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“Competing digital monies”

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Abstract

We compare three competing digital payment instruments: bank deposits, private stablecoins and central bank digital currencies (CBDCs). A simple theoretical model integrates the theory of two-sided markets and payment economics to assess the benefits of interoperability through a retail fast payment system organised by the central bank. We show an equivalence result between such a fast payment system and a retail CBDC. We find that both can improve financial integration and increase trade volume, but also tend to reduce the market shares of incumbent intermediaries.

Keywords: payments, CBDC, big tech, banks, stablecoins

JEL classifications: E42, E58, G21, L51, O31.

1 Introduction

After decades of relative stability in the market structure of retail payments, new contenders are now vying to challenge bank deposits as a form of retail money for payments. A first set of

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contenders are private stablecoins.[1] Growing out of the cryptocurrency sector, stablecoins aim to offer payment and other services in new ecosystems built on blockchains and other forms of distributed ledger technology (DLT). The proponents argue that they could form the basis of new financial ecosystems with tokenised assets.[2] A second set of contenders are a new form of money issued by central banks – central bank digital currencies (CBDCs).[3] Central banks are pursuing CBDCs for different reasons, both for retail use (by households and businesses) and for wholesale use (for transactions between financial institutions). They, too, could form the foundation of new digital ecosystems, built on tokenisation of assets and unified ledgers (Carstens and Nilekani, 2024). Relatedly, central banks can offer retail fast payment systems (FPS), which allow for instant payments between account holders, using existing bank deposits and, in some cases, non-bank payment service providers (PSPs).

These different monies could have very different economic implications, not least for the industrial organisation of retail payment services. Payment markets could become fragmented in competing 'walled gardens', or they could become more efficient, integrated and accessible. The key questions of this paper are: what are the likely implications of these three competing digital monies for the market structure in payments? Moreover, when is it socially optimal to build a public sector infrastructure?

To answer this, we integrate two-sided market theory (see Rochet and Tirole (2002); Jullien and Sand-Zantman (2021)) with payment economics. Based on a theoretical model, we assess the likely impact of these three competing digital monies. The goal is to compare the world in which digital means of payment provided by new non-bank private issuers (stablecoins) compete with bank deposits, with or without public sector provision of digital money or payment infrastructures. In particular, our framework distinguishes between the unique characteristics of bank deposits, stablecoins and CBDCs with respect to their use in different sectors of the economy. This can help to understand the impact of stablecoins on the payment services industry (see Verdier (2024)) and that of a CBDC – or other central bank-operated systems like

[1]Stablecoins are a type of cryptocurrency that aims to maintain a stable value relative to a specified asset, or a pool or basket of assets (FSB, 2023).

[2]Tokenisation refers to the process of recording claims on real or financial assets that exist on a traditional ledger onto a programmable platform (BIS, 2023).

[3]CBDCs can be defined as a form of digital money, denominated in the national unit of account, that is a direct liability of the central bank (BIS, 2020).

FPS – as a public sector infrastructure for innovation (BIS (2021); Shin (2021)).

Our model is necessarily very stylised, capturing only a few key features of each instrument. For example, we model bank deposits as an instrument that is useful in a physical (bricks-and-mortar) market. Cryptocurrencies and stablecoins are used in practice mostly for speculation at current, and the proposed use cases are constantly changing, even in the statements by their proponents.[4] It would be very difficult to capture all the features of different types of stablecoins. As such, we model stablecoin issuers as digital platforms, and consider stablecoins as an instrument that is of use within a specified digital market.[5] We consider that some consumers prefer the physical market, and others prefer the digital market. (We do not go into the reasons for these different preferences). CBDCs are modelled as an instrument that is, by construction, interoperable, and thus useful for transactions in both the physical and digital market.[6] Retail FPS are, similarly, a public infrastructure that allows for real-time transactions in both the physical and digital market, thus enforcing interoperability.

Three key results come out of our model. First, when the payment systems are not interoperable (a situation we call "walled gardens"), access to accounts (financial inclusion) and trade volumes are inefficiently low. Second, when a fast retail payment system ensures interoperability between payment systems, financial exclusion disappears at the cost of some degree of disintermediation. Incumbent intermediaries lose market share to non-bank PSPs. Moreover, and somewhat surprisingly, merchant fees tend to increase because the demand for services provided by intermediaries becomes less elastic.[7] Finally, we show an equivalence result between CBDCs and retail fast payment systems. Both help to achieve a superior outcome to the laissez-faire approach, ensuring that different payment instruments are interoperable.

[4]For instance, Bitcoin was initially pitched as a "peer-to-peer electronic cash system" (Nakamoto, 2008), and has since been touted as an investment product, store of wealth ("digital gold") and much more. Stablecoins were initially introduced to address the problem of price volatility in cryptocurrencies, tying their value to central bank-issued currencies (especially the US dollar), but have since been touted as the onramp and offramp of money into and out of the crypto ecosystem, a means for cross-border payments and much more. See Auer et al. (2022).

[5]One could imagine this digital market being the ecosystem of tokenised assets in a blockchain/DLT-based financial system. Alternatively, one could understand this to refer to e-commerce and the type of closed ecosystems offered by large technology (big tech) companies, as with the aborted Libra (later Diem) stablecoin proposal from Facebook (now Meta).

[6]We assume that the CBDC is issued by the central bank, but that the system has private intermediaries that offer retail payment services – i.e. a two-tiered system. This is realistic, as all currently live CBDCs, and most of those under consideration, do indeed feature private intermediaries to interact with clients.

[7]Akoguz et al. (2025) study how data interoperability affects competition and welfare in the finance sector. They show that sharing customer data stimulates competition for credit but may indeed increase the prices of payment services.

Our paper contributes to the literature on payment markets, showing how competing digital monies can result in both desirable and undesirable market structure outcomes. Relative to other papers on CBDCs, stablecoins and FPS (see next section), we offer a compelling, theoretical exploration of the implications of different monies and policies for the industrial organisation of payment markets. Moreover, we give a unique application to a key sector in the economy whose main service (payments) is key to transactions in many other sectors.

The paper is organised as follows. Section 2 briefly reviews the related literature. In order to set the stage for the theoretical discussion, Section 3 discusses private walled gardens and public infrastructures in practice. Section 4 outlines our baseline model. Section 5 discusses payment systems with walled gardens. Section 6 studies the impact of introducing a fast payment system. Section 7 compares with the outcome of a retail CBDC. Section 8 concludes.

2 Related literature

A growing body of literature is helping to inform current policy debates on the future of the digital economy and the monetary system. One strand assesses digital platforms in the monetary system, including competition between platforms and outcomes in terms of market shares, pricing and financial inclusion (Belleflamme et al., 2022, Croxson et al., 2022). This literature shows how platforms can become dominant in certain markets. Some explicitly look at the role of user data in cementing market power (Cong and Mayer, 2022).

Other studies examine competition between different forms of digital money, in particular between CBDCs, stablecoins and cryptocurrencies (Benigno et al., 2019, Cong and Mayer, 2025). Stablecoins, a type of cryptocurrency that aims to keep a fixed rate against sovereign currencies or assets, suffer from shortcomings, particularly around the credibility of asset backing (Arner et al., 2019). However, they could become widely used in the future. The growing literature on CBDCs is summarised in Auer et al. (2022), and includes seminal works like Andolfatto (2020), Williamson (2022) and Chiu et al. (2023). This work generally looks at the macroeconomic implications of competing currencies, rather than the industrial organisation outcomes.

Our study combines these perspectives, showing how digital currencies may compete and what this will mean for payment markets and welfare in the digital economy and monetary system.

We contribute to the literature by explicitly comparing the public and private provision of payment solutions. This echoes a strand of the literature, which studies interoperability in payment systems (see Bianchi et al. (2021) for a survey). In our paper, we consider interoperability in a two-sided platform. We define interoperability as the ability of consumers on one payment platform (the bank platform or the digital platform) to make transfers to merchants on another platform. As in other papers, we find that interoperability may soften competition for merchants and increase merchant fees (Crémer et al. (2000), Chen et al. (2009), Øystein Foros and Hansen (2001), Matutes and Padilla (1994)).

There is also literature on platform competition and interoperability in the context of CBDC provision. Siciliani (2018) studies competition for retail deposits between asymmetric platforms: incumbent and entrant. He also compares various outcomes according to the assumptions on single-homing, multi-homing and interoperability of platforms. We use a different framework of Hotelling competition, with simultaneous price setting, and fixed fees on the merchant side.[8] Ahnert et al. (2025) also analyse competition between a bank and a platform offering tokens. However, they model a different definition of interoperability. In their paper, the first-best is achieved when merchants can sell everything online, because the matching technology online is perfect. We assume instead horizontal differentiation between trading environments, which implies that the first-best is a mix of brick-and-mortar and online sales. Brunnermeier and Payne (2022) assume that an incumbent platform may choose to restrict the portability of the payment information of its users to an entrant platform and restrict the convertibility of tokens.

Relative to these studies, we thus offer a simple model with an explicit focus on competition between bank deposits, stablecoins and CBDCs or FPS. This yields important insights on the implications of each.

3 Private walled gardens and public infrastructures in practice

In practice, digital payment innovation has often been driven by large private sector players operating "walled gardens". M-Pesa, launched in 2007 in Kenya by Vodafone and Safaricom,

[8] In his paper, the incumbent plays first, sets fixed membership fees on the consumer side and transaction fees on the merchant side. In contrast, in our paper, merchant fees are not competed away and the number of consumers who join either platform depends on the fees charged on the merchant side. Therefore, our model of Hotelling competition between platforms follows a two-sided market logic.

has enabled large gains in expanding access to digital payments, yet quickly became a closed-loop system. Similarly, AliPay, launched in 2009 in China, is very widely used, allowing for free peer-to-peer payments and very low-cost payments to merchants, yet there are fees for making payments outside its ecosystem or withdrawing funds. Similarly, in the current cryptocurrency and decentralised finance (DeFi) sector, stablecoins often allow payments within their ecosystem, but there are fees for redeeming them into fiat currency. The largest stablecoins at the moment are Tether (USDT) and Circle (USDC), both of which are denominated in the US dollar.[9]

To respond to private walled gardens, public authorities have a number of possible tools. One is to enforce interoperability and possibly to regulate access fees. For example, Kenya's Competition Authority decided in 2018 to enforce the interoperability between M-Pesa and other mobile money operators (Feyen et al., 2021). Similarly, the People's Bank of China intervened in 2019 to enforce interoperability between AliPay, WeChat Pay and other providers and to regulate fees. In the stablecoin space, the European Union (EU) imposed requirements on stablecoin issuers under the Markets in Crypto Assets (MiCA) Regulation.[10] At the time of writing, the US Congress is debating stablecoin regulation, including the "Guiding and Establishing National Innovation for U.S. Stablecoins" (GENIUS) Act and the "Stablecoin Transparency and Accountability for a Better Ledger Economy" (STABLE) Act.

Another option is to create public payment infrastructures, such as central bank-operated retail fast payment systems (FPS) or CBDCs. FPS allow for payments in real time between different providers, such as banks and non-bank payment service providers (CPMI, 2021). In Brazil, the Pix instant payment system, launched in November 2020, offers users the opportunity to make payments, peer-to-peer or to merchants, through a phone number, a quick response (QR) code, or other means (Duarte et al., 2021). Within a year of its launch, Pix services were offered by over 770 banks and non-bank PSPs, and used by over two thirds of the Brazilian population. Peer-to-peer payments are free and payments to merchants cost an average of 22 basis points - compared to 2. 1% for credit cards.

CBDCs have been the subject of intense research and development efforts in many countries.

[9] This paper does not go into the issues of currency denomination of stablecoins, nor the possibility of currency substitutions ("stealth dollarisation") in economies that do not use the dollar.

[10] In particular, stablecoin issuers must maintain full reserves to back their tokens at all times, meet prudential requirements, maintain clear redemption policies and ensure strong risk management.

Some central banks in emerging market economies have launched pilots (e.g. in China and Peru). At the time of writing, three central banks (in The Bahamas, Jamaica and Nigeria) had launched a live retail CBDC. Generally, private sector banks and non-bank payment service providers (PSPs) provide retail services in these CBDC systems. To date, both peer-to-peer payments and merchant payments have zero fees, with the possibility of introducing low, non-zero fees in the future. Meanwhile, several central banks in advanced economies (e.g. in Switzerland) have progressed in work on a wholesale CBDC. In the euro area, the European Central Bank (ECB) is progressing in its work on a digital euro, looking at both retail and wholesale use cases.

Retail CBDCs share several similarities with FPS (Aurazo et al., 2024). The key difference is that FPS facilitate the transfer of claims on private intermediaries, whereas CBDCs are a claim on the central bank (Auer et al., 2023). They can thus be conceived of as a form of digital cash.[11]

4 Model

We aim to build a simple model of the market for digital payments. Thus, we extend the models of Armstrong (2006), Rochet and Tirole (2006) and Verdier (2024) to study competition between two intermediaries offering payment services: a bank (b) and a platform (p). Our framework enables us to analyse whether public infrastructures such as a central bank-operated fast payment system or a central bank digital currency may improve total user surplus compared to the case in which payment systems are separated by walled gardens.

4.1 Payment intermediaries

Two payment intermediaries, indexed by j, compete to offer payment services to consumers and merchants: a bank ($j = b$) and a platform ($j = p$). Consumers and merchants are placed along a Hotelling line (Hotelling, 1929), which captures their taste differences.[12] The intermediaries offer differentiated services that will be relatively more or less attractive to consumers with different tastes. The bank is located at point 0 on the Hotelling line, where there is a physical

[11] CBDCs may offer further functionalities such as programmability and offline payments. These could become relevant in the future, but go beyond the scope of this paper.

[12] We adopt the terminology used in the payment industry: sellers are also called "merchants". Similarly, buyers are also called consumers.

market, and the platform is located at point 1, where there is a digital market (which could represent e-commerce or an ecosystem of tokenised assets). The intermediaries incur no costs. Consumers need to open an account with an intermediary to make payments. The bank offers a payment instrument that is accepted by "brick and mortar" retailers, whereas the platform offers an online payment instrument.

In all of our analysis, we maintain several simplifying assumptions.

- all merchants "single-home" in the sense that they choose exactly one trading mode: b for "brick and mortar" or p for online. The number of merchants who select b is denoted by N_S. We also assume that the market is covered on the seller side. The number of online merchants is therefore $(1 - N_S)$.

- potential gains from trade between any couple (merchant, consumer) are always positive, so consumers trade with all the merchants they have access to through the payment system.

- consumers pay no fees, but incur a transportation cost if they open an account with an intermediary. Some consumers may decide to open no account, in which case they are excluded from the financial system. We assume that transportation costs are high enough so that no consumer opens an account with both intermediaries.

- Merchants pay a fixed fee to the intermediary with whom they open an account and also incur transportation costs.

4.2 Buyers

There is a continuum population of consumers who are uniformly distributed on the Hotelling line. They may open an account through intermediary $j = b$ located at point 0 or $j = p$ located at point 1, or none. Consumers incur linear transportation costs t_B per unit of distance when they "travel" to open an account.[13] The number of consumers who open an account with intermediary j is denoted N_B^j, where the index B stands for "buyers".

[13] Transportation costs are understood here to refer to users' need to adapt to a payment service that does not coincide exactly with their preference – some users will have a taste for digital-only interactions, while others may prefer physical interaction in the market.

Consumers do not pay any fee to open an account, nor do they pay any transaction fee.[14] We assume that each consumer trades with each 'accessible' seller. Therefore, with walled gardens, a consumer who has an account with the bank trades with physical merchants, whereas a consumer who has a platform account trades online. Consumers who do not open any account only trade with physical merchants. With an FPS or a CBDC, a consumer trades with all merchants.[15]

Each transaction generates a surplus α that is divided in proportions r and $1-r$ between consumers and merchants, where $r \in (0,1)$ represents the relative bargaining power of consumers. (A higher r means that the consumer can capture more of the surplus). The trading possibilities depend on the organisation of the payment system. In the case of walled gardens, online trading is only possible for consumers who have opened an account with the platform. Physical trades can only be paid for by bank deposits. With an FPS or a CBDC, consumers also trade with merchants affiliated with the other intermediary, but the total surplus of a transaction is reduced by a factor $q < 1$ to capture the loss of ancillary services provided by the intermediary.[16]

Therefore, a consumer located at point x on the Hotelling line can open an account with the bank, and obtain utility:

$$u_B^b = r\alpha N_S - t_B x, \tag{1}$$

or open an account with the platform and obtain utility:

$$u_B^p = r\alpha(1 - N_S) - t_B(1 - x). \tag{2}$$

We make the following assumption:

$$(H_1) : r\alpha < t_B. \tag{3}$$

[14]This is in line with observed practice: for both in-store and online purchases, banks and digital platforms generally charge fees to merchants, through a merchant discount rate (MDR), and do not charge fees on consumers. In this analysis, we abstract from rewards or benefits to users, as with credit card points or cash-back to consumers.

[15]We motivate this assumption by the interoperability services offered by fast payment systems, such as Pix in Brazil, which has allowed new providers like Nubank and the non-bank Mercado Pago to offer interoperable payment services with incumbent banks.

[16]This can be interpreted to include bank credit or credit card points and rewards for deposits, and information on available products for the platform.

Assumption H_1 implies that multihoming (opening accounts with both intermediaries) is too costly for all buyers. The third option is therefore to open no account at all (financial exclusion). The utility of this third option is normalised to zero. The indifference condition between the first and the third option determines the number of consumers who open a bank account:

$$N_B^b = \frac{r\alpha N_S}{t_B}. \tag{4}$$

Similarly, the indifference condition between the second and the third option determines the number of consumers who open an account with the platform:

$$N_B^p = \frac{r\alpha(1 - N_S)}{t_B}. \tag{5}$$

Finally, a share of buyers could be "unbanked" (financial excluded), meaning unserved by both the bank and the platform. This may be particularly likely in emerging market economies where transportation costs are particularly high.

4.3 Sellers

A continuum population of merchants may sell products in the physical market or in the digital market. They are uniformly distributed along the Hotelling line and incur transportation costs t_S per unit of distance if they open an account with one of the intermediaries, located at the extremities of the Hotelling line.

Merchants pay fixed fees f^j to open an account with intermediary j and do not pay any variable fee for payment transactions. The difference between the platform fee and the bank fee is denoted $\Delta f = f^p - f^b$. Merchants also obtain a fixed utility $v_0 > 0$ of having access to banking services, which we assume to be sufficiently large such that their market is covered in equilibrium (although the market for consumers may not be fully covered).

A merchant who chooses brick and mortar trade attracts the N_B^b consumers who have a bank account. Therefore, the net utility of a merchant located at point x on the Hotelling line who sells in the physical market is:

$$u_S^b = v_0 + (1-r)\alpha N_B^b - t_S x - f^b. \tag{6}$$

If he or she joins the platform to sell in the digital market, he or she derives a utility:

$$u_S^p = v_0 + (1-r)\alpha N_B^p - t_S(1-x) - f^p. \tag{7}$$

The indifference condition between these two options determines the number N_S of merchants who choose physical trading:

$$t_S(2N_S - 1) = f^p - f^b + (1-r)\alpha(N_B^b - N_B^p), \tag{8}$$

that is:

$$N_S = \frac{1}{2} + \frac{1}{2t_S}[f^p - f^b + (1-r)\alpha(N_B^b - N_B^p)].$$

Finally, we make a second assumption:

$$(H_2) : t_B t_S > r(1-r)\alpha^2,$$

to ensure the concavity of profit functions and the existence of an interior equilibrium in which sellers single-home.

5 The equilibrium with walled gardens

5.1 Timing of the game

We model competition in the economy with walled gardens as a game between the two intermediaries with the following timing:

- Each intermediary $j = b, p$ announces their fee f^j to sellers.
- Merchants decide on their trading mode $j = b, p$, and open an account with the corresponding intermediary.

- Consumers choose whether to open an account with the bank, the platform or none.
- Consumers trade with all merchants that accept their payment instrument.

5.2 The Nash equilibrium

The Nash equilibrium of this game is obtained when each intermediary selects a fee that maximises its profit while taking the fee of its competitor as given. Neglecting operating costs, the profit functions are

$$\pi^b = f^b N_S,$$

for the bank, and

$$\pi^p = f^p(1 - N_S)$$

for the platform. Under assumptions H_1 and H_2, this game has a unique equilibrium that is easily characterised. In fact, using equations (4) and (5) that determine the numbers of consumers who open an account with the bank and the platform, we can transform (8) into an equation relating the number of physical merchants N_S to the merchant fees. We obtain an affine relationship:

$$N_S = \frac{1}{2} + A_0(f^p - f^b), \tag{9}$$

where

$$A_0 = \frac{t_B}{2[t_B t_S - r(1-r)\alpha^2]},$$

and $A_0 > 0$ from assumption (H2). Proposition 1 gives the equilibrium of competition between intermediaries in a walled gardens economy.

Proposition 1. *Under assumptions H_1 and H_2, the walled garden economy has a unique equilibrium (denoted by upper indices G) characterised by:*

$$N_S^G = \frac{1}{2}, \tag{10}$$

$$N_B^b = N_B^p \equiv N_B^G = \frac{r\alpha}{2t_B}, \tag{11}$$

$$f^b = f^p \equiv f^G = t_S - \frac{r(1-r)}{t_B}\alpha^2. \tag{12}$$

Proof. The profit functions of the two intermediaries are

$$\pi^b = f^b N_S,$$

for the bank, and

$$\pi^p = f^p(1 - N_S)$$

for the platform. The first order conditions for an interior Nash equilibrium are thus

$$\frac{\partial \pi^b}{\partial f^b} = A_0(f^p - 2f^b) + \frac{1}{2} = 0,$$

for the bank, and

$$\frac{\partial \pi^p}{\partial f^p} = A_0(f^b - 2f^p) + \frac{1}{2} = 0$$

for the platform. The assumption H_2 ensures that the profit functions of the intermediaries are concave with respect to prices. By combining the two first-order conditions, we obtain the results stated in Proposition 1. Moreover, the assumption H_2 ensures that all merchants prefer to single-home in equilibrium rather than multi-home. □

5.3 Welfare analysis

Social welfare equals the total surplus generated by the transactions undertaken by consumers and merchants less the transportation costs. The N_B^b consumers who have an account with the bank trade with N_S merchants and the N_B^p consumers who have an account with the platform trade with $(1 - N_S)$ merchants. Thus the total volume of trade is

$$V = N_B^b N_S + N_B^p(1 - N_S),$$

and social welfare equals:

$$W = v_0 + \alpha[N_B^b N_S + N_B^p(1 - N_S)] - \frac{t_S}{2}[N_S^2 + (1 - N_S)^2] - \frac{t_B}{2}[(N_B^b)^2 + (N_B^p)^2]. \qquad (13)$$

Using Proposition 1, we see that at the equilibrium of the walled garden economy, the volume of trade is

$$V^G = \frac{r\alpha}{2t_B} \tag{14}$$

and social welfare equals

$$W^G = v_0 + \frac{r(2-r)\alpha^2 - t_B t_S}{4t_B}, \tag{15}$$

where $W^G > 0$.[17]

The equilibrium that results from competition between intermediaries separated by walled gardens is characterised by financial exclusion. In fact, there is a proportion

$$1 - N_B^b - N_B^p = 1 - \frac{r\alpha}{t_B} > 0$$

of consumers who do not have access to electronic payment systems. The volume of trade is low, as consumers can only trade physically or online, but not both.

We show now that with the same technologies (i.e. assuming that interoperability is not feasible) a central planner could increase welfare above the level reached in the walled gardens equilibrium.

Proposition 2. *Under interoperability , social welfare is maximum for* $N_S = \frac{1}{2}$, *and* $N_B^p = N_B^b = \frac{\alpha}{2t_B}$, *which corresponds to a volume of trade*

$$V^* = \frac{\alpha}{2t_B},$$

higher than the equilibrium value. Similarly financial exclusion is reduced but not eliminated. The proportion of buyers who have no access to the payment system in the welfare optimum reduced to $(1 - \frac{\alpha}{t_B})$, *which is however still positive.*

Proof. Immediate after differentiating formula (13), which gives the expression of social welfare, with respect to N_S, N_B^b and N_B^p. □

[17] We have that $W^G > 0$ because v_0 is sufficiently large such that the market is covered on the merchant side in equilibrium.

6 The equilibrium with a fast payment system

Another way to reduce financial exclusion is for the authorities to introduce a new technology, in the form of a central bank-operated fast payment system (FPS) that provides digital payments services to all buyers. This offers the possibility of interoperability between the bank, the platform and a new type of intermediary, namely (non-bank) payment service providers (PSPs). PSPs offer consumers with payment services of lower quality $q < 1$ than incumbents but for negligible fees and no transportation costs. As a result, the FPS allows buyers to purchase items in both locations. We now analyse the new equilibrium between the incumbent intermediaries.

6.1 Buyers

With an FPS, consumers have access to all merchants, but with a loss of ancillary services when they pay a merchant who has an account with a different intermediary. This implies that in that case, the gains from trade are multiplied by a factor $q < 1$. Buyers have three options:

- open an account with the bank, in which case their utility is

$$r\alpha[N_S + q(1 - N_S)] - t_B x,$$

- open an account with a non-bank PSP, giving utility

$$rq\alpha,$$

- or open an account with the platform, giving utility

$$r\alpha[qN_S + (1 - N_S)] - t_B(1 - x).$$

Indifference between the first two expressions gives the number of buyers who open an account with the bank:

$$N_B^b = \frac{r(1 - q)\alpha N_S}{t_B},$$

while indifference between the last two expressions gives the number of buyers who open an account with the platform:

$$N_B^p = \frac{r(1-q)\alpha(1-N_S)}{t_B}.$$

6.2 Sellers

Sellers only have two options. They can open an account with the bank, in which case they obtain utility

$$v_0 + (1-r)\alpha[N_B^b + q(1-N_B^b)] - t_S x - f^b,$$

or with the platform, and obtain:

$$v_0 + (1-r)\alpha[N_B^p + q(1-N_B^p)] - t_S(1-x) - f^p.$$

The indifferent seller determines the number N_S of sellers who open an account with the bank. After using the above expressions of N_B^b and N_B^p and simplifying, we obtain an equation similar to equation (9):

$$N_S = \frac{1}{2} + A_1(f^p - f^b),$$

where

$$\frac{1}{A_1} = 2[t_S - \frac{r(1-r)(1-q)^2\alpha^2}{t_B}],$$

with $A_1 > 0$ from (H2) and $(1-q)^2 < 1$.

6.3 The Nash equilibrium with an FPS

Proposition 2 characterises the equilibrium with an FPS.

Proposition 3. *Under assumptions H_1 and H_2, the equilibrium with an FPS (denoted by upper index F) is characterised by:*

$$N_S^F = \frac{1}{2}, \tag{16}$$

$$N_B^b = N_B^p \equiv N_B^F = \frac{r\alpha(1-q)}{2t_B}, \tag{17}$$

$$f^b = f^p \equiv f^F = t_S - \frac{r(1-r)}{t_B}(1-q)^2\alpha^2. \tag{18}$$

Moreover, all consumers have access to an electronic payment instrument.

Proof. The only difference with respect to the game associated with walled gardens is that the parameter α is multiplied by $(1-q) < 1$. Thus the Nash equilibrium is unique and given by the same formulas once α is replaced by $\alpha(1-q)$. In particular the number of buyers who associate with one of the incumbents is lower, but the rest of the market is covered by PSPs and the FPS. Moreover, the fees paid by the merchants are **higher** because the demand for each incumbent is less elastic.[18] □

Comparing with Proposition 1, we see that the introduction of a FPS has several consequences:

- Financial exclusion disappears because all consumers gain access to an electronic payment instrument.
- The market share of the incumbent intermediaries is reduced by a factor $(1-q)$.
- The fees paid by merchants **increase** because the demand functions become **less** elastic since $A_1 < A_0$.

We now study the impact of the FPS on social welfare.

6.4 Welfare analysis

The first consequence of introducing an FPS is that the volume of trade reaches its maximum level: $V^F = 1$. However, the gains from trade are not fully exploited, since only a fraction N_B of transactions realise the full surplus α, while the remaining fraction realises only the surplus $q\alpha$. Social welfare equals

$$W^F = v_0 + \alpha[N_B + q(1-N_B)] - \frac{t_S}{4} - t_B(N_B)^2. \tag{19}$$

Using Proposition 2, we can replace N_B by its equilibrium value:

$$W^F = v_0 + \alpha[q + \frac{r\alpha(1-q)^2}{2t_B}] - \frac{t_S}{4} - \frac{r^2\alpha^2(1-q)^2}{4t_B}.$$

[18] Compatibility softens competition for merchants, which is the same result as in Matutes and Regibeau (1988) or Øystein Foros and Hansen (2001). Our assumptions differ, because we consider cross-side compatibility. Here, compatibility is reached through the FPS and there is a market expansion effect on the consumer side, which is caused by the entry of PSPs.

The comparison with the walled garden economy is easy, since it corresponds to the case where $q = 0$. Therefore

$$W^F - W^G = \alpha q - \frac{r(2-r)\alpha^2 q(2-q)}{4t_B} = \alpha q[1 - \frac{r(2-r)(2-q)\alpha}{4t_B}].$$

Assumption H_1 states that $r\alpha < t_B$. Moreover $(2-q)(2-r) < 4$. Thus $W^F > W^G$. Wrapping up all our results, we obtain the following proposition:

Proposition 4. *The introduction of an FPS has the following consequences:*

1. *Financial exclusion disappears.*
2. *The volume of trade is at its maximum level, but the gains from trade are not fully exploited.*
3. *The shares of consumers who open an account with incumbent intermediaries is reduced.*
4. *The profits of incumbent intermediaries increase, since they charge higher fees to merchants, while they still cover all the market on the merchant side.*
5. *Social welfare is increased.*

7 Central bank digital currency

Another policy option that can reduce the inefficiencies caused by financial exclusion and imperfect competition between intermediaries is to issue a retail CBDC. A retail CBDC is defined as a digital payment instrument, denominated in the national unit of account, that is a direct liability of the central bank, and is open for use by households and businesses. This section discusses several designs that are possible for the CBDC.

7.1 The CBDC is only distributed by incumbent intermediaries

This design is essentially equivalent to a FPS without PSPs, assuming that incumbent intermediaries are constrained by the central bank to provide fast payment services at no fee for consumers. In this case, all buyers open an account with one of the incumbents, but they have the option between a full service account that offer maximum quality of service but implies transportation costs, and a CBDC wallet, that only gives them a lower quality of service q but negligible transportation cost. Transportation costs are a simple tool to model product differentiation for ancillary services, while basic payment services are the same for all. Even if this CBDC design is very similar to the FPS analysed above, there are two interesting differences:

1. first, the risk of disintermediation is less acute since incumbent intermediaries keep the management of CBDC deposits, which might be used as reserves or collateral for repurchase agreements or interbank loans.

2. second, the quality of service q becomes a policy variable that can be controlled by the central bank.

In practice, some central banks have envisaged such a system. For example, the Swedish Riksbank has tested the integration of the e-krona network with a POS terminal, and demonstrated it was possible to update the software on a single POS terminal to support payment processing separate from traditional card payments (see e-Krona Pilot phase 2 report by the Riksbank; Riksbank (2022)). Concretely, this means that any merchant accepting the bank payment instrument would be able to accept the CBDC.

7.2 Integration of the CBDC within an existing FPS

Another possibility has been explored by the Reserve Bank of India (RBI), which is to integrate the CBDC within an existing FPS. This aims to avoid costly duplication of infrastructure. This trade-off is well explained by the RBI: "*An Indian CBDC should be able to utilise the current payments infrastructure like UPI, digital wallets like Paytm, Gpay etc. Interoperability between payment systems contributes to achieving adoption, co-existence, innovation, and efficiency for end users. It would be key to integrate a CBDC into the broader payments landscape of India which would possibly help drive end user adoption (both for the public and merchants). This will obviate the need for the creation of a parallel acceptance infrastructure. RBI would have options in how it plans to achieve interoperability, from the use of established messaging, data, and other technical standards to building technical interfaces to communicate with other systems. Integration between systems through APIs shall allow a light yet secure inter-operable architecture. It will be necessary to ensure the robustness of APIs as well for heightened cyber-security. However, barriers to interoperability would likely exist that cover technical, commercial,* *and legal aspects. Dialogue with stakeholders would be the key to addressing these. Achieving interoperability is a collaborative process and will require the active involvement of all industry players in the Indian payments landscape*" (RBI, 2022). This integrative solution could enhance competition and the quality of services. One potential drawback could be concentration of all (bank deposit and CBDC) payments in one infrastructure, which could generate additional cyber-risks and other operational risks for central banks.

7.3 CBDC and disintermediation

An important point, already discussed above, is that a CBDC is modelled here not to provide the full extent of ancillary services provided by incumbent intermediaries. This is captured in our model by assuming that the gains from trade are reduced by a factor $q < 1$ when they are mediated by a PSP rather than by the CBDC rather than by the bank or the platform. This parameter q is influenced by the design of the CBDC, and can be viewed as a policy variable. The trade-off for public authorities is between disintermediation (which increases for a higher q) and financial inclusion (more buyers and sellers benefiting from a higher quality of service). This is related to the view that a CBDC could crowd out not only bank deposits but also stablecoins.

In fact, in our simple model, increasing q is always good for social welfare.[19]

Proposition 5. *An increase in q has two effects on social welfare: it increases the quality of service for the fraction of payments managed by PSPs, but it decreases the fraction of payments managed by intermediaries. In our specification, the net impact is always positive.*

Proof. A total differentiation of W^F given by equation (19) gives:

$$\frac{dW^F}{dq} = \frac{\partial W^F}{\partial q} + \frac{\partial W^F}{\partial N^B}\frac{dN^B}{dq}$$

After simplifications, we obtain:

$$\frac{dW^F}{dq} = \alpha[1 - \frac{r\alpha(1-q)(2-r)}{2t_B}].$$

[19] Of course, this welfare gain has to balanced with the possible costs incurred by the central bank when improving the quality of the payment service.

Now $r\alpha < t_B$ by assumption H_1 and $(1-q)(2-r) < 2$. This implies that

$$\frac{dW^F}{dq} > 0.$$

□

8 Conclusion

This paper has modelled a world of competing digital payment instruments: bank deposits, private stablecoins and central bank digital currencies (CBDCs). We have shown that if consumers' tastes differ, banks and platforms may carve up the market to extract rents from merchants through fees, which may not be socially optimal. Introducing a retail fast payment system (FPS) can be similar to a CBDC, and can increase financial inclusion and social welfare. However, surprisingly, it can make the demand for incumbent services **less** elastic and therefore increase equilibrium merchant fees.

In our very simple set-up, a retail CBDC is essentially equivalent to a FPS. This suggests that introducing a retail CBDC might not be a top priority for countries where an efficient FPS is already in place.[20]

Our model holds lessons for current debates on the future of the monetary system. In particular, it shows one means by which CBDCs could increase welfare and help to achieve an improved market structure, relative to a laissez-faire approach.

Of course, the model abstracts some key issues around the interaction of stablecoins and other instruments in practice, and the business model of banks and other private payment service providers in various systems. We leave these important questions to the policy discussion and future research.

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