is not permitted and mobile money providers reached consensus on interoperability without being mandated to do so.

[25] In Kenya, M-Pesa has homogeneous agents that each perform all of these functions. On the other hand, in Uganda, different agents are responsible for different functions.

In this section, we describe economic frameworks to think about interoperability of mobile money agents using first, the experience of interoperability for ATMs, and then the theory of access pricing and co-investment in network industries. We end the section with a discussion of recent empirical evidence on the relationship between competition and investment in network industries.

5.1 Interoperability of ATMs

The experience of interoperability in the market of ATMs is particularly relevant for understanding the key issues facing interoperability of mobile money agents. We can think of agents as ATMs and mobile money service providers as banks. In most parts of the world, ATMs are now interoperable with a pre-negotiated interchange fee between banks and/or a surcharge to use another bank's ATM. However, this was not necessarily the case to begin with. In New York, ATMs were introduced by Citibank in the 1970s. Even though it would have been cheaper to introduce ATMs in consortium with other banks, Citibank chose to differentiate itself through the ATM technology and expand its market. It only became interoperable with ATMs of other banks ten years later after it started losing market share to a consortium of six banks with interoperable ATMs (CGAP (2019)). Other banks in other parts of the US followed different strategies by forming consortium of interoperable ATM networks.

This example clearly illustrates the key trade-offs that a bank (mobile money provider) might face with interoperable ATMs (agents). Banks benefit from having large ATM networks: they can offer lower deposit rates as depositors prefer a bank which provides a larger network of ATMs, and thus better access to their deposits (Matutes and Padilla (1994)). In general, banks increase the value of their networks by increasing the size of their ATM network (Scholnick, Massoud, Saunders, Carbo-Valverde and Rodríguez-Fernández (2008)). However, when ATM networks are interoperable, depositors can benefit from the large ATM network of the bank, but they can also benefit from the higher interest rates paid by a rival bank with a smaller ATM network (Matutes and Padilla (1994)). In the case of mobile money agents, the trade off is starker as large agent networks require substantial upfront investment from providers - costs of training agents can be quite high (Davidson and Leishman (2012)). Providers may also use their agents as a way to differentiate their products, especially when agents perform auxiliary functions like financial education of consumers, recharge services for airtime and bill payment services.

5.1.1 Emergence of interoperable ATM networks

We first provide theoretical insights on shared ATM networks based on the existing literature. Matutes and Padilla (1994) examine the trade-off between the network effect of shared ATM networks (consumers prefer a bank with a larger network and banks benefit from lower deposit rate) and substitution effect (consumers may switch to rival banks with higher deposit rates if ATM networks are interoperable). They focus on a setting where banks first agree to share their ATM networks and then compete on deposit rates. In the baseline case, they assume that there are no interchange charges or other fees involved in the agreement.

In the absence of interchange charges and fees, they find that either a subset of banks joins the interoperable network (partial compatibility), or no bank does (incompatibility). Partial compatibility only arises when network effects are large and the substitution effect is not too large. All banks agree to share their ATM networks (full compatibility) under two circumstances: i) when banks want to use compatibility agreements to deter entry of new players in the market, ii) or when banks can impose positive interchange or withdrawal fees, iii) or when the switching costs for depositors is relatively high. High switching costs and positive interchange/withdrawal fees can typically be used to limit the substitution effect of having a fully interoperable ATM network (Matutes and Padilla (1994). The underlying economic intuition of these findings are likely to apply to the case of agent interoperability as well.

5.1.2 Pricing of interoperable ATM networks: Interchange fees

The second issue to consider is pricing in interoperable networks of ATMs, or in our case, agents. Even when banks (mobile money providers) decide to share their ATM (agent) network, they still need to decide the terms of this agreement. For ATMs, this is typically done by setting an interchange fee that is paid by participating banks of an interoperable ATM network.

In the case of mobile money, if a consumer chooses to transact with a "foreign" agent affiliated to a different provider (foreign provider) than her own, then the customer's provider (home provider) would pay an interchange fee to the foreign provider. This fee would compensate the cost faced by the foreign provider for providing services to a foreign customer. The home provider may choose to charge a part of this fee to its customer (akin to foreign fees for using another bank's ATM). The foreign provider may also charge the foreign customer for the transaction (commonly called surcharges in the case of ATMs). The key question would then be how providers set these fees and if there is a need to regulate them. These fees have a direct impact on consumer welfare since they affect consumer search for the most economical ATM (or agent, in our case). They can also have an indirect effect on consumer welfare by affecting the number of ATMs (agents) deployed, the price of the transactions themselves, and the level of competition between service providers.

The existing economics literature has tried to address several contentious policy issues in ATM pricing. Though most of the examples of these policy issues come from the context of ATM deployment in a mature market like the US, the theoretical insights can inform the discussion of interoperability of mobile money agents in the developing world. The first policy issue, broadly defined, concerns the setting of the interchange fees. Introducing interchange fees can be an incentive for providers to share their network (or have interoperability), however, the ultimate welfare outcomes depend on how providers set these fees. Empirical evidence for ATMs from the UK, Australia and the US has shown that interchange fees were set by banks in a way that led to mark-ups of close to 100%, meaning that these fees were much higher than the cost of providing ATM transactions.

Several theoretical models rationalize this empirical finding by showing that providers cooperate to set the interchange fee and this amounts to tacit collusion (McAndrews (2003)). A high interchange fee softens competition for end consumers but increases competition for processing foreign transactions (Donze and Dubec (2006)). This makes it possible for the interchange fee to be used as a device for collusion by providers. This is widely recognized by regulators in the ATM and electronic card industries, and in these industries it is not uncommon to have oversight on how interchange fees are set.

5.1.3 Pricing of interoperable ATM networks: Surcharges

Even more contentious than the setting of the interchange fee has been the debate around ATM surcharges (the fees charged by the ATM owner bank to a foreign customer). Several papers have examined the pricing structure of ATMs, focusing particularly on surcharges. Massoud and Bernhardt (2002) provide a spatial model of ATM pricing. Their model is consistent with several observed empirical findings. They find that banks price discriminate between their consumers and foreign consumers (consumers of other banks). While they charge their own consumers the marginal cost of providing ATMs for usage, they extract their profits by charging high surcharges for usage to foreign consumers. Surcharges have a direct and indirect effect on the revenues of the bank. The direct effect captures the direct revenue from the surcharge imposed on foreign consumers. The indirect effect captures the revenue from the foreign consumers that decide to switch to the bank and become home consumers. They might have an incentive to do this if the ATM network of the bank is large enough and once they become home consumers, they do not have to pay the high surcharges for ATM usage which they previously paid as foreign consumers. Consistent with the theoretical results, Hannan, Kiser, Prager and McAndrews (2003) find that banks with larger market shares are more likely to impose surcharges for foreign consumers.

Proponents of surcharging have argued that it is necessary to sustain ATMs in remote, and otherwise unprofitable locations, thus expanding access to cash withdrawal services (McAndrews (2003)). On the other hand, there are two main concerns against the practice of surcharging. First, surcharging a foreign customer by the ATM owner adds to the foreign fee already paid by the customer to its home bank, making the fee structure complicated for consumers (McAndrews (2003)). Second, consumers would be inclined to switch to banks with a larger network of ATMs to avoid paying these fees, thus reducing competition in the market for deposits(McAndrews (2003)). Some concerns were also raised that surcharging amounted to consumers paying a fee to access their own money (Hannan et al. (2003)). The issue of surcharging became prominent in public debates in the US in 1996 when state governments and courts made illegal any rules imposed by service providers to disallow surcharging.

Following this ruling, ATM deployment dramatically increased in the US, as surcharging was a new incentive for banks to provide this service. Theoretical literature rationalizes this empirical finding. Donze and Dubec (2009) provide a model of two horizontally differentiated banks that first choose the interchange fee jointly and then provide ATMs and compete for customers. After setting up the model, they compare welfare outcome under three regimes: i) consumers can access all ATMs (home and foreign) free of cost, ii) consumers pay a foreign fee to their home bank for using a foreign ATM , iii) consumers pay a foreign fee to their home bank and a surcharge to the foreign bank when using a foreign ATM.

Somewhat surprisingly, the paper finds that consumer welfare is higher in regime two (foreign fees) than in regime one (free ATM usage for home and foreign ATMs). The economic intuition driving the result is the following: under regime one, since all ATMs are identical for consumers, they make many foreign transactions for no additional fee which generates a large gross surplus. The banks take this into account in pricing the end product (deposits) and are able to extract the surplus by setting high account fees. Under regime two, consumers make fewer foreign transactions and ultimately pay lesser to the bank.

Even more striking is the result on regulation of surcharges. The authors find that when surcharging is banned, the profits of the bank in equilibrium depend on the interchange fee, and banks have the incentive to collude to set this fee (except under regime three). They also evaluate consumer welfare while allowing banks to jointly set the interchange fee. They find that consumers prefer regime three to regime two when the shopping space is large and the value of having more ATMs is high. When the shopping space is relatively smaller, consumers do not benefit from paying the additional surcharge as accessing ATMs is easier than in a bigger shopping space. This result is consistent with empirical evidence from the US. In 1996, the US changed from regime two to regime three and Knittel and Stango (2008) find that in areas with high travel cost (where the shopping space is large) consumer welfare improved after the regime change. The opposite was true in areas of low travel cost.

The empirical literature on ATM pricing apart from Knittel and Stango (2008) is limited, but illustrative.[26] Hannan et al. (2003) find that the probability of surcharging increases with the bank's market share of ATMs and decreases with increasing density of the ATM network. They also find evidence that banks use surcharges to attract new customers to their own networks, but do not find any evidence that big banks use surcharges to attract existing customers of smaller, local banks.

5.2 Co-investment in Network Industries

In network industries like telecommunications, providers face high investment cost to expand access. In our case, training agents and expanding the agent network is a considerable investment for mobile money providers (though considerably less than the case of telecommunications infrastructure). For a provider that has invested in a large network of agents, introducing agent interoperability would mean that a part of the gains from its investment are recovered by competing providers. If mobile money providers expect that agent interoperability might be mandated in the future, they would have fewer incentives to invest in the agent network. On the other hand, once one provider has made investments in the agent network, other providers may free-ride on this investment

[26]See Verdier (2011) for a comprehensive review of the literature on interchange fees.

in the case where agent interoperability is mandated.

Bourreau, Cambini and Hoernig (2018) and Bourreau, Cambini, Hoernig and Vogelsang (2021) discuss a similar problem taking the general case of network industries. In any network industry (telecom, mobile money or others), an under-investment problem may arise because new infrastructure is costly and the gains from the infrastructure will likely be shared by other firms and their consumers. This under-investment problem is made worse when there is uncertainty about the level of demand for the firm's service.

To deal with this, typically, in industries like telecommunications, regulation mandates incumbents to have access obligations. For example, in Europe, during the initial roll-out of broadband infrastructure, incumbent operators were mandated to share their infrastructure with other providers under these access obligations. The other providers pay an access fee to the incumbent, which may or may not be regulated.

A recent regulatory alternative to access obligations (in order to expand coverage of services) is allowing, encouraging or mandating "co-investment" in infrastructure (Bourreau et al. (2018)). Co-investment, instead mandating access to competing providers, works as a way to share the cost of infrastructure by different service providers.

5.2.1 Co-investment versus access obligations

Bourreau et al. (2018) provide a theoretical comparison of the access pricing regime and the co-investment regime in terms of spurring coverage, and in terms of total welfare. The authors consider the case of a network industry where providers face uncertain demand and might have incentives to co-invest. There are two firms, one of which is the incumbent in the market and the other a potential entrant. The incumbent first chooses the areas to invest in and then the entrant chooses whether to co-invest or to pay an access fee. After co-investment or paying an access fee, the entrant can access the shared infrastructure in the same way as the incumbent, and at no additional cost. Note that in this case, decisions by both the incumbent and the entrant are taken before the demand uncertainty is resolved.

The authors compare three different scenarios. In the first "pure access" scenario, there is no possibility of co-investment. The entrant can ask for access to the incumbent's infrastructure by paying an access fee. The second scenario that they consider is of "pure co-investment" where the entrant can share the cost of investment in areas that the incumbent has planned to invest in. Crucially, in this scenario, the entrant cannot ask for access to the incumbent's infrastructure as an alternative to co-investment. The final scenario that the authors consider is a combination of the first two: the entrant is allowed to decide whether to pay an access fee to the incumbent or to co-invest.

The authors find that compared to the first scenario of pure access, the pure co-investment regime fosters competition in areas where the network is shared, and also leads to greater coverage. Under the mixed regime, the authors find that both total coverage and co-investment coverage is lower than in the pure co-investment scenario. The authors conclude that in scenarios with a high degree of uncertainty of demand, the pure co-investment regime is the most preferred regulatory regime.

5.2.2 Timing of co-investment

The next important question that this literature considers is the timing of the co-investment. Regulators may allow firms to "co-invest" in infrastructure deployment ex-post, meaning that entrants can wait until any uncertainty of demand is resolved and then decide to co-invest. The importance of demand uncertainty and the timing of co-investment is highlighted in Bourreau et al. (2021). The set up of the theoretical model is largely similar to Bourreau et al. (2018). After the investment stage, the two firms compete with each other and set the prices of their services. In areas where the entrant and the incumbent both co-invest, they each make duopoly profit. In areas where only the incumbent operates, it makes monopoly profits or less. In all cases that the authors consider, the information about the level of demand is revealed only after investment takes place.

The first case that Bourreau et al. (2021) consider (the benchmark) is where the entrant makes its co-investment decision before the deployment of the infrastructure and without information about the level of demand in the area. This means that both the entrant and the incumbent face the same demand uncertainty. In this case, the authors find that in equilibrium, firms choose to co-invest only in those areas of the market where the sunk cost of investment is low. In this equilibrium, there might also be areas where only the incumbent invests and gets monopoly profits (under the condition that duopoly profits are lower).

The authors contrast this case of ex-ante co-investment with the case where the entrant has the option to wait for the demand to be realized and then co-invest. In this case, the authors highlight two distortions that arise: market structure distortion and coverage distortion. First, the probability of entry in co-investment areas decreases if the entrant knows the level of demand before the co-investment decision. At the same time, the probability of entry in monopoly areas increases. This shift in probabilities is called the market structure distortion. Second, in this case, the incumbent's incentive to invest are reduced and this translates to lower coverage of the end service compared to the benchmark case. This is called the coverage distortion by the authors. Coverage distortion is especially likely to arise when there is a high degree of demand uncertainty and decreases social welfare compared to the benchmark case.[27]

5.2.3 Empirical evidence on investment in network industries

While the discussion of investment in network industries in the previous sub-section drew lessons from the theoretical literature, there is also recent empirical evidence about the role of competition in facilitating investment in network industries. Björkegren (2022) studies the role of competition policy in affecting investment and welfare in a network industry.

[27]Bourreau et al. (2021) suggest two remedies that partially address these distortions. The first one is a co-investment option that the entrant purchases from the incumbent ex-ante (that is before the demand is realized) and it can be exercised ex-post. The second remedy suggested by the authors is a risk premium paid by the entrant to the incumbent ex-post.

Björkegren (2022) studies the telecommunications market in Rwanda to quantify the effect of competition on investment and welfare. The path of the telecommunications market in Rwanda offers parallels with, as well as lessons for the evolution of mobile money markets. In Rwanda, initially only one service provider was allowed to operate and competitive entry was only permitted after several years. Regulation was such that firms had to be interoperable to allow for cross-network calls. With the presence of competitors, the incumbent reduced its prices and also increased the deployment of towers. The main question that this paper seeks to answer is if market and welfare outcomes could have been better if competition had been introduced earlier in the market.

The paper finds that in the counterfactual scenario of encouraging competition earlier (by granting a licence to a new operator earlier) there would have been a sizeable reduction in retail prices of calls. At the same time, investment in under-served rural areas would have increased. Additionally, the net welfare from the entire mobile network would have been up to 38% higher as a result of introducing competition earlier. In terms of investment, even with the presence of the entrant, most of the incremental profit from additional towers in rural areas accrues to the incumbent. This happens because the incumbent is able to "steal" consumers from the other operators following its investment. Thus, the return on the incumbent's investment is higher in the counterfactual under early competition. However, the results on the incumbent's return from investment depend on the competition policy regime. In particular, the incumbent's return on investment declines with greater interoperability (through lower interconnection charges) but investing in rural infrastructure remains profitable for the incumbent. Greater interoperability also leads to lower retail prices and higher welfare for all the interconnection charges that the paper considers.

5.3 Conclusion

In this section, we have outlined lessons from two different strands of the literature to inform policy on interoperability of mobile money agents. We first consider the literature on shared ATM networks and banking competition. Using existing work, we lay out the incentives and trade-offs involved in making ATM networks interoperable. We then evaluate how interchange fees, foreign fees and surcharges affect these trade-offs. The literature suggests that while interchange fees encourage banks to share their ATM networks, they could also be used as a collusive device. On the other hand, surcharges might be useful in preventing providers from using interchange fees as a collusive device. This calls for regulatory oversight of interoperability agreements and pricing arrangements.

While the first strand of literature looks at the possible arrangements for interoperability when the providers have already made their investments, we then focus on understanding providers' incentives to invest in agent networks when agent interoperability might be possible. In this case, we view agent interoperability as a parallel of the problem of investment incentives in network industries. We provide a review of the latest findings on co-investment, a new strategy recommended by the European Union to facilitate access to the next generation of digital technologies. Recent literature suggests that co-investment may be a better regulatory strategy in terms of social welfare and investment incentives than the traditional regulatory tools based on access pricing.

Finally, we conclude this section by presenting recent empirical evidence on the effect of competition on investment and welfare in network industries, particularly focusing on the timing of regulatory interventions. This literature shows that introducing competition early in the market decreases retail prices, increases welfare and may even increase the incumbents' return on investment in network infrastructure.

6 Data Interoperability

Digital payments, unlike cash payments, only exist to the extent they are recorded. Therefore one side-product of digital payments is data on the consumption patterns, the business activity and the financial decisions of users. We understand data interoperability here as the extent to which the information generated with one payment provider can be transferred to a third party. This information is typically relevant to evaluate risks that are key in the provision of complementary financial products such as credit or insurance. Therefore for consumers, digital payments may not only expand access to basic (yet important) financial services such as storage and transfer of money but can also be the gateway to more sophisticated products where risk evaluation is key. There, data interoperability, by improving the flow of information across firms, can broaden consumers' access to financial services and help build financial advice applications that lower complexity costs for consumers. For payment providers, the ability to leverage payment information to gain a competitive edge in the provision of complementary services should affect their behavior in the payment market, as noted in Section 2, while data interoperability could dissipate this competitive advantage.

6.1 The value of payment data

The literature on banking has long highlighted the specific access to information about borrowers banks enjoy through both the scope of the services they offer (e.g., payment, credit, investment, insurance) and through repeated interactions. An early example is Black (1975) who argues that a bank's ability to observe a customer's payments can serve as a "continuing source of credit of information." Black (1975) also insists on the importance of historical information about customers as a competitive advantage over other potential lenders. This concept of "relationship banking" is formalized in Rajan (1992) who highlights the trade-off this privileged access generates. On the one hand, because banks are better informed about borrowers they can more efficiently adjust funding terms to cash-flow realizations or investment opportunities. On the other hand, relationship banking creates a hold-up problem where the better informed lender can credibly threaten to cut off funding in order to extract more surplus from the borrower, as this would be perceived as a negative signal on the borrower's creditworthiness. In Rajan (1992), this may lead borrowers to turn to uninformed arm-length lenders such as bondholders, or in a more modern version to peer-to-peer lending platforms (Thakor

(2020)). A critical ingredient of this hold-up problem is that the information created inside the bank through interactions with borrowers is "soft," i.e., cannot be easily or credibly transferred to outsiders. A typical example of this type information is the assessment of a loan officer that incorporates multiple sources of information including repeated informal interactions.

The non-transferability of the information considered in the relationship banking literature inherently precludes interoperability. However the information digital payment generates is likely closer to "hard information" in the sense that it is verifiable, easy to store and to a large extent quantitative. A first implication is that payment data can provide a cost-effective resource to assess the individual risk of a user: the collection of payment data and its processing and transformation into risk metrics can be standardized and automated. This can eliminate some of the interactions between loan officers and borrowers, and more generally the need for physical proximity between borrowers and lenders through a costly network of branches. A stream of empirical literature in banking uses that physical proximity as a proxy for information frictions: when hard information is not available, banks need local loan officers with sustained relationships with potential borrowers in order to evaluate credit-worthiness. Petersen and Rajan (2002) attribute the steady growth of the physical distance between lenders and small business borrowers in the US to an increased reliance on hard information and information technologies. The wider availability of payment data and the implied productivity gains could be particularly meaningful in the context of developing countries: Mian (2006) shows that foreign banks that open subsidiaries in Pakistan are willing to lend at arm's length when hard information is available, but are reluctant to do so when the lending decision requires unstructured "soft information" collected through repeated relationship. In India, Rishabh (2022) shows that payment information accessed through a payment fintech not only has stronger predictability for future credit default than the information provided by India's largest credit bureau but renders that credit bureau's information irrelevant once payment information is taken into account.

Another dimension of information being hard is that exploiting it does not require the interpretation of the person or entity that collected it unlike, for instance, the subjective assessment of a loan officer (Liberti and Petersen (2019)). This feature is important for data interoperability because it makes payment information portable: any third party that can access it may profitably use it. In that sense, data interoperability can be distinct from other forms of payment interoperability: interoperable payment providers inherently share data, but payment data can be portable across firms with no existing connection. In practice, Application Programming Interfaces (APIs) can facilitate the interconnection between payment providers and third parties and allow for faster and cheaper data extraction. The speed and cost-efficiency of APIs are more valuable for applications that require more frequent updating (e.g., accounting, financial advice), and are a central digital infrastructure in the development of open banking (see, e.g., Payment Service Directive 2 in the European Union). However, for lower-frequency decisions such as credit, the mere fact that users can provide banking statements can constitute a critical piece of hard information.

Ghosh, Vallee and Zeng (2021) show how this basic form of data sharing has a downstream effect on the provision of credit. In the theoretical part of the paper, they highlight two channels through which the additional signal provided by payment data affects lending outcomes. First, additional information improves the borrower's ability to screen lenders. While this may result in a more efficient allocation of credit, enhanced screening also has differential effects across loan applicants: better-than-average lenders (given the extra signal) are more likely to receive funding while worse-than average lenders are less likely to receive funding. This result echoes the more general finding that improving lenders' screening ability through information technologies has distributional effects. For instance, Fuster, Goldsmith-Pinkham, Ramadorai and Walther (2022) show that the use of machine learning algorithms in the US mortgage market is less likely to benefit Black and Hispanic minorities than the White majority group. Second, additional information reduces the uncertainty lenders face when originating a loan. If lenders are risk-averse (more generally, subject to financial constraints), lower uncertainty reduces the required return for lenders, hence the cost of funding across the board for borrowers. Next, Ghosh et al. (2021) use data from a FinTech lender in India to confirm the prediction of the model. They show that borrowers' ability to provide digital payment data to the lender is associated with better lending outcomes for small businesses: an interquartile increase in the share of cashless payment increases the likelihood of obtaining a loan by 2.7%, i.e., more than 10% of the baseline likelihood of getting approved, and a 42 basis point decrease in interest rate. This relationship is stronger for internet transfers that provide richer information about counterparts than for mobile payment. The paper exploits an exogenous variation to the adoption of digital payment (the 2016 Indian demonetization) to show that the relationship between the use digital payment and credit outcomes is likely causal.

More generally multiple types of complementary services can benefit from access to payment information. For instance, applications plugged into payment providers' APIs can help users navigate financial decisions such as the choice between different payment or credit options, the refinancing of existing credit lines, budget management or access to financial aid (Plaitakis and Staschen (2020)). These applications have the potential to reduce some of the complexity and behavioral costs discussed in Section 4.

6.2 Who should have control over payment data?

The Indian case studied in Ghosh et al. (2021) highlights how data interoperability is distinct from other forms of payment interoperability that require pooling resources and investments across players (e.g., payment networks, agent networks) or coordination on compatible technical solutions. On the contrary, data interoperability merely requires that data be portable from one firm to another firm, even though implementing this portability at scale and cost-efficiently may involve technologies such as APIs. This suggests that obstacles to data interoperability may not lie so much in the cost of building common infrastructures as in the incentives to share data. This naturally raises the question of who should have control over data, and hence the ability to share it.

Jones and Tonetti (2020) provide a general framework that supports consumers' ownership of data. In their model, the distinctive feature of data relative to other factors of production is that it is non-rival: data is costlessly replicable and can therefore be used infinitely many times with no opportunity cost. This suggests there are significant economic gains to data being used broadly. The use of payment data for credit allocation discussed earlier is consistent with meaningful efficiency gains from transferring data from one service to a different service. Jones and Tonetti (2020) show there can be quantitively significant under-sharing of data if firms control it and are concerned that access to data makes them more likely to be displaced by competitors. By contrast, consumer ownership implements a higher degree of data sharing and comes closer to the social optimum. Key to this result is the assumption that consumers cannot commit not to share data in the future, i.e., they cannot enter into an exclusive data sharing agreement with one particular firm.

Some of the regulatory frameworks and public infrastructures around payment data favor consumer's control over payment data, consistent with Jones and Tonetti (2020). For instance, PSD2 in Europe creates a mandate for banks to give third parties such as tech firms access to payment history through APIs, upon consent by the consumer. This effectively implements data interoperability but also a deeper form of integration as these third parties could use APIs to initiate payments through the banking system infrastructure. Note that tech firms are not subject to a reciprocal data sharing mandate with banks (Carstens, Claessens, Restoy and Shin (2021)). In India, the central bank created a legal framework for regulated entities ("account aggregators") that can collect and consolidate information from multiple financial institutions as well tax authorities and transmit it, with the customer consent to a third party (e.g., banks, insurance companies). Making data available through accounts aggregators is optional for financial institutions but firms that do not provide access are also precluded from using the information provided by accounts aggregators (D'Silva, Filková, Packer and Tiwari (2019)). In both cases, one rationale for giving users control over personal data is to facilitate access to other financial services, such as credit. This is different from Jones and Tonetti (2020) or Dosis and Sand-Zantman (2019) where users' control over personal data allows them to monetize it.

6.3 Payment data production

Data are different from other factors of production in that it is to a large extent a by-product of production. This has several consequences. First it can create increasing returns to scale economy-wide whereby higher output and consumption generates more data which improves productivity, hence leads to higher output, more data etc. In Jones and Tonetti (2020), this occurs within the firm, which takes advantage of data generated by its own production. In addition, because data is non-rival, returns to scale can be magnified at the economy level if the structure of the market for data incentivizes data sharing across firms.[28] Second, firms may alter their production decisions to generate more data. In Farboodi and Veldkamp (2021), firms offer products at lower prices (even possibly at zero-prices) because they value access to the data generated by these sales. This general insight suggests that incentives to invest in payment infrastructures and the pricing of payment services should be sensitive to the payment provider's ability to exploit payment data for other services and to its ability to retain control over this data and monetize it.

Parlour, Rajan and Zhu (2020) provide some insights into the relationship between the pricing of payment services, the production of payment data and consumers' ability to transfer data. They model a payment market where a legacy payment provider, a monopolistic bank, faces the entry of a new payment provider, a FinTech firm. First, entry has a competitive effect: lower prices for payment allow new users to access digital payments, and induces some users to switch from the bank to the FinTech firm. Users who remain with the bank (those who have a strong "taste" preference for the bank over the FinTech firm) may however face higher prices for payment. In addition, because payment data is used by the bank to assess credit risk, the quality of the bank's loans declines as it loses access to part of the payment market. Introducing data portability has an upside and a downside for the bank. On the one hand access to payment data produced by the FinTech firm improves the bank's ability to screen borrowers in the credit market. On the other hand, consumers are less inclined to use the bank's payment services to generate information and improve their access to credit. Overall, Parlour et al. (2020) argue that the development of digital payment providers outside the banking system and the interoperability of data between these new players and banks can have significant impacts not only on the payment activity of banks, but also on their credit activity and ultimately on their stability. Another takeaway is that the interoperability of payment data is likely to affect the pricing of payment services.

6.4 Payment data sharing and credit markets

As Ghosh et al. (2021) and Parlour et al. (2020) suggest, payment data can be particularly effective in credit markets. The question that the interoperability of data then raises is the impact of making this information available across lenders. The extant literature in banking has studied the impact of information sharing mechanisms such as credit bureaus. Information sharing has the potential to alleviate the adverse selection problem that lenders face in credit markets and can endogenously arise (absent regulation) when competition between banks is not too high (Pagano and Jappelli (1993)). Jappelli and Pagano (2002) and Djankov, McLiesh and Shleifer (2007) provide cross-country evidence that data sharing leads to higher aggregate bank lending and lower credit risk. Liberman, Neilson, Opazo and Zimmerman (2018) try to assess the equilibrium effects of restricting information sharing. They use a change in the regulation of credit bureaus in Chile in 2012 that removed information about past default for a part

[28] Farboodi and Veldkamp (2021) note that when data is used to improve the precision of predictions, as would be the case with payment data for credit or insurance applications, there is a natural limit to returns to scale since forecast errors cannot be reduced beyond zero.

of the population, and estimate both distributional and aggregate effects. They show a decrease in borrowing by 6.4% for borrowers negatively impacted by the reform (those who did not experience past defaults) and an increase by 11.8% for those positively impacted. However, because more borrowers are negatively impacted than positively impacted, the aggregate effect is a contraction in credit supply of 3.5%, consistent with the idea that adverse selection has increased in the credit market.

Data sharing is also likely to affect competition in credit markets. A first potential effect is to weaken banks' bargaining power based on the information accumulated over time on their pool of borrowers. Rajan (1992) shows this type of relationship lending allows banks to leverage their informational advantage to extract surplus from borrowers. The portability of data could then mitigate this information hold-up problem. The interaction between adverse selection and competition leads to more nuanced predictions. A stream of papers have studied the impact of screening abilities on credit when lenders competes with imperfect information about borrowers' quality (e.g., Hauswald and Marquez (2003)). He, Huang and Zhou (2020) build on this literature by introducing the possibility for consumers to transfer data from one lender to its competitor. In their models, Fintech firms do not produce as much information as banks but can better exploit it to evaluate credit risk. That improved precision can have ambiguous effects on borrowers' welfare (and even on total welfare). On the one hand, higher precision for all lenders leads to a more efficient allocation of credit by lenders. On the other hand, higher precision for some lenders increases adverse selection for the other lenders. The latter may then compete less aggressively, which allows the former to raise prices (interest rates). In that context, the systematic transfer of bank payment information to fintech lenders may eventually make borrowers worse off by weakening competition. This happens even if the transfer of payment information to a potential lender is optional. Indeed, denying access to personal payment information is then a signal of poor credit risk in equilibrium. In that case, good credit risks are forced to share information and bad credit risks suffer either from the stigma of not sharing or from the improved precision of the FinTech's screening when they share information.

The idea that allowing for payment data sharing leads to equilibria where keeping this information private carries an extra cost because it is interpreted as a bad signal is also present in Parlour et al. (2020) and Ghosh et al. (2021). This points to potential downsides of giving consumers control over payment data. First, data sharing can be associated with privacy costs for consumers. Second, lenders' improved ability to screen loan applicants need not lead to more efficient credit allocation when these borrowers face financial constraints. In that case, additional information can eliminate one channel through which stronger borrowers cross-subsidized weaker ones (similar to the Hirshleifer effect, see Hirshleifer (1971)).

6.5 Conclusion

Payment data interoperability raises questions at the intersection of two streams in economics and finance. The first one has its roots in a long-standing literature on banking that studies the origin and consequences of banks' informational advantage in screening and monitoring lenders. This literature highlights that the use of payment information for lending decisions creates a complementarity between the two activities. Payment data sharing through interoperability has then the potential to improve the efficiency of credit markets by favoring entry and competition, by reducing asymmetric information both across lenders and between lenders and borrowers, and by lowering uncertainty for lenders. This literature also cautions that higher data sharing can have distributional effects that adversely impacts certain groups of borrowers despite positive aggregate effects, and that differential abilities to process data can have a countervailing effects on the reduction of information asymmetries across lenders. The second stream focuses on the allocation of data control rights and its impact on the efficient use of information. Because payment data is a highly valuable input, access to it may in itself justify entry into the payment market and pricing below marginal cost. The benefit of access is higher if the payment provider can retain control over the data its customers generate. Firms' control over data may however lead to suboptimal information sharing ex post (inefficiently low data interoperability), even when markets for data exist. This concern underlies policy frameworks where customers have control over payment data.

7 Concluding remarks

We have reviewed various streams of academic literature to shed light on how the degree of interoperability in mobile payments affects market outcomes and welfare. First, building on the IO literature on tying, we have provided several arguments on why mobile network interoperability may have significant impacts on market outcomes. In particular, lack of interoperability may affect competition both in the telecom and in the payment markets, both discouraging entry and softening in-the-market competition.

Second, in relation to the IO literature on compatibility, we have shown that, absent regulation, interoperability at the platform level may fail to emerge, even if welfare-improving, when a dominant player enjoys strong network externalities or when consumers can join several platforms. We have also discussed some insights from the behavioral IO literature, showing that when consumers face search costs or when fees structures are complex or hard to observe, the intended pro-competitive effects of interoperability may be considerably weakened or even backfire.

Third, we have discussed how interoperability at the agent level can be analyzed through the lens of the literature on on co-investment in network industries and of studies on ATMs' interoperability, showing when in these markets we are likely to observe consumers being served by agents of different providers, and what the implications in terms of pricing and welfare are.

Finally, building on the banking literature and on studies on data ownership, we have highlighted how data interoperability creates a complementarity between payments and other financial services, which may increase overall efficiency but also have adverse impacts on some types of firms and consumers. We have also highlighted how access to consumers' data may in itself promote entry in the payment market, while at the same time leading to inefficiently low data interoperability ex-post.

Many of the dimensions we have highlighted would certainly benefit from further research. One key and probably under-explored aspect concerns the pricing of interoperable systems. Indeed, in practice, tariff systems for interoperable mobile-payment systems are a recent phenomenon, sometimes limited to certain kinds of transactions (e.g., P2P but not P2M), and still far from universal. An interesting topic for future research is to study the optimal design of such a system (from both the firms' and the regulator's perspective). One novel element of this problem is that consumer multi-homing imposes a natural upper bound on the difference between on-net and off-net transfers that telecom/payment providers can charge each other. Moreover, consumers' ability to compare tariffs across providers may be imperfect, thereby opening the door to possibly more complex anti-competitive practices.

Another, we believe, very interesting dimension for future research concerns the connection between data interoperability and other forms of payment interoperability. Key aspects of interoperability such as allowing payments across networks, sharing distributors and agents, or bundling telecom and payment networks, have implications for access and control over payment data. In settings where capturing the value of that data is central for firms' decisions, the question of data interoperability should be a key driver of payment interoperability at a broader level.

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