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Ecosystem Models for a Central Bank Digital Currency: Analysis Framework and Potential Models

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Abstract

For an intermediated central bank digital currency (CBDC) to be successful, central banks will need to develop sustainable economic models where intermediaries and end users derive value and central banks achieve their policy goals. This note presents a framework for analyzing different economic models of CBDC ecosystems. We analyze the trade-offs of three main CBDC ecosystem models, each with different levels of central bank involvement in activities of the ecosystem and the usage of different policy levers. The policy levers considered in the framework are control over intermediary access to the CBDC network, prices and quality standards. Our analysis suggests that a central bank provision of network infrastructure enables direct control over intermediary access requirements, prices and quality standards upstream. Providing a central bank digital wallet increases development costs but allows the central bank to set quality standards downstream and to promote competition. Delegating the network service to a regulated entity reduces costs for the central bank but may limit its strategic autonomy to control upstream pricing and intermediary access. Our analysis also suggests several areas of future research: central bank pricing models, intermediary revenue models, and quality and privacy standards.

Topics: Central bank research; Digital currencies and fintech; Financial services
JEL codes: E, E5, E58, E6, E61, L, L5

Résumé

Pour arriver à mettre en place avec succès une monnaie numérique de banque centrale (MNBC) avec intermédiation, les banques centrales devront élaborer des modèles économiques durables qui leur de permettent de réaliser leurs objectifs stratégiques, tout en procurant de la valeur aux intermédiaires et aux utilisateurs finaux. Cette note présente un cadre pour l'analyse des différents modèles économiques des écosystèmes de MNBC. Nous analysons les avantages et inconvénients de trois principaux modèles qui se distinguent par les niveaux de participation de la banque centrale aux activités dans l'écosystème et l'utilisation de différents leviers de politiques. Les leviers examinés dans le cadre sont le contrôle de l'accès des intermédiaires au réseau de MNBC, les prix et les normes de qualité. Selon notre analyse, le fait qu'une banque centrale fournisse l'infrastructure de réseau permet un contrôle direct, en amont, sur les exigences d'accès des intermédiaires, les prix et les normes de qualité. Une banque centrale qui fournit un portefeuille numérique assume des coûts de développement accrus, mais elle peut ainsi établir les normes de qualités en aval et favoriser la concurrence. À l'inverse, si elle délègue la gestion des services de réseau à une entité réglementée, elle réduit ses frais, mais restreint son autonomie stratégique en ce qui a trait au contrôle des prix et de l'accès des intermédiaires en amont. Notre analyse fait aussi ressortir plusieurs pistes de sujets qui pourraient faire l'objet de recherches dans l'avenir : modèles de tarification des banques centrales, modèles de revenus des intermédiaires et normes de qualité et de protection des renseignements personnels.

Sujets : Recherches menées par les banques centrales, Monnaies numériques et technologies financières, Services financiers
Codes JEL : E, E5, E58, E6, E61, L, L5

Executive summary

This paper presents a framework for analyzing different economic models of a central bank digital currency (CBDC) ecosystem and suggests three potential models.

- An economic model of a CBDC ecosystem is defined as the division of economic activities performed by different agents in the system and the contractual terms under which those activities are to be carried out.
- Activities in the ecosystem include the issuance and ledger updates of CBDC balances (exclusive to the central bank), the network activity of connecting payor and payees (or their intermediaries) and end-user activities such as onboarding, wallets and customer service.
- The framework permits a systematic analysis of the economic, technological and impact trade-offs within and across different CBDC ecosystem configurations.

We analyze the trade-offs of three main CBDC ecosystem models:

- Model 1: The central bank is responsible for providing the network infrastructure. Intermediaries provide all end-user services.
- Model 2: The central bank is responsible for providing the network infrastructure and a basic wallet for end users. Intermediaries provide all other end-user services.
- Model 3: The network infrastructure is provided by a regulated entity. Intermediaries provide all end-user services.

Our analysis indicates the following:

- Model 1 would enable the central bank to have direct control of the intermediary access requirements and of prices and quality standards upstream; reduced development costs for the central bank; and lower risk of market disruption downstream.
- Model 2 offers the opportunity for the central bank to influence quality downstream, setting a standard for intermediaries and promoting competition in the downstream market through the provision of a central bank digital wallet. It allows for intervention in case of market failures and ensures the ability to cater to segments of the population that may be overlooked by intermediaries.
- Model 3 may lower the costs borne by the central bank; however, it would limit its strategic autonomy to control upstream pricing and intermediary access. An open question is the trade-offs involved in leveraging specific components of established fast payment systems.

Additional work would be needed to provide specific guidance on the pricing model of the central banks and the revenue model of intermediaries, as well as on quality and privacy standards to be set by the central bank.

1. Introduction

This paper develops a framework to analyze different economic models of a central bank digital currency (CBDC) ecosystem and provides options for policy-makers. This is the first in a series of papers pertaining to policy and design considerations. It provides findings on the ecosystem configuration based on our initial analysis of the trade-offs in the models presented.

We define an economic model of a CBDC ecosystem as the division of economic activities performed by different agents in the CBDC system and the contractual terms under which those activities are carried out. In simpler terms, an economic model specifies "who does what and under which terms."

The framework provides a method to categorize different potential configurations of a CBDC ecosystem. This allows us to analyze the economic, technological and impact trade-offs within and across different configurations. While we do not evaluate those trade-offs in this paper, our framework allows policy-makers to start making high-level choices about the main components of the ecosystem while we progress with more detailed policy analysis and research on those trade-offs.

The essential activities within the ecosystem can be divided into upstream (intermediary-facing) activities and downstream (end-user–facing) activities. The necessary upstream activities are the issuance and ledger updates of CBDC balances (i.e., settlement of transactions) and the network that creates the connection between payor and payees (or their intermediaries). Examples of end-user activities include onboarding assistance, wallet provision and other customer service tasks.

The contractual terms that define and regulate the ecosystem include:

- entry terms—who can perform different activities
- pricing—at what prices activities can be offered
- quality
- privacy—what can be done with the data of the ecosystem

The actors in the CBDC ecosystem are:

- the central bank
- intermediaries (which could be private and public entities, and which may or may not be divided into subcategories with different rights and requirements)
- end users such as individuals and merchants

Given that the discussion is around a CBDC, in all our models the central bank is always responsible for issuance and ledger updates. Further, we assume that the underlying technology infrastructure would be set up so that CBDC balances conform with the legal concept of a direct

liability of the central bank. Using the framework, we analyze the trade-offs of three main configurations:

- Model 1: The central bank is responsible for providing the network infrastructure. Intermediaries provide all end-user services.
- Model 2: The central bank is responsible for providing the network infrastructure and a basic wallet for end users. Intermediaries provide all other end-user services.
- Model 3: The network infrastructure is provided by a regulated entity. Intermediaries provide all end-user services.

The analysis of the models is guided by the recognition that the chosen model must deliver value to all participants of the ecosystem: end users should find it worthwhile to adopt and use it, intermediaries should find it profitable to participate in the ecosystem, and the central bank should be able to advance its chosen public policy objectives. Then, for each model, we discuss how the market structure and various options of contractual terms could affect the potential incentives of intermediaries to enter the CBDC market to offer some or all the potential services to end users, which, in turn, affects availability and adoption by end users.

In the initial stages of designing an ecosystem, the main choice for policy-makers would be the degree of involvement of the central bank in the provision of different activities in the ecosystem.

In Model 1, the central bank does not directly provide access methods to end users. The benefits of Model 1 include the direct control of the intermediary access requirements and of the network prices and quality in the upstream; the leveraging of existing intermediaries' infrastructure and expertise; reduced development costs; lower risk of market disruption; and better alignment with the traditional central bank role (i.e., adopting a role closely analogous to the current one in relation to cash). Allowing wide access to approved intermediaries should create a competitive environment for end-user CBDC services, increasing choices and lowering prices to consumers. In terms of drawbacks, Model 1 would limit the capacity of the central bank to influence prices and quality downstream. Given market failures typical of payment systems and financial consumer products, we cannot rule out that under Model 1 the equilibrium outcome might exhibit high end-user fees, low interoperability of CBDC with other systems, steering of consumers, or exclusion of certain segments of the population.

Given the uncertainties surrounding private sector reactions, Model 2, which allows for additional downstream involvement of the central bank, might have potential benefits. Potential market failures could hinder the adoption and success of any CBDC initiative: such failures could include the reluctance of intermediaries to provide essential onboarding or adequate wallet services, as well as insufficient security measures, lack of interoperability, steering of consumers and inadequate consumer protection. To address such issues and to improve access, quality and competition in the downstream market, central bank involvement could be warranted. Model 2 would allow central banks to establish a downstream quality standard, foster competition

through a central bank digital wallet, enable intervention for market failures and ensure inclusivity for overlooked segments of the population.

Further, our analysis suggests that Model 3, in which the network is provided by a regulated entity different from the central bank, could hamper the strategic autonomy of the central bank in setting pricing and the contractual terms necessary to produce the appropriate incentives in a CBDC ecosystem. Further analysis is needed to evaluate the policy and strategic trade-offs presented by such options.

Our analysis of the trade-offs is mostly directional, meaning that we provide the direction of effects for different policies in each of the models we evaluate. More research is required to make specific predictions and recommendations on the various policy levers, such as pricing; the revenue model for central banks and intermediaries; and quality and privacy standards.

The paper is structured as follows. Section 2 presents the framework based on a generic electronic payment system; it also defines the necessary activities and the contractual terms that would regulate those activities. Section 3 provides an overview of the existing market structure and pricing outcomes in credit and debit card systems and in fast payment systems (FPSs). As we analyze the CBDC models, we refer to current facts in these different payment systems. Section 4 describes a range of potential CBDC ecosystem models and analyzes the three models mentioned above. Section 5 concludes. Appendix A provides a cross-country comparison of different existing FPSs. Finally, Appendix B discusses methods to determine prices in an ecosystem, for example the cost recovery criterion.

2. Framework to analyze CBDC ecosystem models

2.1. Why we need a framework

The purpose of a framework to analyze CBDC ecosystem models is to facilitate policy-makers' decision-making around the following issues:

- the business model of the ecosystem (e.g., the central banks' and intermediaries' pricing)
- access policies (which entities should be allowed in the ecosystem)
- architecture (which entities should do what)

An immediate challenge when faced with the task of providing guidance on these issues is the complex interrelation between decisions about business models, access and architecture. The framework, therefore, provides a structured way for policy-makers to consider the trade-offs of various choices.

More specifically, the framework clarifies the policy trade-offs that central banks will face when deciding their degree of involvement in the ecosystem and designing the regime for access and distribution of CBDC by intermediaries. The framework is based on the idea that for a CBDC to

be sustainable and successful, central banks will have to design the incentive structures for users and intermediaries to find value in holding, using and distributing CBDC.

The rest of this section describes an abstract payment ecosystem using activities and actors as the building blocks of various ecosystem configurations. Then it describes the different types of contractual terms under which different activities could be carried out in the ecosystem. Contractual terms can be understood as part of the policy levers that central banks could use to design the appropriate incentives in the ecosystem.

2.2. Description of the framework

We analyze CBDC models at the ecosystem level. An ecosystem consists of all parties involved in providing and using CBDC services. To be able to achieve its policy objectives, the central bank must ensure that the system is sustainable: the CBDC ecosystem should generate value for all system participants (the central bank, intermediaries and end users) through the incentives of market forces and contractual terms. In other words, intermediaries should find it profitable to participate in the CBDC ecosystem, while users should find it worthwhile to use and hold CBDC. For the central bank, CBDC should advance the chosen public policy objectives, subject to budgetary constraints.[1]

2.2.1. Ecosystem model

We define an ecosystem model as a mapping of activities to actors and the contractual terms under which these activities would be undertaken. Another way to understand an ecosystem model is as a configuration of activities and contractual terms. In the CBDC ecosystem, the potential actors are the central bank, intermediaries (which could be of various subtypes) and end users (customers, merchants and even corporates).

2.2.2. Intermediaries

Intermediaries are legal entities that engage contractually in an activity in the system. Intermediaries most likely will be private firms, but nothing in the economic framework prevents government entities from also being intermediaries. What matters is that the central bank will have to engage in a contractual agreement with another legal entity to perform an activity in the ecosystem. The legal agreement could be a bilateral contract or a regulatory regime that provides the general parameters for how the intermediaries carry out an activity.

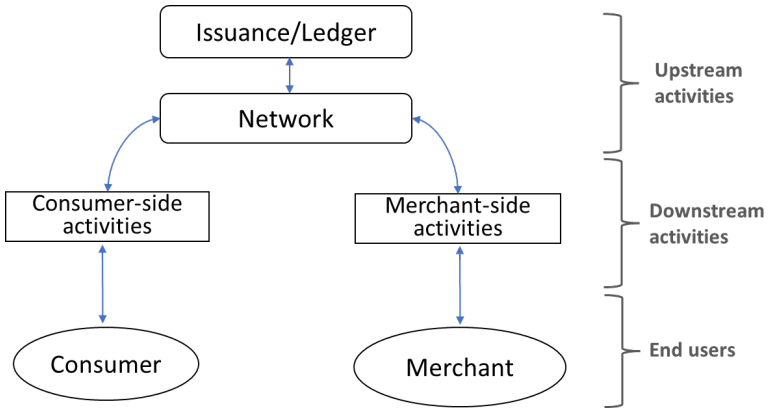
2.2.3. Activities

Activities are components of economic transactions in the ecosystem. Some examples of activities include (but are not limited to) settlement of transactions, know your customer (KYC)

[1] We will discuss the specifics of the central bank's objective in section 4.

and anti-money laundering (AML) checks, customer account opening, wallet provision, point-of-sale (PoS) terminal set-up and customer service. Given the number of actors and activities, the number of possible ecosystem configurations is extremely large. To reduce the number of configurations in consideration, we divide activities into four distinct groups.[2] We distinguish activities based on the side of the payments market they cater to—that is, activities geared toward consumers and toward merchants. We focus on the following subgroups of activities: (1) issuance and ledger updates; (2) network services; (3) merchant-side activities; and (4) consumer-side activities. (See **Figure 1** for a visual depiction of the activities and their relation to each other.)

Figure 1: Schematic description of activities in a payment ecosystem



Issuance and ledger updates

As a central bank liability, CBDC is a balance on the ledger of the central bank. Issuance is the process of creating balances by making entries on the central bank's balance sheet.[3] This is the only activity in the ecosystem that needs to be exclusive to the central bank. As a liability on the central bank's balance sheet, CBDC must be an asset of another party, implying that the central bank maintains a ledger of ownership of those balances. It is important to mention that in an intermediated model, the identity of the ultimate owner of the balances does not need to be known by the central bank. This is in fact the assumption that most major central banks are working on. Ledger updates are changes in the ownership of CBDC balances, which require credits and debits in the ledger of the central bank. Although ledger updates could be

[2] Although these groups and activities could themselves be subdivided into granular subcomponents, we chose this aggregation so that the groups of activities are economically distinct.

[3] Note that this is not a technology-focused description of issuance. In technology descriptions, issuance is sometimes described as the process of creation of a cryptographic item representing the balance even if this item has not been passed on to another party.

outsourced to the private sector, we assume in this paper that the central bank is solely responsible for these updates.

Network services

A payments network has two main roles. The first is to create a communication link between the payor and payee to facilitate a transaction. The second is to communicate the transaction to the central bank so that the ledger can be updated accordingly.

The network services do not need to be provided exclusively by the central bank: network services could be provided by one or more private intermediaries; alternatively, the central bank could provide a public network parallel to private networks. The linking of payee and payor through the network is presumed to occur via access methods provided by the intermediaries servicing merchants and consumers (e.g., payment terminals for merchants and banking apps for consumers). However, with this framework we will also be able to consider situations in which an access method provided by the central bank allows the end user to connect to the network.

In this paper, we view the network from the economic perspective and not as a technological component. In practice, the networks are the entities that establish the "schemes," which are the rules of the payment instrument that help coordinate the intermediaries of payors and payees.

Merchant-side activities

Merchant-side intermediaries provide services specifically for merchants, such as the PoS payment terminals to accept different methods of electronic payment, debit and credit cards, and capacity to accept payments online through website integrations. Today, these types of activities are typically performed by merchant-acquirer businesses, but other types of firms may also service merchants in other ways. An intermediary may be involved on both the consumer side and the merchant side of the market, although this is not necessary.[4]

Consumer-side activities

Consumer-side activities include anything required by current legislation to permit a consumer to hold balances at a deposit-taking institution. For instance, a consumer-side intermediary may be involved in identity verification for the purposes of managing the risks of financial crimes. Other consumer-side activities include the provision of a method to access balances to make balance queries or payments, such as an e-wallet or a web interface for online banking. As with the consumer-side and merchant-side activities, an intermediary may be involved on both the payor and payee sides of the market. We distinguish between the two sides to analyze different types of transactions. For example, in a person-to-person transaction, we would have consumers on both sides of the transaction, one as a payee and one as payor.[5]

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[4] Section 3 provides examples of these types of intermediaries.

[5] Other user cases can easily be analyzed, including government-to-person in the case of distribution of benefits or person-to-government in the case of paying for services.

The activities described above are a small subset of activities that occur in a payment ecosystem, and each group contains many sub-activities. For our framework, we divide the activities (issuance and ledger updates, network activities, merchant-side and consumer-side activities) into groups relevant to our analysis of market structure and the resulting incentives. Our grouping has a close mapping to the current organization of activities in debit and credit card markets and FPSs, allowing us to compare our proposed CBDC ecosystem configurations with models of and observations from market structures in other electronic payment markets.

In later sections, we consider different ecosystem configurations by varying which entities perform any given activity and the contractual terms under which these activities are provided. We discuss potential consequences and analyze the trade-offs between different configurations.

2.3. Contractual terms

We call "contractual terms" all the parameters under which each activity described above is to be carried out. These terms are set by the designer of the ecosystem, which in this case is the central bank. In this way, the problem faced by the central bank is in effect a principal–agent problem: the central bank, as the principal, is designing contracts to create incentives for intermediaries, who are agents in the system, to provide services to end users in the ecosystem. We divide the contractual terms into the following groups: entry, pricing, quality and privacy.[6] These terms could be established by regulatory frameworks or bilateral contracts between the central bank and the intermediaries.

2.3.1. Entry

The contractual terms for entry establish:

- which types of entities can provide a particular activity in the ecosystem
- the entry requirements an entity must meet to join the ecosystem and be a provider of a given activity

The determination of which entities can provide an activity in the ecosystem can range from monopoly (when only one entity can be a provider) to free entry (where any entity meeting the requirements can be a provider). The entry terms establish how an entity would have to be constituted legally to enter and the type of oversight it would be subject to. The entry requirements could be similar to the ones established in different regulatory regimes of financial intermediaries in banking (e.g., the *Bank Act*) or the payments market (e.g., the *Retail Payment Activities Act*).

[6] Other contractual terms that could also be considered in the analysis framework in the future are the length of contracts, terms for promotion and advertising, and triggers of contract termination.

2.3.2. Pricing

The contractual terms for pricing establish how the price of the different activities in the ecosystem are determined. For the purposes of our framework, the relevant prices are the fees to and between intermediaries and the fees faced by end users.

Network fee

The first fee faced by intermediaries is the network fee, the price charged by the network for providing the "scheme" and connection that facilitate the transaction between intermediaries on behalf of their end users. The network's service would also include connecting intermediaries to the central bank to transmit the transaction information to the ledger. This network fee could be fixed or *ad valorem*, range from positive to negative, and be charged to all or only specific intermediaries.

The optimal price for the service provided by the network would depend on the number of users as well as on many other decisions about the ecosystem design. For example, the optimal network price would depend on which entity provides the network. The network fee could be set by the central bank if it is the sole network provider, could be regulated by the central bank, or could be determined by the market equilibrium. More research and policy work are needed to help determine the appropriate level of these fees.[7]

Central banks, as designers of their CBDC systems, will need to decide which side of intermediaries should be charged this fee. As a starting point, if the current debit card market structure is a guide, the fee would be charged to the merchant side in PoS transactions. For person-to-person transactions, where both sides are individuals, some of the new FPSs being developed by central banks around the world could provide guidance. In some of those cases, where the central bank is the network provider, the price for network services in person-to-person transactions is zero. An example is Pix in Brazil (see Appendix A for a comparison of pricing of various FPSs).

Interchange fee

Intermediaries could also potentially encounter transaction fees within the system, akin to existing interchange fees of electronic payment systems, which they might need to pay to other intermediaries. This is one of the most important prices in current point of sale payment ecosystems. The revenue from these fees is usually used to cross-subsidize the end users on the consumer side through credit card rewards, cash backs and other benefits. As with any platform, payments are two-sided markets that generate positive network effects to one side of the market when the other side of the market expands. In these types of markets, cross-subsidies

[7] Beyond determining the optimal price that a platform would charge on its own, researchers have to understand the effects of the *entry* of a benevolent platform (like a CBDC) into a competitive market. Liu, Reshidi and Rivadeneyra (2023) examine the optimal pricing of a public payment platform that considers the responses of incumbent platforms.

are used to incentivize users from one side to join the platform. Therefore, setting the right interchange fee will be crucial to create the appropriate incentives in the ecosystem.

End-user fee

Besides the network fee and potentially an interchange fee, all other prices are for services provided to end users by intermediaries. The services provided to end users are likely to be quite varied. From the perspective of the analysis framework, we label the prices of all those services as end-user fees. Examples include onboarding services, wallet services and transaction services. As with the network fee, end-user fees could be set by the central bank if the bank provides some end-user service (e.g., a wallet), could be regulated by the central bank, or could be determined by the market equilibrium.

2.3.3. Quality

The contractual terms for quality are related to the quality of the service provided to intermediaries and end users. For example, product guidelines that establish the speed at which a service is provided, its resiliency, its peak load capacity and user authentication, as well as anti-fraud guidelines.[8] In general, quality guidelines are important in payment systems as a tool to manage the extent to which intermediaries steer users with non-price factors.

One example of a quality term could be establishing a minimum speed of payments processing to prevent intermediaries from steering users by making CBDC a slower payment option. Another example of quality guidelines is the functionality and interface of the CBDC product offered to end users.[9]

The contractual terms for quality could be determined in various ways. The central bank could:

- determine specific terms for quality
- permit the industry to set standards in a self-regulated way
- let the market determine the equilibrium quality of the services
- create channels for dispute resolution so that end users can exert pressure on intermediaries
- do a combination of the above

Currently, there is debate over whether quality guidelines pose a challenge to intermediaries' willingness to participate. This is because such guidelines may limit the ability of intermediaries to horizontally differentiate their CBDC offerings.

[8] Some of these terms might already be considered by the *Retail Payment Activities Act*.

[9] The Central Bank of Brazil requires all intermediaries to provide a consistent visual experience to Pix users within their own apps.

2.3.4. Privacy

Contractual terms for privacy are the terms that specify the conditions under which an intermediary could monetize the data collected from users. In traditional industrial organization analysis, the terms for privacy would typically be included under the contractual terms for quality. We give privacy its own category to highlight that monetization of data could be an important margin to provide incentives for intermediaries to participate in the ecosystem. The analysis of the regulatory environment for privacy and compliance is the subject of another ongoing policy paper.

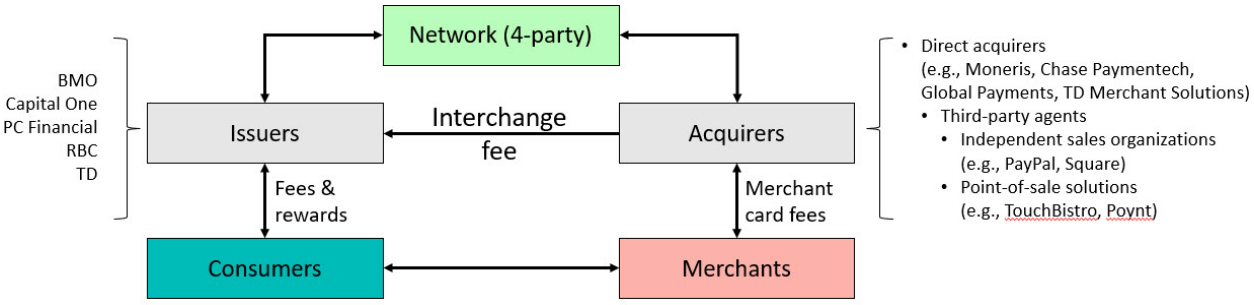
3. Existing market structure

The broad nature of the framework enables us to draw conclusions about the proposed CBDC ecosystem models by comparing them with existing electronic payment systems. In this section we describe the structure of debit and credit card schemes, as well as FPSs.

There are two prevalent types of card-based retail electronic payment systems distinguished by the number of different players: the three-party system and the four-party system. In both systems, consumers and merchants interact with intermediaries called issuers and acquirers, respectively, who facilitate the network access necessary to conduct transactions. The key difference between the systems is whether the issuer and acquirer are the same entity (three-party system) or different entities (four-party system). For example, the Canadian debit card network resembles a three-party structure, as does the American Express network, while the Canadian credit card market operates under a four-party system.

We summarize key features of the existing market structure using the example of the four-party system illustrated in **Figure 2**.

Figure 2: Illustration of a four-party system



On the consumer side, the card issuers, such as the top five Canadian banks, distribute cards to consumers. These cards may entail fees—in effect, transfers from consumers to the issuers—but also come with benefits in the form of rewards such as cash back. When consumers present their payment cards at the PoS, the card issuer facilitates the network access. In return, the issuers receive an interchange fee for completed transactions from acquirers who facilitate the network access for merchants.

On the merchant side, it is important to bear in mind the often highly layered structure (for a detailed overview, see Huynh, Shcherbakov and Welte 2022). In existing debit and credit card markets, the network access on the merchant side is facilitated by "direct providers" such as Moneris Global Payments. However, not all merchants interact directly with these providers. Instead, they may contractually engage with third-party agents who themselves rely on contractual arrangements with direct acquirers to access the network: for example, Square. Finally, it is important to account for PoS solution providers who provide ancillary services (or services for which the payment system integration is itself the ancillary service). These integrated and tailored PoS solutions are highly valuable to merchants and possibly a source of social welfare.

When determining the entry requirements of a potential CBDC, we therefore must account for not only the entry requirements for direct access to the network, but also—to the extent that it can be influenced—the promotion of indirect access for specialized solution providers. To this end, search and switching cost frictions in the market for merchant payment service providers (PSPs) must be carefully scrutinized. Existing integration/bundling of the PoS and online merchant businesses with other financial services provided by the merchant acquirers can potentially result in additional costs indirectly related to the acceptance of a new payment method such as CBDC. Hence, the incumbency advantage of existing players can significantly limit competitive pressure from a new payment instrument.

Additional important features of the current market are highly relevant for the discussion of potential CBDC ecosystem models.

First, the highly layered structure of the merchant side points to the complexity of defining what constitutes a relevant market. For example, large chain stores and small family-owned businesses are likely to face different price and choice sets when it comes to procuring access to different payment methods' networks. Similarly, the impact of introducing a new payment method—CBDC—is likely to be heterogeneous.

Second, and relatedly, sufficiently tailored end-user solutions may allow acquirers or their subsidiaries to engage in price discrimination by becoming quasi-monopolists in narrow markets. It seems reasonable that the horizontal differentiation is increasing toward the lower layers of the vertical structure, particularly on the merchant side.

Finally, FPSs geared to low-value and retail transactions are becoming increasingly common around the world, with many countries introducing them in the past two decades.[10] These systems offer individuals and businesses the convenience of real-time payments at lower costs compared with traditional payment methods. They also fit our framework of analysis and are therefore useful for drawing comparisons to possible CBDC ecosystem models. In fact, these

[10] The Committee on Payments and Market Infrastructures (2021) reports that 60 jurisdictions have introduced FPS.

systems are provided by both central banks and private sector schemes and, regardless of the operator, typically settle in central bank money, underlining their similarities to CBDCs. This has prompted the debate over whether FPSs are a substitute for CBDCs. Many of the possible use cases of FPS and CBDC are the same, but one important difference is that in an FPS the end user does not directly hold the liability of the central bank.[11]

Some established FPSs include Pix in Brazil, UPI in India and CoDi in Mexico (for an overview of these, see **Table A-1** in Appendix A), and in Canada work is underway to launch the Real Time Rail. While the design and features of these FPSs may differ, they generally involve intermediaries on the payor and payee sides, alias databases, and multiple access channels to enable seamless and secure payment transactions. To ensure the success and widespread adoption of retail CBDCs, central banks can consider incorporating design elements from FPS. They can also pursue interoperability with existing FPSs to enable users to transact as seamlessly as possible. Additionally, privacy and security measures employed by FPSs can inform the development of CBDCs, ensuring the privacy and security of CBDC transactions.

4. Ecosystem models

Now that we have described the analysis framework, we will use it to establish the range of potential models of the ecosystem and analyze three main ones. The main variation among these models is the degree of involvement of the central bank in the activities of the ecosystem. **Table 1** shows different potential models depending on how the network services are provided and whether the central bank directly offers services to end users.

In all models, the central bank issues CBDC. Beyond issuance, the degree of involvement of the central bank in the upstream and downstream layers can vary. In the upstream layer, network infrastructure can be provided by the central bank, a utility, or the private sector. In the downstream layer—which includes all other necessary end-user activities such as onboarding and KYC-AML checks—the central bank can potentially be involved in providing an app for customers or merchants.

The three models we will analyze more in detail are as follows:

- Model 1: The central bank exclusively provides the network. Intermediaries provide all end-user–facing activities.
- Model 2: The central bank exclusively provides the network. The central bank provides an end-user app for holding balances and making payments, alongside wallets provided by the private sector; intermediaries provide all other end-user–facing activities.

[11] See chapter 3 of the BIS 2021 annual report, which elaborates on the differences and similarities of FPSs and CBDC. The report concludes that CBDC offers a direct link between the public and the central bank, like cash does today, so CBDC might have a role even if a jurisdiction has launched a successful FPS.

- Model 3: A regulated utility provides the network. Intermediaries provide all end-user–facing activities.

The other models indicated in **Table 1** will be discussed briefly as variations of models 1 to 3. We expect that the main models will be the ones of most interest to policy-makers.

For a system to be sustainable, the combination of contractual terms and division of activities must create the appropriate incentives. The designer of the ecosystem is constrained by both market forces and the incentives of intermediaries and, as a result, cannot set the terms arbitrarily. Therefore, the analysis of each model will make reasonable assumptions about the participation incentives of incumbent and new firms in each part of the ecosystem.

The models can also vary in the dimensions of the four sets of contractual terms described in the previous section: namely, prices, entry, quality and privacy terms. Naturally, there is large within-model variation regarding the four contractual terms. Therefore, we focus broadly on the economics of each of the models and highlight commonalities and differences in terms of their implications for the incentives of participants in the payment ecosystem.

We will analyze each model in terms of several outcomes of interest:

- central bank policy objectives (e.g., universal access, financial stability, payment efficiency)
- end users' adoption and usage and intermediaries' willingness to distribute
- central bank costs and social costs

For each of these outcomes of interest, we draw on the economic literature if there is sufficient empirical evidence or theoretical predictions. Where no such evidence exists, we note those for future research and analysis.

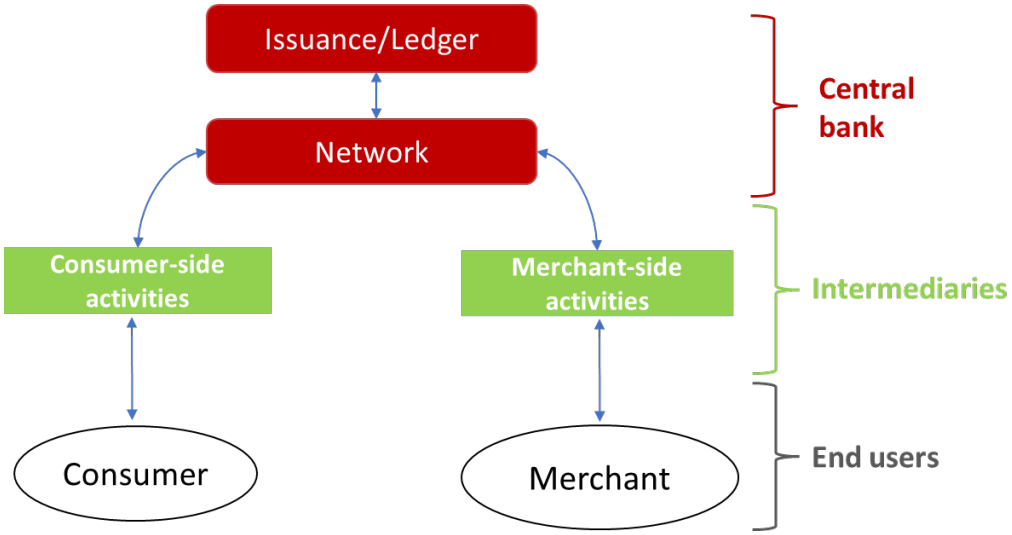
Table 1: Taxonomy of ecosystem models by degree of involvement of the central bank in the upstream (network) and downstream (apps) markets

		Upstream			
		Central bank provides network	Regulated entity provides network	Central bank and private sector provide network(s)	Private sector provides network(s)
Downstream	Private sector provides apps and services	**Model 1**	**Model 3**	Model 5	Model 7
	Private sector provides most apps and services / central bank provides basic app	**Model 2**	Model 4	Model 6	Model 8

4.1. Model 1

Model 1 will be our benchmark for the economic analysis, so we provide the most detail for it. **Figure 3** shows this model graphically. For each of the detailed models, we first provide a description of the market structure, then discuss entry, pricing, quality and privacy terms.

Figure 3: Model 1—Central bank performs ledger and network activities, while intermediaries undertake all other end-user activities



4.1.1. Market structure

In this model, the central bank is responsible for issuing and providing the network infrastructure and network activities. Intermediaries provide all end-user services, such as onboarding and wallets. Therefore, end users (consumers and merchants) do not interact directly with the central bank, but instead go through consumer-side and merchant-side intermediaries. In the following sections, we discuss the requirements for intermediaries to enter the market and the quality/content provided, as well as potential restrictions of the pricing structure and data privacy and usage.

4.1.2. Entry

We assume in this model that the central bank would not seek regulatory power to require intermediaries to join the ecosystem. Instead, the central bank would seek to provide intermediaries with sufficient incentives to participate. Further, given that in this model the central bank does not interact directly with end users, the entry requirements the central bank imposes on intermediaries would play a crucial role in creating the incentives for intermediaries and in furthering its public policy objectives.

The requirements should therefore strike a balance between ensuring sufficient competition and innovation in the market and managing risks. Two key risks for CBDC are an adoption rate that is

too low to make it a widely usable mean of payments and, on the other hand, the possibility of fraud and money laundering that could undermine confidence in its use.

In general, the requirements could be similar to those outlined in the existing legislation. In Canada, that could be the *Bank Act* (regulating financial institutions) or the *Retail Payment Activities Act* (regulating payment service providers not covered under the *Bank Act*). These two regimes already address important aspects, such as ownership, risk management and consumer protection.[12]

Each jurisdiction will need a detailed discussion of the specific entry requirements. In this paper, we focus solely on the economic assessment of how potential restrictions—in terms of pricing and quality provision—could affect intermediaries' incentives.

One key decision is which types of intermediaries should be allowed to enter and provide services to end users. We specifically consider traditional financial institutions, such as banks and credit unions, regulated nonbanks (such as fintechs) and public nonfinancial institutions.

Traditional financial institutions are regulated and have well-established financial products, which ensures they have the infrastructure and expertise to verify identities of users and minimize the risks of fraud and money laundering. Additionally, allowing regulated nonbanks could promote innovation and competition. Involving public nonfinancial institutions in the distribution of CBDC could offer the benefit of leveraging existing networks with clear nonprofit objectives. However, their lack of expertise in providing financial services and the potential perception by traditional financial institutions that nonfinancial institutions reduce or eliminate the role of intermediaries—which may also increase the costs of integrating such institutions into the ecosystem—are possible downsides.[13]

In general, the more "open" the market for intermediaries becomes in terms of who is potentially allowed to enter, the larger the role played by entry requirements in terms of risk management and consumer protection when it comes to ensuring that potential risks are mitigated.

4.1.3. Pricing

In considering pricing for this model, we analyze prices in the upstream and downstream markets separately. Here, we cannot fully analyze the complex interactions between them, so instead we explain the main factors that would influence the determination of prices. In the following subsections, we focus on the implications of the different prices for intermediaries and

[12] Consumer protection is also addressed in the *Financial Consumer Agency of Canada Act*, which empowers the Financial Consumer Agency of Canada.

[13] At this point, it is difficult to establish the net effect on the incentives of traditional financial institutions from the entry of nonbanks or an institution like Canada Post. Technology trends point toward customer service through white-label solutions, which could allow these new entrants to quickly acquire technology and expertise.

end users. Future work should expand this analysis, in particular the options for cost and fee models in the ecosystem.[14]

Upstream prices

These are the fees that are charged to intermediaries either by the central bank or by other intermediaries. As mentioned in the previous section, the upstream fees include the network fee and transaction processing fees, similar to existing interchange fees in current electronic payment systems.

Network fees

These are fees remitted to the network operator. In Model 1, since the central bank provides the network, it also sets and collects the network fee. On top of this, the central bank decides if this fee is charged to some or all intermediaries. Note that the specific fee will depend on the central bank's objectives—both business model objectives and public policy objectives—as well as its considerations about costs (development, maintenance, operational) and benefits (e.g., Should seigniorage be included?). Appendix B contains a detailed discussion of the objectives and considerations to determine the upstream prices.

In principle, lower prices are desirable for the system as a whole. The impact on individual parties would depend on how the fees affect the incentives and equilibrium contracts. More generally, any pricing above marginal costs would imply efficiency losses and redistribution of surplus within the payment ecosystem.

A low network fee could translate into CBDC being a low-cost alternative to existing payment systems. However, to the extent that payments are profitable lines of business for existing market participants, it might lead CBDC to being perceived as (unfair) competition, in turn limiting the extent to which these intermediaries are willing to promote the use of CBDC. Note that, theoretically, prices could be charged to one or both sides of a transaction, and they can be positive or negative (i.e., a subsidy).

Interchange fee

The second upstream price that can be affected by the central bank is the interchange fee, which is not remitted to the network operator but instead is a transfer between the participants of a transaction (typically from a merchant-side intermediary to a consumer-side intermediary in most credit card ecosystems). This interchange fee can in principle be negative (i.e., it could be a transfer from a consumer-side intermediary to a merchant-side intermediary).[15]

The degree to which a central bank (or other public authority) would be able to control such a price will depend on how a central bank's mandate is modified with respect to the issuance of

[14] In Appendix B, however, we analyze cost recovery, which is frequently used by central banks to price the services they provide.

[15] For a discussion on the trade-off between fixed and *ad valorem* fees, we refer to Shy and Wang (2011).

CBDC, or whether another public authority has or would be given a relevant mandate. Regulatory changes could either allow for direct price setting from the central bank or enable regulatory power over such a fee. Regulatory power could be granted either to set interchange fees only for its own CBDC system or to oversee such interchange fees of other systems as well. Many central banks already have such regulatory powers to oversee fees in existing payment systems.

Interchange fees have been shown (theoretically and empirically) to help incentivize adoption in two-sided platforms by transferring some of the value of the network externality from one side of the market to the other. However, the literature has also shown that inefficiently high interchange fees can materialize in equilibrium, harming welfare (see Halaburda, Kim and Shcherbakov 2023). Specifically, this occurs if excessive fees are passed on to end users (consumers) in the form of benefits, which lead to inefficiently high adoption and usage relative to other—cheaper—forms of payment.

The issue of the optimal interchange fee—in this case, the optimal fee would be the one that best achieves the goals of the central bank—highlights the crucial interdependency between the upstream and downstream prices. If consumer-facing intermediaries earn an inefficiently high interchange fee, they are incentivized to aggressively compete for consumers in the form of benefits (to either directly steer consumers away from adopting or to indirectly recover part of the costs through high prices) provided that these prices are unregulated.

Downstream prices

These are the fees charged to end users by intermediaries, for example, account opening and maintenance fees or payment-processing fees. This includes the margins for acquirers and issuers in the current four-party (credit card) system.

In Model 1, the assumption is that the central bank is not directly involved in the downstream market; therefore, any involvement in prices would need to occur through regulation. To intervene in downstream prices, central banks would need to exercise explicit regulatory powers if available or be granted new powers. These powers could also be granted instead to other specialized public authorities, as is frequently the case with regulation of prices.

Regulation could take one of two approaches:

- It could authorize the public authority (central bank or otherwise) to impose restrictions on downstream prices.
- It could empower such authority to set these prices directly through contractual agreements.

We focus here on the economic consequences of any such potential intervention in pricing. In doing so, we must assess the impact of any such regulation on the two relevant value components for intermediaries. The first is the “direct” component, which is the potential profit earned through CBDC distribution. The second, is an “indirect” component, which captures

cross-product externalities (i.e., distributing CBDC may either increase or decrease profitability from the intermediary's other products). Any assessment of the quantitative importance of this effect would need to account for consumers' and merchants' multi-homing in a multi-product set-up.

Refer to Appendix B for a detailed composition of the various fees and prices applicable to consumers and merchants. However, we account for the fact that potential one-sided interventions or regulations would potentially entail different implications for person-to-person and person-to-business transactions.

No intervention in downstream prices

The benchmark case is one where there is no direct intervention in downstream prices. One clear benefit of this approach would be that the intermediaries might be more willing to distribute as they would have full control over their product pricing and could in this way internalize any externalities between CBDC and their other financial products. Another positive aspect of this set-up is that it would require minimal legal framework alterations because there would be no public regulation of end-user fees.

The downside is that the lack of regulation may result in an inefficient equilibrium pricing structure. Examples of this would be intermediary pricing (intended to retain profitability in existing business lines) that deters the adoption and use of CBDC, or if an inefficiently high interchange fee were to result in excessive use. Provided that the interchange fee can be set appropriately by a regulator, and barring a complex private transfer scheme between intermediaries, the latter issue seems circumventable.

There remains the broad trade-off between, on the one hand, a higher willingness to distribute by intermediaries and possibly higher fees / lower surplus for end users and, on the other hand, lower adoption overall. This is because both intermediaries and end users (particularly merchants) require market power to recoup the fixed costs of adoption. This can be addressed in two ways:

- A sufficiently open interface in providing end-user services (subject to entry requirements being satisfied) can promote a competitive environment that limits rent extraction by individual intermediaries.
- The authorities can use regulatory powers to intervene in the price setting, with the downside of limiting the desirability to intermediaries of promoting CBDC.

Importantly, low fees in the upstream market (network fee, interchange fee) are helpful in promoting a competitive downstream environment by limiting the amount of costs that need to be recovered by intermediaries.

Intervention in downstream prices

Interventions in downstream prices can be done in multiple ways: for example, directly by setting CBDC-related prices or imposing caps or average pricing/revenue targets on specific

intermediary policies or indirectly by means of market competition through easing or hardening entry/licensing constraints.

Given that the power for these interventions would need to be explicitly granted to a public authority, we focus on what we deem as the most realistic direct interventions: setting average price targets for CBDC-related services (access/wallet provision, transfers) and imposing price caps. Note that price caps may be strict: for example, by prohibiting intermediaries from charging fees to specific user groups (as is the case for Pix in Brazil and e-CNY in China).

An advantage of such interventions is that the public authority would have some power to affect end-user prices in a way that allows the central bank to create the right incentives to internalize the two-sidedness of the system. Another advantage is that CBDC would be competing horizontally with the payment products of some intermediaries. Moreover, price caps and average price targets may limit the degree of price discrimination intermediaries engage in. This is particularly relevant given the substantial heterogeneity in fees faced by end users of existing payment methods, which tend to favour high-income individuals, especially in the form of credit cards.

The key disadvantage of these types of interventions are that they make it generally more difficult for intermediaries to want to participate in CBDC distribution, especially intermediaries holding products that might be perceived by end users as very close substitutes to CBDC. These issues would be amplified if upstream prices are such that substantial downstream revenues are required for intermediaries to profit from involvement in the CBDC ecosystem. Moreover, market participants could avoid price control measures by shifting fees to unregulated auxiliary or bundled services and other measures. This limitation of enforcement needs to be considered together with other costs of intervening.

Notably, insufficient incentives for potential upstream intermediaries could result in slow and low adoption, acceptance and equilibrium usage of CBDC as a payment instrument. Direct price intervention may therefore be incompatible with the initial objectives of introducing CBDC or would require building a separate upper layer of the distribution system that can guarantee delivery of the product to end users (similar to Model 2).[16]

Overall, interventions in the downstream market's pricing structure tend to favour end users (by keeping prices low) at the expense of intermediaries, whose profitability would be constrained. The specific implementation will therefore depend on which type of participants will require stronger incentives to join the system and how many changes would be necessary in the regulatory framework.

[16] Even in the latter case, it is not guaranteed that the strategic responses of the incumbents in the upstream market (such as Visa and Mastercard) would not have adverse effects on the usage of the new means of payment.

It is important to note that the central bank could still maintain control over other attributes of its CBDC product. Therefore, even if the central bank does not intervene in terms of end-user pricing, it could still employ agreements that would allow it to maintain control over such aspects as CBDC privacy, account limits, the transparency of CBDC contracts and fees, promotion, and advertising.

Finally, even if prices are regulated for basic services (wallet access, transfers), the central bank could incentivize intermediaries by allowing flexibility in pricing for more complex services that integrate CBDC. This applies, for example, to tailor-made solutions for merchants to use at the PoS. An open access environment for these intermediaries to enter at low costs (in the form of upstream prices), subject to fulfilling entry requirements, may be desirable as it would promote a competitive environment for these types of services—in terms of both quality and innovativeness of the services provided and the resulting prices.

Note that even these interventions require that the central bank or public authority be granted substantial powers, which in some jurisdictions, as is the case in Canada, might not currently be in place. Moreover, any sufficiently tailored intervention would require substantial knowledge and information. These interventions might not be feasible, either legally or practically.

4.1.4. Quality and content

Model 1 would enable the central bank to oversee the quality of the network infrastructure and its network services. However, it would give the central bank limited ability to directly affect the quality of the services provided to end users by intermediaries. Irrespective of the entry requirements in terms of safety and security, we assume the central bank would set strong quality standards to ensure a sufficiently good end-user experience. This would help promote adoption by end users, which is critical to realize potential network effects and make a positive impact on welfare in the payment ecosystem (for details, see Huynh et al. 2020 and Jiang 2020).

The quality standards, however, should not be so stringent that they promote a competitive environment in the provision of end-user access. One potential option for central banks to ensure high standards while promoting competition by easing the entry of intermediaries is to provide basic technological infrastructure at low/no cost, allowing for customization and integration into existing systems. Such an approach has, for example, been used by the Central Bank of Brazil in the rollout of Pix and in India during the rollout of UPI. While the development would naturally entail costs, these would likely be lower than those associated with a fully developed central bank app (see Model 2 below).

4.1.5. Privacy

We briefly summarize the economic considerations of privacy to highlight that the monetization of data could be an important margin that could provide incentives for intermediaries to participate in the CBDC ecosystem. The usage of data in general, but specifically for data monetization, would be limited by privacy and compliance legislation, which varies across

jurisdictions.[17] Broadly speaking, in terms of privacy, two different types of CBDC products are possible: a registered product (intermediaries collect holder information) and nonregistered CBDC (intermediaries do not collect holder information).

Different end-user information could be subject to different restrictions—that is, payment transaction data could be subject to different authentication methods, for example smaller-value payments might require less information.

In general, the central bank has two main options:

- Allow intermediaries to ask customers for their permission to use their data (with the implication that intermediaries will attempt to monetize it). This would occur in the form of specific consent given via opt-in (as stipulated by, e.g., the General Data Protection Regulation in the European Union).
- Restrict intermediaries from using end-user data for other purposes.

Any restrictions by the central bank on intermediaries' use of data directly implies potentially reducing incentives for intermediaries to support the CBDC ecosystem. However, this trade-off whereby intermediaries ideally want to monetize private information provided by end users also applies to existing products in the financial ecosystem (e.g., bank accounts). This consideration needs to be balanced with the end-user desire for privacy (see, e.g., ECB 2020, which highlights privacy as one of the key concerns for future users of a digital euro).

This implies a clear trade-off, where privacy increases end users' incentives to adopt while lowering incentives of intermediaries. Intermediaries might then need to or would seek to be compensated in other ways: for example, through higher prices.

4.1.6. Summary

Below, we list some of the potential benefits and drawbacks of Model 1. Note that these are directional statements. Calculating the net effect on incentives of intermediaries and outcomes for end users would require formal quantitative work.

In terms of benefits, Model 1:

- aligns better with the traditional role of central banks in the financial system
- leverages existing infrastructure and intermediary expertise
- provides more incentives to intermediaries to distribute

[17] In Canada, the *Privacy Act* and the *Personal Information Protection and Electronic Documents Act* cover how governments and businesses, respectively, handle personal information. These principles-based acts emphasize minimal collection, adequate protection, informed individuals and regulatory oversight. Recent bills are expected to introduce new enforcement mechanisms, privacy rights and data mobility rights.

- allows central banks direct control of prices and quality in the upstream market (network services)
- offers lower development costs and risk of market disruption

In terms of drawbacks, Model 1:

- provides no opportunity to directly set a quality standard for downstream services
- offers no direct control over downstream prices, potentially requiring the need for regulation
- offers diminished ability to address market failures in the downstream market
- could lead to low end-user adoption because of higher fees downstream

4.2. Model 2

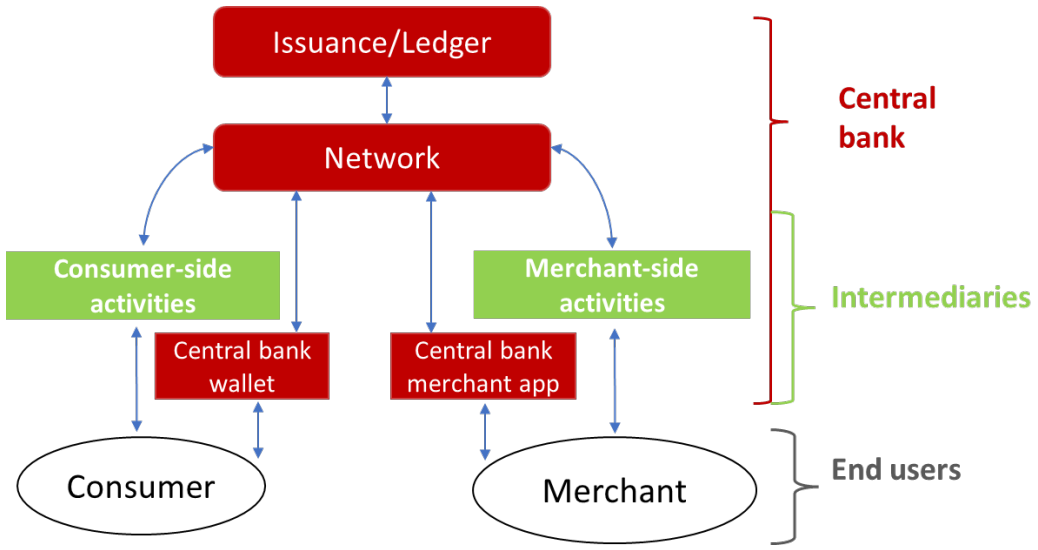
4.2.1. Market structure

In this model, the central bank is responsible for issuing and providing the network infrastructure and for offering some end-user services in direct competition with private sector intermediaries. Intermediaries will play the same roles as in Model 1 in providing end-user services. **Figure 4** shows this model graphically.

The involvement of the central bank in the downstream market might be warranted if market failures impede the adoption and success of CBDC. These failures could occur, for example, if intermediaries find it unprofitable to offer essential onboarding services for new users to join the ecosystem, or if intermediaries do not provide adequate wallet services to promote CBDC adoption. Other potential market failures that might require intervention include insufficient security measures, lack of interoperability and inadequate consumer protection regulations.[18] Although there are many potential market failures, each warranting different interventions (ranging from regulation to provision), in this paper we concentrate on the example of wallet provision. We consider this intervention mainly because it addresses the plausible market failure of underprovision to low-revenue customers and because it has the potential to have a large impact in the downstream market on improving access, quality and competition.

[18] For example, in the case of security, Kahn and Rivadeneyra (2020) analyze the negative externality emerging from providers of digital wallets underinvesting in security for the sake of attracting customers with convenience of access.

Figure 4: Model 2—Central bank performs ledger and network activities and provides a basic app to consumers and merchants, while intermediaries undertake all other end-user activities, including apps



4.2.2. Entry

We consider the case where the central bank gets involved in the downstream market by providing digital wallets, which would enable end users (consumers and merchants) to maintain balances and conduct payments. We refer to these wallets to as the CB apps.

The central bank could delegate the onboarding and customer relationship management to a specialized third-party service provider. In the Canadian context, two potential options are as follows:

- A public entity with experience in servicing customers performs onboarding and customer relationship management on behalf of the Bank.
- Private intermediaries could onboard customers to the central bank wallet, but customer relationship management could still be delegated to a public entity.

This is not an exhaustive list of options for delegation, but it illustrates how a central bank could engage private entities or other public institutions to provide wallets to end users.

Involving private intermediaries to assist in onboarding customers to the CB wallet while entrusting a public entity with customer relationship management could create healthy competition and variety in the access methods for customers. However, it could have an impact on the entry incentives of the intermediaries involved in distribution. Also, this approach might hinder the uptake of the CB wallet because intermediaries could have an incentive to steer customers to use their own wallets. It is not clear how existing intermediaries would respond to this distribution model, and their reactions may differ based on the CB wallet's particular

functions, price and service quality. Nevertheless, given the widespread fear of disintermediation, intermediaries may react strongly, prompting them to avoid involvement with CBDC altogether (which also extends to the case where rollout occurs through a public entity).

It is important to distinguish between two types of digital wallets that could be offered:

- **Custodial**. With custodial wallets, end users would outsource their wallet custody (usually their private keys) to a third party, in this case the public intermediary. A higher level of risk would be in place as sensitive user information would be with the delegated intermediary and could be targeted in cyberattacks. Furthermore, the custodian would have complete control over the balances and related processes. A clear drawback of this type of wallet provision would be the high level of involvement of the central bank, through a designated intermediary, in end-user activities, which is an area in which central banks do not have expertise or a comparative advantage compared with private intermediaries.
- **Non-custodial**. These wallets are also referred to as "self-custodial," where end users would have full control over their balances and would not need to share any private information with a trusted third party. This implies that the safety of the wallet details would rely completely on the end users themselves.

The trade-off, therefore, is between more involvement by the chosen intermediary in end-user activities (custodial wallet) and higher safety risks and reputational costs to the central bank in case access to CBDC accounts is lost by users (non-custodial wallet). Given the risks to customers, the non-custodial wallet might be warranted only for low-value transactions.[19]

Another important consideration regarding CB apps is whether different end users require different types of wallets, such as consumers and merchants. While this approach might be necessary for certain use cases, it can also create hurdles for adoption and usage. While it might seem simpler to have one single type of app, this might not be straightforward, especially as many merchants nowadays are dependent on PoS devices for completing their digital payments and exhibit a strong preference to have their payment options bundled in one device. Therefore, while end-user–specific wallets might be necessary for certain use cases, it is important to consider the potential drawbacks and ensure that the adoption process remains as simple and accessible as possible for all parties involved.

4.2.3. Pricing

Upstream prices

Even though the pricing structure and considerations for Model 2 may be comparable to those discussed in Model 1, the downstream market would be impacted by the introduction of a

[19] Kahn and Rivadeneyra (2020) analyze this trade-off and the additional role that a central bank could have in establishing minimum standards of security.

central bank digital wallet and its associated payment capabilities, which is likely to affect the equilibrium outcome. Moreover, existing intermediaries may perceive central bank involvement in the downstream market as forcing them compete with a new, vertically integrated competitor and induce concerns about a leveled playing field.

For upstream pricing, the main explicit and novel issue to consider is whether intermediaries offering the CB wallet would need to incur fees to access the CBDC network or process transactions.

The central bank would likely not charge access or transaction fees to intermediaries when they use or initiate payments using the CB wallet. This, however, would affect the level of competition in the downstream market, as the intermediaries that do not offer a CB app would be competing with a cheaper wallet. In terms of potential effects, this might be beneficial for competition if other intermediaries can follow suit and compete for providing app services. If the central bank were to charge intermediaries access or transaction fees when they offer such services through their private wallets, it could lead to the foreclosure of a market for payment apps. Those intermediaries not offering the CB wallet might, of course, choose to continue operating if they can generate profits from other sources.

If we expect that private intermediaries involved in CBDC distribution would make most of their profits from processing payments, then the inability to compete properly with the CB app could trigger some intermediaries to abandon any involvement in the distribution of CBDC. However, if we expect that intermediaries will rely on other channels for profit, then offering a CB wallet might still be feasible and could increase competition in the downstream market.

The real effect of the CB wallet would depend on the arrangements the central bank makes with other intermediaries. Moreover, we must assess whether it is realistic to assume that those using a CB wallet and processing payments through it would not still need to use the account opened at a specific intermediary or face account fees when doing so.

Downstream prices

In terms of downstream prices, Model 2 differs from Model 1 mainly in that the central bank would have more control of the prices charged to end users associated with wallet access and payment initiation fees through the CB wallet. Therefore, unlike Model 1, regulation would not be the only way of intervening downstream. The total effect on downstream competition would reflect the direct pricing choices of the CB wallet services, the choice to intervene or not on intermediary end-user fees and the feedback of these two on upstream prices.

If the central bank decides to charge end users very low fees for the CB app, then it would directly affect the distribution and pricing incentives of other CBDC intermediaries. The competitive effect may be higher, especially if the fees related to the processing of payments are set too low. Thus, a trade-off exists between, on the one hand, increased competition and higher end-user welfare through lower end-user fees on the CB wallet and, on the other hand, lower willingness to distribute by intermediaries.

4.2.4. Quality and content

In Model 1, the central bank would have the ability to directly control the quality of the ledger and network (upstream). However, in the downstream, the central bank can only rely on quality requirements for end-user services. This means that the quality of the end-user services may not be entirely in the central bank's control. In contrast, Model 2 provides the central bank with the opportunity to not only directly control the quality upstream, but also to offer specific quality downstream. While having more control on quality can lead to better end-user services, it also comes with the trade-offs of increased involvement and responsibility.

The CB wallet would be developed with ease-of-use as a priority to ensure that it is accessible and user-friendly for all kinds of users, regardless of their technical expertise. This may include not only simplifying the user interface and design but also implementing clear and concise instructions for navigating the wallet's features.[20]

The CB wallet could also be designed to function as a foundational technological infrastructure that intermediaries could access without incurring significant development costs to create their own digital wallets. This approach has the potential to offer several benefits, such as increased financial inclusion, increased competition and quality standardization. This could be achieved two ways:

- The central bank could develop the CB app, which intermediaries could integrate via an application programming interface. This method would enable intermediaries to maintain their brand and offer their services within the CB app.
- Everything could be run through the CB app. This method would allow intermediaries to onboard their customers and redirect them to use the CB app.

Each approach has potential implications. The first approach preserves the diversity and innovation of individual intermediary wallets while providing access to the CBDC ecosystem through integration with the CB app. This allows intermediaries to leverage their expertise and continue offering their unique value propositions. The second approach, relying solely on the CB app, may enhance universal access by streamlining the user experience and ensuring consistency across transactions. This approach could prioritize convenience and simplicity, potentially sacrificing some innovation and competition that comes with intermediary-led wallet solutions.

Ultimately, the choice between these approaches depends on the policy objectives of the central bank. If fostering innovation and competition is a priority, allowing intermediaries to maintain

[20] An example of this approach is the Pix system in Brazil, where the central bank has established interface and user experience guidelines (see Appendix A for a comparison of various FPSs).

their own wallets can be advantageous. However, if universal access and simplicity are paramount, concentrating transactions within the CB app may be more desirable.

4.2.5. Privacy

The provision of a CB wallet might lower the incentives of private intermediaries to join the CBDC distribution system. This is because it would directly affect the potential for them to monetize data, especially if consumers were to rely too heavily on the CB wallet for payments.

The willingness of consumers to use the CB wallet, which might store their payment transaction data, would depend on their trust in the central bank versus other private intermediaries.

Finally, if payments are being initiated through the CB wallet and not through private intermediaries, this could affect not only the monetization of data but other spillover channels as well. For instance, the intermediaries that rely on payment data to learn consumers' credit quality would be significantly affected by the loss of this information (see Parlour, Rajan and Zhu 2020). One way to protect these positive spillover channels might be to allow data portability.

Open banking is likely to influence this.[21] Leaving aside open banking, it is important to note the privacy differences between Model 1 and Model 2. In Model 1, the central bank would not be able to influence privacy directly if intermediaries find ways to monetize the data or restrict portability.[22] However, in Model 2, the central bank could directly and independently decide whether to allow data portability for the data generated within its wallet. This gives the central bank greater control over the privacy implications of CBDC adoption, as it can choose to prioritize data protection and portability.

4.2.6. Summary

The viability of the central bank providing direct access to the CBDC ecosystem through its own app requires further analysis. At first glance, granting intermediaries the ability to hold and make payments through a CB app seems less cumbersome for the central bank than helping end users open CBDC accounts and doing other customer service activities. However, this might not be the case, as the central bank would still need to assist end users via specific intermediaries with app-related administrative issues (e.g., updating account details, lost keys). This would be the case especially if the central bank were to offer a custodial wallet.

Below, we list some of the potential benefits and drawbacks of Model 2. Similar to the list provided for Model 1, these are directional statements. Calculating the net effect on incentives of intermediaries and outcomes for end users requires more formal analysis.

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[21] Several countries have already implemented open banking regimes. In Canada, framework legislation for open banking is expected to be introduced in 2024.

[22] To be compliant with AML principles, it is likely that a CBDC would not be too different in terms of privacy from current electronic payment options offered by commercial banks.

In terms of benefits, Model 2 provides:

- direct control of prices and quality in the upstream (network services), as in Model 1
- the opportunity to offer specific quality in downstream services, thereby setting a base-level quality standard for others to follow
- the ability to cater to niche user segments that may be overlooked by intermediaries
- a CB wallet that could increase competition in the downstream market, potentially resulting in lower prices and increased end-user welfare
- the potential for increased competition and quality standardization through intermediaries accessing the CB wallet as foundational technological infrastructure

In terms of drawbacks, Model 2 involves:

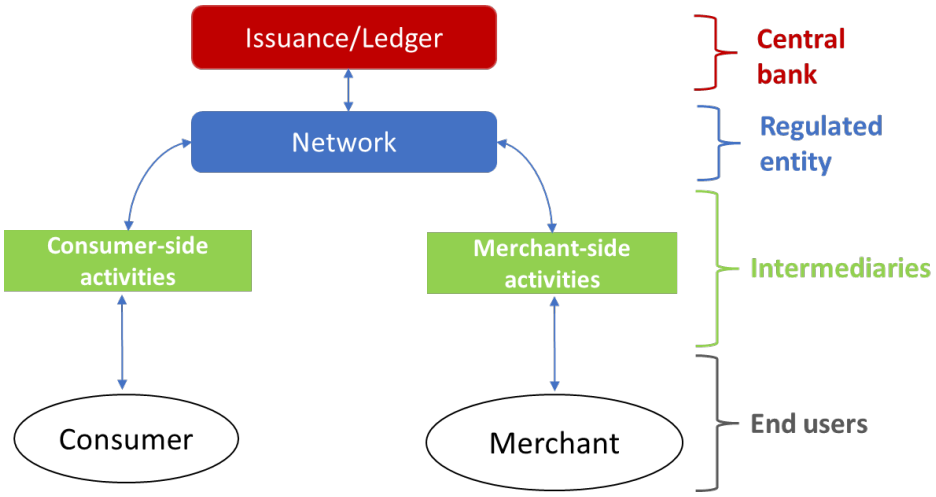
- increased involvement with end-use services for wallet support via an intermediary
- higher development and resource costs compared with Model 1
- the potential for private intermediaries to be disincentivized to join the CBDC distribution system if the CB app proves to be a more efficient and cost-effective option for end users
- the potential that existing intermediaries would perceive they are competing on an uneven playing field

4.3. Model 3

An idealized version of Model 3 is one where the central bank is responsible for issuing CBDC while the network infrastructure and services are provided by another regulated entity.[23] **Figure 5** illustrates this model.

[23] Several countries have specialized entities, separate from the central bank, in charge of operating national payment systems. Canada, the United Kingdom and New Zealand are examples.

Figure 5: Model 3— Central bank provides the ledger and a regulated entity provides network activities, while intermediaries undertake all end-user activities



4.3.1. Entry

This model has no entry per se of the network; instead, an agreement is reached between the central bank and the operator of the network. In the downstream, the trade-offs emanating from the policy choices for the entry of intermediaries are relatively unchanged from Model 1. This assertion is true to the extent that the access rules of the regulated entity and the network they provide are similar to the ones assumed for Model 1. If the access requirements of the network provider and the CBDC system differ, then whichever is tightest would be the one effectively setting the access rules.

4.3.2. Pricing

As in Model 1, we make the distinction between upstream and downstream prices as well as who would be in charge of these pricing decisions. In Model 3, however, we could separate the price of settlement, which is provided by the central bank, and the price of network services, which is provided by the regulated entity. The entity operating the network might have some flexibility to establish the rules and pricing structures for network services. This not only distinguishes Model 3 from Model 1 but also raises considerations about potential limitations on the strategic autonomy of the central bank. Specifically, it imposes constraints on the central bank's decision-making capacity, especially concerning the determination of upstream prices. This deviation from centralized control may introduce inefficiencies in pricing and raise concerns about potential cost pass-through implications.

Note that it is unclear at this point whether the *total* social cost of a CBDC transaction would be lower or higher by using a network provided by a regulated entity for CBDC compared with Model 1. It will depend on the price that the network provider sets for its services to the intermediaries. For example, Pix in Brazil charges intermediaries 0.1 cents per transaction. (See Appendix A for a comparison to other FPSs.)

Aside from these key differences, the discussion of the impact of specific up- and downstream prices and associated (potential) regulation on the incentives of agents in the CBDC ecosystem is largely unchanged relative to Model 1. However, it is important to bear in mind the feedback effects between changes to the upstream prices (potentially arising from cost differences or the involvement of additional stakeholders) and downstream prices.

4.3.3. Quality and content

The discussion of quality terms should also be similar to Model 1. An additional difference from Model 1 is that here the central bank does is not directly in charge of the quality of the network infrastructure and its services. Similar quality benchmarks could be achieved through negotiating with the entity in charge of the network, though restrictions might be applicable. The interaction between quality considerations and the choice of the network provider will matter to the extent that any trade-off discussed in Model 1 could be quantitatively changed if the price of the network and ledger components affect the incentives of intermediaries.

4.3.4. Privacy

As for the quality terms, the discussion about privacy terms should also be similar to Model 1. The interaction between the privacy considerations and the choice of the network provider will matter to the extent that any trade-off discussed in Model 1 could be quantitatively changed if the price of the network and ledger components and the rules for data monetization set by the regulated entity affect the incentives of intermediaries.

4.3.5. Summary

Model 3 proposes the use of a regulated entity for the provision of the network infrastructure in the CBDC ecosystem. The key trade-off when comparing Model 3 with a purpose-built separate infrastructure (Model 1) is the potential reduction of costs (borne by the central bank), risks and interoperability concerns in exchange for the involvement of additional stakeholders. This may inhibit the strategic autonomy of the central bank in terms of pricing or access requirements. Notwithstanding the potential reduction of costs borne by the central bank, it is unclear at this point whether the *total* social cost of using a regulated entity's network for CBDC would be larger or smaller than in Model 1. At the same time, such an arrangement whereby the central bank has to engage more rigorously with other stakeholders could be beneficial for the acceptance of intermediaries.

Below is a summary of potential benefits and drawbacks of Model 3. Similar to the lists provided for models 1 and 2, these are directional statements.

In terms of benefits, Model 3:

- separates the responsibility of issuing CBDC and providing the network infrastructure and services, which can lead to specialization

- potentially reduces costs borne by the central bank and risks associated with building a new network from scratch

In terms of drawbacks, Model 3:

- gives the central bank no ability to directly affect quality in the network layer
- restricts the strategic autonomy of the central bank in decision making and in particular in determining upstream prices, which may introduce inefficiencies in pricing and cost pass-through
- may introduce stricter entry requirements than desired, thus negatively impacting competition and access to CBDC

4.4. Other models

Other potential models exist for CBDC ecosystems with different market structures and involvement from the central bank (see **Table 1**). One such model is Model 4, where the central bank delegates a regulated entity to provide the network infrastructure and services (as in Model 3) while also providing end-user services (as in Model 2). Since Model 4 combines elements from both models 2 and 3, the discussion of market entry, pricing, quality/content and privacy should be similar to that of these two models.

Models 5 and 6 propose increasing competition by letting the public network compete with private networks, but they might not be feasible because private networks might lack the incentive to enter the market due to lower end-user fees set by the central bank network. Moreover, increased competition might lead to more distortions in interchange fees, as found in studies by Guthrie and Wright (2007), Chakravorti and Roson (2006) and Edelman and Wright (2015). For instance, credit card companies may pay more rewards or benefits to consumers, inducing them to overuse their cards, while increasing the fees to merchants. It is important to note that these studies have focused on competition among profit-maximizing private platforms. An exception is Liu, Reshidi and Rivadeneyra (2023), who shift the focus toward CBDC as a benevolent payment platform operating within an oligopolistic market, aiming to maximize total surplus rather than profits. Their research reveals that the competitive equilibrium featuring a benevolent payment platform results in higher social welfare compared with the equilibrium driven solely by profit-maximizing private payment platforms.

Other models, such as models 7 and 8, suggest that private firms could provide the network infrastructure and services. However, these models, which resemble the current debit/credit card system, might be inefficient given the public policy objectives underlying any CBDC. The primary distinction between privately run networks and publicly regulated entities lies not only in the potential inefficiencies discussed in Model 3, but also in the profit motive. Private networks seek to maximize profits, while regulated entities, as considered in Model 3, explore set-ups where the system follows cost recovery approaches or even prioritizes welfare maximization as an

objective. This fundamental difference can introduce additional inefficiencies in the system, including higher upstream fees that are ultimately passed on to end-users.

Note that, in general, not letting private firms provide network services in the CBDC ecosystem does not mean that the public CBDC network cannot bring competitive effects to the market. Debit and credit cards would still exist in the payments market. The lower price of the CBDC network would incentivize some intermediaries to switch from offering private payment options to offering CBDC to their customers, rendering competitive effects.

5. Conclusion

This discussion paper proposes a framework to systematically analyze different CBDC economic models and discusses the trade-offs of three main models. Based on our analysis of the models analyzed, we find that if eventually issued, a CBDC under Model 1 would offer the following benefits: lowest development costs for central banks, lowest risk of market disruption, leveraging of existing intermediaries' relationships and expertise and a better alignment with the traditional role of central banks in the financial system. Model 2, on the other hand, offers benefits in terms of the opportunity to offer specific quality downstream, which could set the standard for intermediaries as well as increase competition in the downstream market through the provision of a central bank digital wallet. Furthermore, Model 2 enables the ability of the central bank to intervene in case market failures arise and to cater to segments of the population that may be overlooked by intermediaries.

Finally, regarding the use of a regulated entity for the provision of the network, our analysis suggested that while this model may lower the costs borne by the central bank, it could limit the strategic autonomy to control upstream pricing, quality and intermediary access, or require additional regulatory intervention to manage that risk. In other words, Model 3 leads to a trade-off between potentially lower costs for the central bank and possible restrictions on the central bank’s strategic autonomy because of the involvement of additional stakeholders.

The framework is also useful to identify specific research and policy questions. Setting up a sustainable economic model will require multiple coherent policy levers. The following are examples of these questions: How should upstream and downstream pricing structures be jointly determined? How would adoption and usage be affected by the chosen pricing structure? How would the costs of the system be recovered and distributed among the central bank, intermediaries, and end users?

Appendices

A. Comparison of fast payment systems

Retail central bank digital currency (CBDC) and fast payment systems (FPSs) could be regarded as substitutes for specific use cases and policy objectives (e.g., enhancing efficiency, competition and innovation in digital payments). Consequently, some ecosystem design considerations for a retail CBDC can be informed by those for FPSs. For this purpose, **Table A-1** presents an overview of Brazil's, India's, Mexico's and Sweden's FPSs and their respective ecosystems. Among others, it covers aspects such as intermediaries, alias databases, fees, functionalities and access channels. This table is reproduced from the paper "The Economics of Fast Payment Systems: A Cross Country Comparison" by Dalvi, Rivadeneyra and Robichaud (2024).

Table A-1: Comparison of selected fast payment systems

	Pix	Unified payments interface (UPI)	Cobro Digital (CoDi)	Betalningar i realtid (BiR)	RIX-INST
Country	Brazil	India	Mexico	Sweden	Sweden
Launch year	2020	2016	2019	2012	2022
Settlement (end user)	Real time (24/7/365)	Real time (24/7/365)	Real time (24/7/365)	Real time (24/7/365)	Real time (24/7/365)
Settlement (Interbank)	Real time	Delayed	Real time	Real time	Real time
Settlement instrument	Public money	Public money	Public money	Private money	Public money
System owner and operator	Banco Central do Brasil (BCB)	National Payments Corporation of India (NPCI)	Banco de Mexico (Banxico)	Bankgirot	Riksbank
System access fees for intermediaries[1]	- Yes (cost recovery) - Fee of BRL 0.001 per transaction	- Yes (cost recovery) - Estimated fee of INR 0.16 per transaction (or 0.02% of average transaction value)[2] - Per-transaction fee paid by the remitter bank	- Yes (cost recovery for the large value system (SPEI), which settles CoDi transactions) - Fixed per-transaction fee based on total real-time gross settlement (RTGS) (i.e., SPEI) volume from the previous year - None on CoDi usage itself	Fixed yearly and per transaction fee charged by Bankgirot	- Yes (cost recovery) - Monthly fee + per-transaction fee charged by the Riksbank[3]
App provider(s)	- Bank apps - FinTech apps - PSP apps	- NPCI app (BHIM) and white label technology - Bank apps - Prepaid payment instrument (PPI) issuer apps - Other apps[4]	- Banxico app (for QR code generation) - Bank apps to generate QR codes and accept a request-to-pay	- App (Swish, provided by Getswish AB) - Customers' and merchants' transactions are settled in BiR through Swish, and the end-user functionalities are provided by Swish	- App (Swish, provided by Getswish AB) - Customers' and merchants' transactions are settled in BiR through Swish, and the end-user functionalities are provided by Swish
Alias database owner (architecture)	BCB (centralized)	NPCI and PSPs (decentralized)	Banxico (centralized)	Swish (decentralized)	Swish (decentralized)
Merchant discount rate (MDR)	- Yes (market pricing) - Fee of 0.22% of transaction value on average	Zero (regulated pricing)	Zero (regulated pricing)	- Yes (market pricing) - Fees are bank-dependent - Fixed recurring fee + per-transaction fee	- Yes (market pricing) - Fees are bank-dependent - Fixed recurring fee + per-transaction fee

				(about 2 SEK = 0.26 CAD)	
Interchange fees	Zero (regulated pricing)	Zero (regulated pricing)	Zero*	NA	NA
Customer fees and incentives	- Zero (regulated pricing) - Intermediaries are given freedom to offer rewards/incentives; the BCB/Pix does not offer any directly	- Zero (regulated pricing) - Discounts and cashback offers in apps from TPAPs	Zero (regulated pricing)	Zero (market pricing)	Zero (market pricing)
Other revenue opportunities for intermediaries	- There are no restrictions/regulations on banks, fintechs and PSPs generating revenue through Pix outside of fees (e.g., commercial use of data)	- Commission from utility and telecom companies when UPI is used to pay bills and for mobile recharges -Commission on collected loan payments - Upfront fees on loan disbursals - Some government subsidies for the payment sector		- No restrictions/regulations on banks, fintechs and PSPs generating revenues through Swish (e.g., commercial use of data)	- No restrictions/regulations on banks, fintechs and PSPs generating revenues through Swish (e.g., commercial use of data)
Payment types	- P2P, P2B, B2B, P2G, G2P	- P2P, P2B, P2G, G2P	- P2P, P2B, P2G*, G2P* - Request to pay (RTP) using QR codes	- P2P, P2B, P2G, G2P -Self-service checkout in physical stores	-P2P, P2B, P2G, G2P - RTP -Self-service checkout in physical stores
Functionalities and access channels	Mobile apps, RTP through static and dynamic QR codes, internet banking, branches, ATMs, banking correspondents, phone number aliases, offline transactions (TBD)	Mobile apps, static QR, dynamic QR, customer-presented QRs, audio QR, NFC, in-app payments, e-commerce websites, feature phones, use of phone numbers for payments, push, pull, RTP, offline transactions, bill payments, foreign inward remittances, pre-authorized debit (pull) and recurring payments (push)	Mobile apps, static and dynamic QR codes, phone number aliases	E-commerce, PoS, mobile apps, static and dynamic QR codes, and use of phone numbers for payments	E-commerce, PoS, mobile apps, static and dynamic QR codes, and use of phone numbers for payments

Cross-border transactions	Not supported	- Foreign inward remittances - Linkage of UPI with Singapore's FPS (PayNow)	Not supported	Not supported	Work in progress with the European Central Bank to leverage TIPS for cross-border and cross-currency fast payments
Transaction limits	- No minimum - Pix participants have option to set maximum limits (subject to Pix rulebook parameters) - Periodical limits set by BCB during overnight hours	- Maximum of INR 100,000 per transaction and per day (for traditional transactions)[5] - Maximum of INR 200,000 for white-listed merchants and specific categories with dual KYC (Insurance, SIP Investment etc.) - Maximum of INR 500,000 for initial public offerings (IPOs) and retail direct scheme (RDS) - Limit on the number of transactions per day varies by bank and app provider	- No minimum - Maximum: MXN 8,000 (approx. CAD 600) per transaction - No daily limits	- General transaction limit on the BiR settlement system - Banks may set their own transaction limits - Daily SEK 2,000 limit for Swish users under 16	- RIX-INST follows the NPC Instant Credit Transfer Scheme Rulebook, which sets general transaction limits - Banks may set their own limits - Daily SEK 2,000 limit for Swish users under 16
Key intermediaries and roles	- **BCB:** Owner and operator of Pix - **Banks, fintechs, PSPs:** Can onboard customers onto Pix, provide the UI through apps, and process transactions; the obligations and roles of each (banks, fintechs & PSPs) are the same within Pix	- **Reserve Bank of India (RBI):** Owner and operator of India's RTGS system in which UPI settles - **NPCI:** Owner and operator of UPI - **Banks:** PSP & issuer banks can onboard customers onto UPI, have their own UPI apps, and can process transactions requests; issuer banks are "UPI-enabled" and only respond to transaction requests from the UPI system - **PPI issuers:** PSP & PPI issuers have a similar role to PSPs & issuer banks	- **Banxico** - **Banks** (RTGS participants) - **Fintechs** - **Merchants**	- **Riksbank:** Owner of RIX-RTGS, which is used to provide liquidity to BiR - **Bankgirot:** Owner and operator of BiR - **Swish:** Mobile app that end users make payments with - **Banks:** Participate in BiR, offer Swish to their customers - **Fintechs and PSPs:** Provide payment services to end users built on Swish	- **European Central Bank (ECB):** Owner and operator of TIPS, the technical infrastructure of RIX-INST - **Riksbank:** Owner and operator of RIX-INST and RIX-RTGS - **Swish:** Mobile app that e users make payments with - **Banks:** Participate in RIX-INST, offer Swish to their customers - **Fintechs and PSPs:** Provide payment services to end users built on Swish

		- **Others:**[6] Encompasses all firms that participate in the UPI ecosystem as TPAPs; TPAPs enter in sponsorship agreements with PSP & issuer banks to connect their apps to the UPI system			
Mandated participation	Yes—Only for institutions (i.e., banks, fintechs and PSPs) with more than 500,000 accounts	No	Yes—Banks participating in RTGS are required to process RTP from CoDi	No	No
Adoption metrics	- Transaction volume per capita/year: 194.8[7] - Transaction volume per capita/year ~2 years after launch: 176.6[8]	- Transaction volume per capita/year: 82.4[9] - Transaction volume per capita/year ~2 years after launch: 1.8[10]	- Transaction volume per capita/year: 0.03[11] - Transaction volume per capita/year ~2 years after launch: 0.02[12]	- Transaction volume per capita/year: 94.2[13] - Transaction volume per capita/year ~2 years after launch: 2.6[14]	Swish moved to RIX-INST in March 2024
Highlights from the broader digital payments ecosystem	- **Credit** and **debit card** purchases accounted for 46.4% (value transacted) of household consumption (2020) - 35.63% of individuals report using a **credit card** for any transaction (2021) - **Debit cards** account for 20% of PoS transaction volumes (2020) - **Credit cards** account for 34% of PoS transaction volumes (2020) - **Debit cards MDR**: Over 1% of transaction value - **Credit cards MDR**: Over 2% of transaction value	- **UPI** share of retail payments (volume) in 2017/2022: 0.2%/63%[15] - **Debit cards** share of retail payments (volume) in 2017/2022: 22%/5% - **Credit cards** share of retail payments (volume) in 2017/2022: 10%/3% - **Debit cards MDR:** Ranging from 0.30% to 0.90% of transaction value[16] - **Credit cards MDR:** Between 2.0% and 3.0% of transaction value		- Percentage of people who paid by **debit** in the past 30 days: 93% (2018); 92% (2020) - Percentage of people who paid by **credit** in the past 30 days: 31% (2018); 36% (2020) - Percentage of people who paid by **Swish** in the past 30 days: 52% (2016); 62% (2018); 75% (2020); 82% (2022) - Percentage of people who paid by **cash** in the past 30 days: 79% (2016); 61% (2018); 50% (2020); 34% (2022) **- Debit** and **credit card interchange fees** were capped at 0.2% and 0.3% (respectively) by the European Parliament in 2015	See the metrics provided for BiR

Public policy objectives	- Overarching BCB objective was to modernize the Brazilian retail payments market - Pix's objective was to make digital commerce in Brazil easier, improve financial inclusion and reduce digital transaction fees for consumers and merchants	- Overarching objective of the RBI was to reduce the use of cash in India and improve financial inclusion - UPI's objective was to improve customer experience and interoperability in digital payments - UPI also opened the door to nonbanks (i.e., TPAPs) to participate in retail payments and promote innovation - UPI was launched in the context of a revamp of India's payment sector launched in the late 2000s	- Financial inclusion of cash-based micro and small businesses - Reduction of usage of cash - Digitalization of payments	- Provided a more convenient way to make P2P payments - Swish was originally only for P2P, but grew to include businesses in 2014 as the app became more popular	- Instant settlement of payments in central bank money - TIPS is a more sophisticated platform, more capable of dealing with the scale at which Swish is being used

[1] Can be composed of fixed and/or variable fees.
[2] Based on a 2022 estimate from the RBI of the cost incurred by the NPCI to process a person-to-business (P2B) transaction of INR 800 (i.e., UPI's average P2B transaction value).
[3] RIX-INST uses the infrastructures of Target Instant Payments Settlement (TIPS) for its operation, which is owned and operated by the European Central Bank.
[4] Apps designed by third-party app providers (TPAPs). More information is provided in the "Key intermediaries and roles" row.
[5] Banks and app providers can set lower limits per transaction than the INR 100,000 limit prescribed by the NPCI.
[6] TPAPs are typically big techs, fintechs, paytechs or financial services firms.
[7] Calculated as the annual transaction volume per capita from January 2022 to December 2022.
[8] Calculated as the 12-month transaction volume per capita from December 2021 to November 2022. Pix was officially launched in November 2020.
[9] Calculated as the annual transaction volume per capita from January 2022 to December 2022.
[10] Calculated as the 12-month transaction volume per capita from October 2017 to September 2018. UPI was officially launched in September 2016.
[11] Calculated as the annual transaction volume per capita from January 2022 to December 2022.
[12] Calculated as the 12-month transaction volume per capita from October 2017 to September 2018. UPI was officially launched in September 2016.
[13] Calculated as the annual transaction volume per capita from January 2021 to December 2021.
[14] Calculated as the annual transaction volume per capita from January 2014 to December 2014. Swish was launched in December 2012.
[15] The shares of retail payments volume for UPI, debit cards and credit cards are based on the RBI's fiscal year (FY) 2016–2017 and FY2021–2022, which extend from April to March of each year.
[16] Depending on the access channel and a merchant's annual revenues. MDR on RuPay debit cards have been regulated to zero by the Indian government.

B. **Considerations to determine upstream prices**

Here we discuss methods to determine upstream prices in Model 1. The optimal decision of the different prices under the direct control of the central bank and of the interchange fee would depend on the chosen central bank objectives. It is important to note that in practical terms we can distinguish business model objectives from public policy objectives. The latter are related to welfare measures such as consumer surplus, monetary sovereignty, innovation, universal access, competition and efficiency. These objectives are harder to quantify at this stage. Therefore, it is easier to focus on business model objectives, which are the objectives from the point of view of the costs and revenues of providing the CBDC ecosystem. These are easier to measure.

Cost recovery is a useful starting point to discuss the pricing options available to central banks. Note that method is frequently used to price central banking services. Nonetheless, as our analysis shows, it is unclear under which conditions cost recovery is equivalent to welfare maximization.

Under the objective of cost recovery, the revenues are equal to the costs of provision:

$$\Pi \equiv p \times q(p) + S(q) - C(q) = 0,$$

where the profit of the central bank is equal to zero by setting the price of CBDC services (p) such that the direct revenue from the demand of CBDC (p x $q(p)$) plus the seigniorage ($S(q)$) equals the costs to the central bank ($C(q)$). This profit function is written in a simplified manner—we have abstracted away from the fact that the distribution model would be intermediated and that the demand will be affected directly by the prices that intermediaries set to end users and only indirectly by the prices of the central bank. Furthermore, we are assuming that the central bank would be able to set only one specific price (i.e., the network fee), and we do not specify whether this price would be charged to all or only some intermediaries. It is important to emphasize also that the profit function in the equation above represents the long-term profitability rather than the profit within a single period. That is, the central bank sets a price that leads to an average profit of zero over time, even though there might be positive or negative profit in some periods.

The determination of the price will depend on the answers to the following questions:

- Should seigniorage be considered or not?
- What are the costs to be considered in this calculation?

Considering seigniorage

Due to the nature of central bank money, the outstanding value of CBDC balances would generate seigniorage, just like cash does today. In typical years, seigniorage is a significant source of revenue for central banks. This could imply a potentially large subsidy (compared to considering only the direct revenue) of the CBDC system.

The cash ecosystem is a useful comparison here. Cash is provided to the intermediaries at zero price, so direct revenues are zero. Therefore, seigniorage revenue is used to cover the costs of bank note development, printing and storage at bank facilities.

Therefore, by analogy, seigniorage from CBDC could be devoted to the development and maintenance of the CBDC system. Note that the fixed and variable costs of the two forms of money might be quite different. Finally, given the electronic nature of the CBDC system, central banks will have the capacity to set a price for transactions, something that cannot be done easily with cash.

A separate question that should be considered in the future is whether the cash and CBDC ecosystems—to the extent that the introduction of CBDC was not triggered by cash no longer being a viable and widely accepted form of payment—should cross-subsidize each other. That is, could the seigniorage of one form of public money be used to subsidize the other?

Costs to be considered

The costs considered in *C(q)* could be the fixed and variable costs of running the core of the CBDC system.[24]

In practical terms, the policies that central banks could consider include the following:

No fees for network

All intermediaries would face a zero price from the central bank for upstream services. In this case, the system would presumably be financed by seigniorage. This option is the closest to cash. This approach could be beneficial for downstream intermediaries and end users to the extent that they pass on the benefits to their customers. This would depend on the level of competition in the downstream market.

As a costless network option, this option could hurt the volume and network effects of existing payment networks. Incumbent payment networks might respond with reduced prices; the opposite, increased processing fees, is also possible and has been observed in practice.[25]

Finally, this might be beneficial to the central bank if it helps with initial adoption of the CBDC network, both at the intermediary and end-user layers. As mentioned above, due to two-sidedness, a zero fee for intermediaries might not in itself be sufficient to encourage adoption. A drawback of this approach is that it might be seen as unfair competition if CBDC is compared with other electronic means of payment instead of cash.

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[24] Large value payment systems and cash are examples of business models of payment systems provided by the central banks. In Canada, in the case of Lynx, the system charges participants a fee based on the volume of payments they process.

[25] Tan and Zhou (2021) show that in the presence of network effects, platform competition can increase prices. In Brazil, merchant discount fees charged by credit cards increased from 2.15% to 2.34% after the introduction of Pix.

Some fees for network

In this case the central bank has several options.

The first is for the central bank to charge a positive fee to one side (e.g., the merchant-side intermediaries) and a negative fee to the other side (e.g., the consumer-side intermediaries). Fees that are different from zero (or from the level consistent with cost recovery) could be justified if the objective is to cross-subsidize one side of the market to compensate for the positive network effect of joining the system.

This, however, might be difficult for the central bank to implement in practice, in part because the intermediaries facing the negative price might not pass on the benefits directly to consumers. Requirements to pass those benefits could imply regulatory powers that might not necessarily be in place. Coming up with a formula to determine the precise pass-through of benefits could also be complex.

The second option is to charge a positive fee to one side (typically the merchant-side intermediaries) while making it free for the other side (namely the consumer-side intermediaries). In this case, the price could be set based on the objective of covering the operational costs. One benefit of this model would be the simplicity of communicating with intermediaries. In Canada, Lynx is effectively run under this model. A drawback of this model would be that without the consumer-side incentives, intermediaries might not have incentives to encourage their customers to use CBDC. Lynx does not face the issue of end-user incentives because the participants in that system do not use this system to directly process client transactions. Examples of this model include Pix in Brazil, which does not charge access fees to its direct intermediaries, but only very low transaction fees to the receiving intermediaries (see Appendix A).

Note that we do not consider a situation in which the intermediaries arrange on their own a system of cross-subsidies because we reason that it is unlikely to emerge as an outcome. Networks solve the coordination problem. As a result, intermediaries could not negotiate many bilateral contracts or establish a scheme standard when it is not endorsed by the network operator (the central bank in this case).

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