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Dear readers,

The second issue of Sveriges Riksbank Economic Review in 2020 has a special theme, namely central bank digital currencies (CBDC) and the e-krona. Regular readers of the Economic Review may remember that there was a theme issue on the e-krona in 2018 which summarized some of the work that had been done then. The Riksbank has since continued to delve into various aspects of CBDC, both from an analytical and a practical perspective. Some of this work is summarized in this issue.

In more detail the articles are as follows:

- **The rationale for issuing e-krona in the digital era**

  Hanna Armelius, Gabriela Guibourg, Andrew T. Levin and *Gabriel Söderberg* describe the rationale for providing e-krona to the public through a partnership between the Riksbank and supervised private payments service providers. They discuss the challenges facing the Swedish monetary system and consider potential ways forward to ensure that the monetary system remains efficient in the future.

- **Is central bank currency fundamental to the monetary system?**

  Hanna Armelius, Carl Andreas Clausen and *Scott Hendry* discuss whether central bank money that is available to all is fundamentally important for the national monetary system, focusing on the need for convertibility between commercial bank money and publicly available central bank money. This issue is particularly important for countries like Sweden, where cash is becoming marginalized.

- **Competitive aspects of an e-krona**

  Mats Bergman evaluates whether the introduction of an e-krona can be justified on grounds related to market power and insufficient competition in the payment markets, today or in a future scenario where cash is absent. He considers in particular the rapid decline of cash use in Sweden; the strong network externalities that characterise the payment market and its associated tendency towards natural monopoly; and the risks for monopoly profits and inefficiencies if the payment market becomes entirely private.

- **The Riksbank's seigniorage and the e-krona**

  Peter Gustafsson and *Björn Lagerwall* discuss how the introduction of an e-krona could affect the Riksbank's ability to generate profits. They also address the question of how high the demand for an e-krona would have to be to cover the Riksbank's current expenses.

- **Central bank digital currencies, supply of bank loans and liquidity provision by central banks**

  Reimo Juks uses a theoretical model to analyze whether the issuance of a central bank digital currency (CBDC) can have adverse effects on the supply of bank loans and thereby macroeconomic activity. Among other things, he discusses banks' measures to deal with increased outflows, and how central banks can offset the potentially adverse effects of CBDC on the supply of bank loans.

- **E-krona design models: pros, cons and trade-offs**

  Hanna Armelius, Gabriela Guibourg, Stig Johansson and *Johan Schmalholz* discuss how the e-krona and the related payments infrastructure could be designed in order to fulfil

the Riksbank's mandate of promoting a safe and efficient payment system, as Sweden moves towards a cashless society. Using four different design models, they discuss possible trade-offs involved in the design of an e-krona, for instance weighing the advantages of more minimalistic approaches against performance as regards enhanced competition and resilience, and the amount of decentralization versus control over data and privacy.

Read and enjoy!

Marianne Nessén and Ulf Söderström

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The rationale for issuing e-krona in the digital era

Hanna Armelius, Gabriela Guibourg, Andrew T. Levin and Gabriel Söderberg*

Armelius, Guibourg and Söderberg work in the Payments Department at the Riksbank. Levin is Professor of Economics at Dartmouth College.

This article describes the rationale for providing e-krona to the public through a partnership between the Riksbank and supervised private payments service providers. This arrangement can foster competition and innovation while ensuring the fundamental security and efficiency of the monetary system. These considerations are increasingly relevant as the use of paper cash falls because commercial institutions may not have sufficient profit incentives to provide an alternative means of payment that is universally accessible. Moreover, in a digitalized economy, Big Tech firms and other multinational enterprises are increasingly likely to issue their own private currencies to facilitate their collection of valuable information about consumer behavior. Therefore, launching an e-krona would help ensure that all Swedish individuals have access to an efficient, convenient, and secure means of payment.

1 Introduction

Digitalization is rapidly changing the payment market in many countries around the globe, as new technology interacts with demographic shifts and changing consumer behavior. These changes are particularly relevant to Sweden. The usage of cash has fallen rapidly, leading to a situation in which many retailers no longer accept cash and some Swedish households who have difficulties using digital payments are worried about how they will be able to pay for ordinary purchases if cash disappears altogether.[1] In the past, cash has also functioned as a back-up alternative if the private electronic systems fail. The systems needed for service payment providers to offer payment services to end users are concentrated among a few key players. This is not unique for Sweden but is a general characteristic of payment markets around the world. What is special about the Swedish situation is that market concentration, in combination with the marginalization of cash, raises concerns not only about robustness and resilience but also about competition on the payment market. This latter question arises because cash no longer poses a competitive threat to the payment services offered by incumbents. Lastly, the marginalization of cash as a means of payment leaves Swedish citizens without access to money issued by the central bank, the safest form of money.

This paper suggests that a well-functioning and trustworthy means of payment should be viewed as a public good that warrants the ongoing direct involvement of the public sector. Firstly, the government has an intrinsic responsibility to maintain a stable store of value and unit of account that facilitates the decisions and plans of households and businesses. This

* We would like to thank Carl Andreas Claussen, Stig Johansson, Johan Molin, Björn Segendorf and Anders Vredin for their valuable comments. The views in this paper are the authors' views and should not be interpreted as the views of the Riksbank or its Executive Board.

1 The Riksbank has pointed to several possible negative consequences of an economy with no public access to central bank issued money. See Sveriges Riksbank (2017), (2018).

consideration provides the fundamental rationale for ensuring that the public has continuing access to money issued or fully backed by the government. Secondly, the government must ensure that the payment system is safe, efficient, and inclusive; that task is broadly similar to its responsibility for ensuring the effective provision of other basic utilities, such as clean water and reliable electric power. This will contribute towards protecting the role of the Swedish krona as a means of payment, store of value and unit of account in Sweden in the face of competition from private digital currency initiatives from Big Tech firms. Thirdly, as companies with a business strategy of commercializing user data emerge, individuals should have the possibility of paying using a public alternative that ensures that the data generated by their purchases is not stored and commercialized. It is the role of the government to protect personal integrity in a democratic society.

In this paper, we highlight the challenges facing the Swedish monetary system and we consider potential ways forward to ensure its efficiency in the future. Sweden is a small, open, and highly digitalized economy with its own national currency that is not commonly used in international trade. Consequently, the Swedish krona may be particularly vulnerable to the advent of currencies such as stablecoins issued by private multinational enterprises (as argued by, for instance, Brunnermeier et al., 2019). While the precise evolution of stablecoins and other forms of privately issued digital currencies remains uncertain, this development provides a compelling rationale for Sweden to minimize the risk to consumers and businesses choosing to switch from the Swedish krona to some other currency. The Riksbank can do so by ensuring that the Swedish monetary system continues to be efficient. We argue that this would be facilitated if the Riksbank were to adopt digital technology in the provision of money by introducing an e-krona. Ultimately, the decision to grant or refuse the Riksbank the mandate to do so will be taken by the Swedish Parliament.

The paper is organized as follows. Section 2 examines the characteristics of Sweden's current monetary system. Section 3 highlights the challenges posed by rapid digitalization. Section 4 considers alternative approaches to addressing those challenges. Section 5 concludes.

2 The current Swedish monetary system

The use of money is at the core of every market economy. Without money, people would have to revert to barter, that is, direct bilateral exchanges of goods or services. Barter relies on a double coincidence of wants in which person A wants to acquire what person B wants to sell and vice versa, and such coincidences are practically impossible in a complex and dynamic economy. By contrast, a form of money that is widely accepted can serve as a medium of exchange that facilitates efficient economic and financial transactions. We refer to the framework that ensures services of money to the public as a monetary system.

This section considers the key characteristics of Sweden's current monetary system, reviews some of the factors that have contributed to its evolution over time, and highlights several fundamental reasons why money, as a public good, warrants the ongoing involvement of the public sector.[2]

2.1 Fostering a stable store of value and unit of account[3]

The most fundamental role of publicly issued money is to provide a stable store of value and unit of account that facilitates the economic and financial decisions of households

2 Using formal economic terminology, public goods are defined as non-exclusive and non-rival, that is, the good is broadly accessible to individuals and businesses, each of whom can derive benefit from that good without reducing the benefits obtained by anyone else. Standard textbooks discuss national defense and radio broadcasting as examples of public goods.

3 Usually, the three functions of money are means of payment, store of value and unit of account. In the following we mainly focus on the two latter and simply assume that money can always function as a means of payment if the two latter functions are fulfilled.

and businesses. In particular, the prices that consumers pay for a representative basket of goods and services should be reasonably stable over time. Large and persistent swings in the value of money (that is, in the general price level) are particularly disruptive for ordinary households and small businesses. After all, wealthy individuals can simply hire a portfolio manager to help insulate their assets from inflation, whereas ordinary households cannot afford to hire a financial planner on an ongoing basis. Likewise, the chief financial officer of a large corporation can utilize sophisticated contracts and financial securities, whereas a small company may be overwhelmed in the face of high or volatile inflation. Price stability is therefore a public good that contributes to broad-based prosperity and efficiency in a market economy.

Thus, in a democratic society like Sweden, there is a strong rationale for assigning responsibility for price stability to a specific agency—namely, the central bank—that is transparent and accountable to elected officials and the general public. In particular, since appropriate monetary policy is essential for fostering price stability, the monetary policymaking process must be effective in serving the public interest rather than the special interests of any particular business or consortium or political interest group.

The framework for fostering price stability has changed over the past century or so. Prior to the modern era, the value of publicly issued money was typically defined in terms of a specific commodity (such as gold or silver), and hence its value could be established by a legal edict. In effect, the central bank would guarantee the value of its notes and coins in terms of a specific quantity of that commodity. The onset of the Great Depression in the 1930s clearly indicated that such a framework was too rigid and not adequate for ensuring a functioning modern economy.[4] Sweden subsequently experimented with other monetary arrangements, each of which ultimately proved unsatisfactory. Since the 1990s, the Riksbank – like many other central banks – has maintained a framework of inflation targeting.[5]

2.2 The central bank's role as lender of last resort

Another important function provided by the public sector, most often through the central bank, is to serve as a lender of last resort (LOLR). In particular, the central bank can expand the supply of publicly issued money and extend short-term credit to commercial banks, enabling those banks to satisfy a temporary liquidity shortfall rather than being forced to liquidate loans or other assets. By fulfilling this role, the central bank can mitigate the economic impact of financial strains and foster the stability of the banking system as well as the broader economy.

The LOLR function was historically not a function of central banks, but the growing role of central banks in the emerging financial system of the 19th century meant that only they could guarantee liquidity in times of financial crisis. The Bank of England thus acted as LOLR as a direct emergency action in the 1866 Guernsey crisis, which led to a seminal analysis by Walter Bagehot, published in 1873, which formulated the classic doctrine of LOLR. Experiences of recurring financial crises in the United States, which did not at the time have a central bank, led directly to the establishment of the Federal Reserve in 1914 (Irwin, 2014). While the function of LOLR has retained its primary nature since Bagehot, and was carried out by central banks as late as during the recent global financial crisis of 2007-2008, central banks have been forced to apply it in new ways to fit new circumstances. Most notably,

4 For more on this, see, for instance, Eichengreen (1996).

5 After World War II, an international framework – the 'Bretton Woods system' – used a system of fixed exchange rates, in which national currencies were pegged against the US dollar. This was an attempt to manage the tradeoff between stability and flexibility. From the mid-1940s until the early 1970s, Sweden's monetary arrangements were thus determined by the Bretton Woods system and the value of the krona was pegged to the US dollar, but that system collapsed in the early 1970s. In the following decades, the value of the krona was pegged to a basket of foreign currencies, but with several devaluations. During the European exchange rate crisis in the early 1990s that arrangement also proved unsustainable, and the peg was abandoned in November 1992.

increased globalization meant that European banks had large exposures in dollars, which in turn meant that European central banks had to acquire dollars from the Federal Reserve in order to be able to carry out LOLR in Europe. Central banks also broadened the set of allowed collateral that could be used to borrow liquidity (see Molin, 2009, and Larsson and Söderberg, 2017).

2.3 Providing a secure means of payment and settlement system

Central banks are involved in the payment market in several ways. Firstly, they produce notes and coins for the public. Historically, most central banks were given a monopoly on note-issuing during the 19th century.[6] In general, the reason for the government becoming directly involved in the payment market has been to mitigate perceived problems in the monetary system (Söderberg, 2018). For instance, the private notes, issued by around 1,500 different banks, in circulation in the United States during the 19th century failed to provide a working unit of account for the country since the notes did not have the same value. This led to documented inefficiencies (Gorton, 2012).

When the American monetary system was overhauled in 1863-1864, during the Civil War, the government took the precaution of creating a public standard that ensured that all notes had the same value. Even so, note production was deemed too inflexible, and when the Federal Reserve was created in 1914, it gradually took over note production from private banks. Similarly, in Sweden, a long government process led to a decision to give the Riksbank a banknote monopoly in 1897. One important reason was that it was deemed that notes had to be completely risk-free and that their issuance should not depend on profit motives. There was no pressing problem that prompted the decision, but the committee delivering the proposal found it imperative that steps were taken to ensure a suitably efficient monetary system to meet the society that was emerging at that time (Söderberg, 2018).

Secondly, central banks facilitate payments between banks and are thus a hub for digital payments. To do this, they issue digital central bank money that is held by financial institutions in accounts in the central banks' Real Time Gross Settlement systems (RTGS systems). The origins of the RTGS systems can be traced back to the creation of the American Federal Reserve's FedWire in 1918, which was computerized in the early 1970s. Electronic RTGS systems then spread rapidly among central banks in the 1980s. The Swedish RTGS system, RIX, was created in 1986 (Bech and Hobijn, 2007). The purpose of these systems is to increase efficiency and safety for digital payments between banks and to facilitate the implementation of monetary policy used to safeguard a stable unit of account (CPMI/IOSCO, 2012). The main reason why central banks provide the central payment system is to help banks to settle payments using their accounts at the central bank, i.e. central bank money, thus abolishing the credit risks that could arise if they instead used commercial bank money. As the central bank system also offers intraday loans to the banks against collateral if they face temporary liquidity shortages, liquidity risks in settlement are also removed.

In line with the above, the Riksbank supplies the general public with money in the form of cash, and banks with money in the form of bank reserves held at the Riksbank, as well as the interbank payment settlement system RIX. Lately, the Riksbank has also supplied money to a designated account in a private settlement system for instant payments made using the mobile phone application Swish. Bank reserves are used to settle payments between the banks in the RIX system. Reserves are also a monetary policy tool, since the main policy rate, the repo rate, is the benchmark for the interest rate paid by the Riksbank on reserves.

Most money in the economy is, however, commercial bank money that is created when private banks extend loans. Only two per cent of the money used for payments in Sweden is cash, the only form of central bank money available to the general public today. The rest

6 There are a few exceptions, for instance Scottish private banks, which are allowed to issue their own notes but under strict restrictions.

consists of demand deposits at monetary financial institutions – typically commercial banks – and at the Swedish National Debt Office. We call these deposits commercial bank money. There is free convertibility between commercial bank money and cash.

In effect, this means that there are mainly three forms of money denominated in krona in the Swedish monetary system: central bank money in physical form (cash), central bank money in digital form (reserves), and private money in digital form (deposits). All three forms of money (cash, bank reserves and commercial bank money) always trade at par value. The Riksbank directly issues the two former, and facilitates payments in the third.

2.4 Tools for maintaining financial stability

As noted above, payments cannot be separated from the issuance of loans – most money in the economy is created through private banks issuing loans, and credit institutions are involved in payments and offer bank accounts to the public. This means that financial stability is a prerequisite for a well-functioning monetary system. Apart from the LOLR function carried out by central banks, governments also have a number of other mechanisms in place to increase financial stability. The two main forms are the various regulations governing the conduct of financial entities and deposit insurance guarantees, which mean that commercial bank money is guaranteed if the bank goes into bankruptcy. In Sweden, following the EU standard, the government promises to protect deposits in private financial institutions in an amount of up to SEK 950,000 per institution.

Both regulations and deposit guarantees have been developed incrementally, usually in the face of financial unrest. Financial regulations did exist in an early form in the 19th century, requiring, for instance, that a bank had a certain amount of capital. As the financial system grew there was increased pressure to increase regulation. In Sweden regulations were tightened in 1903 and 1911. A financial crisis following World War I increased pressure to strengthen regulations, but the momentum fizzled out and only marginal changes were made (Larsson and Söderberg, 2017). Instead, it was the financial crisis of 1929 and the subsequent Great Depression that provided the momentum for the large-scale introduction of regulation, beginning in the United States but also occurring in Sweden. In the United States, this led to the creation of the deposit insurance guarantee (Gorton, 2012).

Some of these regulations were removed in the 1980s and 1990s. In Sweden, a quickly deregulated financial market, together with other factors, led to the financial crisis of 1991. This crisis in turn led to the direct creation of a deposit insurance guarantee in Sweden. After the global financial crisis of 2007-2008, regulations were further tightened , both nationally in most countries (such as the Dodd-Frank Act in the United States) and internationally in the form of the global minimum standard known as Basel III. In the European Union, this also entailed a buildup of the deposit insurance guarantee, as the limit was raised to its present level of EUR 100,000 or SEK 950,000. In addition, a new framework of resolution was added, which means that the government can take over failing banks that are large enough to be deemed to have a systemic effect, to ensure that they can keep operating.[7]

To sum up, the present monetary system is the result of continuous attempts made to mitigate problems as they have arisen. The system has therefore evolved incrementally, and the approach has been one of using several different tools rather than relying on a single one to achieve the desired outcome.

7 For more information, see Swedish National Debt Office (2019).

3 Challenges in the digital era

Taken all together, the initiatives of the private market and the control and stability functions developed by the public sector have worked to maintain stability and efficiency of the Swedish monetary system. The question is whether stability and efficiency can be guaranteed in the digital era without additional measures. In this section, we will point to shortcomings that are already apparent and some other developments that could become problematic in the near future if action is not taken.

The digitalization of society in Sweden, through the low use of cash, has led to a lack of access to central bank money by the general public and in particular among certain groups that do not have digital access. Universal access to basic payment services needs to be fully guaranteed. Another risk that is becoming increasingly apparent is the concentration of a large share of payment services in a few large global companies that can create risks and vulnerabilities for countries and regions, create barriers to entry, and stifle innovation.[8]

There is also a risk that the Swedish payment system will become more vulnerable to disruptions. One such risk comes from the fact that the cross-border payment infrastructure has not kept pace with technological innovations present elsewhere and that services provided by the traditional systems have not been satisfactory. These shortcomings have left a gap that Big Tech companies, as indicated recently by Facebook's Libra initiative, can utilize and which could lead to potential risks to the international monetary system. If Big Tech companies will become dominant on the payment market there are a number of new potential risks. These risks were not explicitly analyzed in the e-krona reports published by the Riksbank (Sveriges Riksbank, 2017 and 2018). This section will therefore devote comparatively more space to these particular risks. Readers who want to know more about the other risks mentioned here are referred to the Riksbank's earlier publications.

3.1 Ensuring a competitive payment market

The payment market exhibits what economists call network effects: one individual's consumption of a good gives benefits not only to the person who is consuming but also to other individuals. There is no point in acquiring a card or a mobile application for payments if very few people are willing to accept this instrument as a means of payment. A merchant will not be willing to invest in the technology used to accept such a card or mobile application if the number of customers wanting to use it is not large enough. The existence of network effects in payment thus tends to create market concentration. Often, a few private firms dominate the domestic payment market and, in some instances, even the global payment market, e.g. Visa and MasterCard or Alipay and WeChat.[9] This means that, in the future, the payment market might become very concentrated even at a global level, which could create two problems. The first is that incentives for further innovation are stifled. The already established firms have little incentive to improve their services since they already dominate the market. New firms, on the other hand, will suffer from high barriers of entry because of the network effects. Secondly, we cannot be certain that the dominant firms will not charge unjustifiably high fees for their payments service for both end users and merchants.

3.2 Resilience and crisis preparedness

The crucial role of payments in society means that the question of resilience in payments is important. If cash is no longer used, payments will be totally dependent on functioning electricity supplies, network connections, and software that handles payments. Disruptions to any of these can be expected in crisis situations, but also in normal times, for instance

8 See Bergman (2020) for an extensive discussion of the competitive aspects of the e-krona.

9 Beside its central role for card payments in Sweden, MasterCard has acquired parts of the Danish and Norwegian automated clearing houses.

because of cyber attacks. On the other hand, cash usage in modern economies is usually also dependent on electricity as cash registers and ATM machines run on electricity. The network effects mentioned above also tend to increase vulnerability as payments are increasingly carried out through a few large operators. This means that the social consequences can be large even if only one of these operators is affected by problems. Such vulnerabilities can be mitigated, for instance through ensuring that there is a larger variety of means of payments, ensuring a robust supply of electricity and electronic communications, and having extensive back-up functions in readiness, should the need for them arise. It is ultimately the role of the government to ensure that the payment market has sufficient resilience, which motivates a crucial role for the central bank in the payment market.

3.3 A payment system and money that work for all individuals in society

Paying with digital money requires access to technology and knowledge of how to use that technology. Even paying with a card usually requires the management of accounts through a computer or smartphone. Certain groups in society, such as the elderly but also groups with different forms of disability, find it hard to pay with digital forms of payment. These groups are already experiencing problems in making payments, since not all shops, restaurants and cafés accept cash, and their problems might increase in the future. A payment market dominated by private firms could theoretically also develop digital payment forms that are suitable for these groups, for instance solutions that are very easy and cheap to use. But the fundamental problem is that these groups have very different needs, and that it might not be profitable for private firms with a large market share to develop forms of payment for all of them. The digital era might therefore mean a form of financial exclusion for certain groups.[10]

3.4 Big Tech firms and stablecoins could change the landscape

A longer-term trend is the entrance of large IT companies, such as Google, Apple and Facebook, into the payment market. As a consequence of network effects, the market player that wins the critical mass of users often captures a very large share of the market. These companies already have large, well-established networks of customers, often on social media platforms, which can give them a competitive edge. There may also be a strong link between social media and the possibility of being able to pay friends in the network, which may lead to very rapid growth in IT company payment applications. This has happened in countries such as China with the Wechat and Alipay applications. Other examples include Apple Pay, Google Pay, Facebook Pay and Samsung Pay.

In June 2019, Facebook announced its plans to launch its own cryptocurrency called Libra in cooperation with a number of other companies.[11] The Libra is a so-called 'stablecoin' which means that its value should not fluctuate like it does for many cryptocurrencies such as Bitcoin. In order to achieve this the intention is to link the Libra to a basket of currencies such as the dollar, euro and yen. This means that Facebook and other companies would supply payment services that do not use Swedish kronor (SEK), which could have consequences for Sweden if Libra becomes popular.[12] It is already possible, in certain countries, to have a payment card that is linked to a cryptocurrency. When the card is used, the cryptocurrency is exchanged for the relevant national currency and the payment is made through the traditional card system. This is an example of how switching costs are lower

10 In Sweden, the County Administrative Boards and the Post and Telecommunications Authority have responsibility for the public's access to general basic payment services.

11 For more on Libra ee Segendorf et al. (2019).

12 The same reasoning applies also if some of the world's leading central banks together decided to issue a global central bank currency, as suggested by Carney (2019). Although that currency might be better managed and would be backed by sovereign states, it could still threaten the monetary independence of Sweden.

in the digital world. Another example is that, for online shopping, changing prices into a different currency is a lot easier than in a physical store where goods are priced with stickers.

A successful penetration of Sweden by a multinational digital currency would pose a fundamental challenge to the Swedish monetary system. Consider a scenario in which the bulk of payments and financial transactions in Sweden are conducted using the digital currency of a multinational private enterprise. Such a currency might be referred to as a 'stablecoin', but its value would presumably be linked to major global currencies and not the Swedish krona. That means that Sweden would lose the ability to adjust monetary policy to domestic conditions. Historically, the exchange rate of the krona has helped serve as a cushion during times of negative macroeconomic shocks. In contrast, the stablecoin's exchange rate would be adjusted to the prevailing conditions in the countries whose currencies are in the basket.

In effect, in such a scenario, Sweden would no longer have a stable unit of account. Swedish prices and wages would be denominated in terms of the privately issued stablecoin. The pitfalls of such a system are evident from Sweden's historical experience as recounted above, and would, in effect, make the Riksbank lose control over monetary policy.

Given such adverse consequences, one might wonder why Swedish residents would ever concede to using a privately issued stablecoin instead of the krona. To address that question, we need to return to the issue raised above: namely, the fact that payment systems exhibit strong network externalities. In particular, the benefits of joining a network are magnified by the extent to which other consumers and businesses also participate in that network. And the term 'externality' means that each individual's decisions reflect the direct benefits which accrue to that individual but not the indirect consequences that could transpire if a large number of individuals were to make that same decision. Moreover, the benefits of the decision might be fairly immediate, whereas the consequences might not be apparent for some time. Furthermore, private payment companies may decide to offer services that are cheap or even subsidized since they also benefit from gaining access to consumer data, in addition to their payment services. This could give them a competitive advantage.

The relevance for Sweden's monetary system is quite clear. If the existing payment network is not very convenient or efficient, there could be a window of opportunity for some multinational enterprise to establish a more convenient and efficient network using its own privately issued stablecoin. That enterprise could offer various forms of discounts and coupons to incentivize the participation of Swedish consumers and retailers. As the size of the network expanded, other consumers and retailers would have increasingly strong incentives to join it, and hence the network could become ubiquitous quite rapidly. With prices and wages being specified in terms of the stablecoin, consumers and retailers would also shift their financial holdings into stablecoin-denominated assets, and banking institutions would hold reserves denominated in stablecoin.

Stablecoins could also challenge the role of the central bank as a lender of last resort (LOLR). This role hinges on the central bank's ability to issue the same currency as the liquidity needs of the commercial banks. If commercial banks were to have large liabilities denominated in privately issued stablecoins, then the Riksbank could not create currency to lend to them in times of illiquidity.[13] Thus, if a privately issued stablecoin came into general use in Sweden, Sveriges Riksbank would no longer be able to serve as LOLR; rather, the multinational enterprise would need to serve that function, and any failure to do so could become a major threat to Sweden's economic and financial stability.[14]

13 A stablecoin is both 'money' and a financial infrastructure/payment system. The latter implies that the account structure, or register, on which stablecoin transactions are settled is outside of the central bank.

14 There is an interesting historical antecedent in the experiences of the Bank of Amsterdam (1609-1820). As explained by Frost et al. (2020), modern stablecoins would have difficulties fulfilling some important functions such as supplying liquidity for settlement and LOLR.

3.5 Loss of privacy

Apart from the possibility of losing the national unit of account, the rapid entrance of Big Tech firms onto the payment market also entails other possible problems. Since these companies have a business model that consists of collecting and selling consumer data, consumer privacy and integrity could potentially suffer. In countries like China, it has become evident that these types of companies can gain a large market share very rapidly. The interconnectedness between social media usage and payments opens up opportunities to use payment data for marketing purposes. And since marketing is generally more lucrative for these firms than payment service provision, there are strong incentives for firms to subsidize payment services to gain access to valuable data. We already see a few global Big Tech firms with a business model of collecting data dominating completely in other realms in our personal life. It is the role of the public sector to ensure that consumers in the future still have other options available to them when it comes to personal payments.

4 Potential approaches

The risks highlighted in this paper have their roots in changes in technology. It is likely that attempts to mitigate the risks will entail some form of changes to the monetary system – in other words the monetary system needs to be updated in the face of new challenges. We can think of two main alternatives:

- A regulatory update that takes into account the specific risks raised by the ongoing changes.
- Provision of central bank issued digital money accessible to all, i.e. an e-krona.

We would like to stress that these measures can be seen as complements rather than substitutes. According to economic theory, it can be optimal, in the face of uncertainty, to use many tools to achieve one target (see for instance Brainard, 1967). In the following, we will briefly discuss the advantages and disadvantages of these two approaches.

4.1 A modernized regulatory system

As described in section 2, regulations have been and continue to be a vital part of the financial and monetary system. Regulations have been updated intermittently. Most often, these intermittent changes have been motivated by financial turmoil, and in order to reduce risks in the financial system. The most recent example are the regulations enacted in many countries, including Sweden, after the financial crisis in 2007-2008. Though there are national differences in the resulting regulations, an international minimum standard for banking regulations under the name of Basel III was also created.

Regulatory changes can also be a way to reduce the risks associated with the ongoing changes in the monetary system. For instance, in November 2019, new legislation was passed in Sweden that makes it mandatory for larger banks to supply a minimum of cash services across the country. It is theoretically possible that regulations could address at least some of the problems that have been identified in this paper. For instance, in order to increase the robustness of the system, regulations could make it mandatory for actors on the payment market to devote more resources to building back-up functions. Similarly, each of the problems identified in this paper could hypothetically be addressed by regulations. There are, however, a number of challenges to this approach.

The first challenge when it comes to regulation is the *design issue*. Once the problems that the regulations are intended to mitigate have been identified, the regulations must be designed in a way that achieve the goal as efficiently as possible. However, there is a fundamental information problem here, which makes it difficult to design regulations perfectly. One issue has to do with *unintended consequences of regulation* that are difficult to predict when regulation is designed. For instance, higher regulatory demands on firms,

which entail higher costs of compliance, might lead to barriers of entrance to new firms on the market. In this example, reduced competition is not the intention, but it is a side-effect of the means chosen to achieve another goal. Additionally, it cannot be guaranteed that the regulations will achieve the goals they are intended to achieve. The G20 countries' joint Financial Stability Board has therefore initiated a continual monitoring on the effectiveness of the post-crisis regulations and of any unintended consequences (FSB, 2019).

The second challenge is that all regulation entails some form of *monitoring* to ensure that the regulated firms comply with the requirements. Such monitoring is costly, for instance in terms of work spent by supervisors. However, the regulated firms also have to spend person-hours on ensuring that they comply with regulations – on top of other potential costs of the regulation. Increased regulation therefore shifts resources away from more productive activities to monitoring.

The third challenge is inherent in the process of creating regulation. It is a slow political process, not least in order to make a satisfactory analysis of the possible consequences of regulation. Regulatory change, in other words, can and should not be carried out often – if it is being changed too often, it also undermines confidence in its consistency which confuses market actors. This means that regulations are *inflexible* when circumstances change. Sometimes this inflexibility itself has consequences for the effectiveness of the regulations. Market actors can, for instance, find ways of circumventing regulations, reducing their effectiveness further. A key example here is the emergence of 'shadow banking', i.e. innovative financial practices that could circumvent existing financial regulation. It was in that sector that many of the problems behind the global financial crisis of 2007–2008 were created. As market players change their behavior, regulations tend to lag and updating them takes considerable time and analytical effort.

In sum, regulations are important but they are slow to adapt to change, and they have problems in the form of potential unintended consequences and costs of monitoring.

4.2 Implementation of an e-krona

The second main alternative is to ensure that the public has access to central bank issued digital money, i.e. an e-krona. As mentioned above, central bank money already exists in digital form in Sweden in the form of bank reserves. It was previously also possible for the Swedish public to have electronic government deposits with the National Debt Office, and the public can at least temporarily, pending payment to their bank accounts, hold government money in digital form in their tax accounts. But an e-krona would not only entail the possibility to hold government digital money but also to pay with it. An e-krona would thus be a new feature of the monetary system.

Just like in the case of regulation, the *design* issue is crucial in minimizing the risk of *unintended consequences*. Design is also about efficiency: how do we ensure that the goals that we want to attain are reached as efficiently as possible? An e-krona, just like regulation, would then need to have specific goals followed by a deep analysis on how to design the e-krona to attain these goals. For instance, if increased resilience is the main goal, it might become necessary to design the e-krona as a separate infrastructure from today's digital payments infrastructure. Likewise, if it is available for all, then it will have to be designed to be easy to use. The desired level of anonymity, which in effect would be a tradeoff between integrity and the risk of malicious use, would also have to be decided on, and then brought about with a suitable design.[15]

In contemplating these design issues, a key consideration is that digital technology is evolving rapidly, posing the risk that the payment system will reach a 'tipping point' that becomes practically irreversible. One implication is that a protracted process for perfecting

15 For more on the question of design see Armelius et al. (2020).

the e-krona prior to launch could turn out to be futile, and hence it might be sensible to develop and launch the e-krona on a more expedited time frame, followed by an ongoing process of improvements and refinements thereafter. As mentioned above, the ultimate decision to give the Riksbank permission to do so rests with the Swedish Parliament.

The rapidly evolving digital world is also highly relevant for the process of regulating private forms of money. Such regulations necessarily involve tradeoffs between specificity and flexibility. Specific regulations can help protect the public interest but may require frequent revision to reflect changes in technology, facilitate transparency and efficiency, and ensure broad compliance by regulated firms. Indeed, these issues are likely to be acute in the context of overseeing huge multinational enterprises and global payment networks. Such revision takes considerable time and, by the time the revisions are ready to be implemented, there is considerable risk that they will no longer be adequate for the situation for which they were devised. A direct government presence in the payment market in the future, through an e-krona, could therefore potentially be a *more adaptable* instrument than regulation, or a good complement to regulation, to handle ongoing changes.

These considerations underscore the rationale for a two-pronged strategy of regulating private payments and launching the e-krona. By issuing a public form of digital money, the central bank will maintain a direct presence in the payments system and facilitate the effectiveness of its regulatory framework for private payments.

4.2.1 An e-krona does not necessarily exclude the private sector

It is important to note that public provisioning of an e-krona can still entail the participation of the private sector. An e-krona could, for instance be supplied through a public-private partnership, so that the government supplies the critical infrastructure while the private market can compete at the customer level. This would be one way of achieving the best of both worlds. The government would retain control and ownership over a critical infrastructure, while innovation and competition would be stimulated through free access to the platform. It would be similar to the model for supplying physical cash to the public that has worked well before – where the public accesses cash indirectly through the banking system.

There are potential precedents for such an arrangement. Since the 1990s, there has been a general tendency towards privatization in society, whereas government monopolies were more common prior to that. In Sweden, rail tracks and high-voltage transmissions are, for example, still owned by the government, while many of the electricity distribution networks, as well as critical parts of the telecom network, are privately owned (Bergman, 2020). In the latter case, the public sector is still very much involved with detailed regulation of price as well as quality.

Public-private partnerships, like the one in the Swedish electricity distribution, combine government ownership in one part of the distribution chain with private ownership in another.[16] Indeed this is the solution chosen for cash handling and distribution in Sweden and many other countries where the central bank has the wholesale responsibility while the private sector handles the retail side.

4.2.2 International cooperation for improved cross-currency payments

Some Big Tech initiatives in the payment market have had cross-border payments as one of their main objectives, in particular Facebook's Libra initiative. This has increased focus on current deficiencies in the traditional systems. Central banks around the world have initiated different work streams on so-called Central Bank Issued Digital Currencies (CBDC), of which an e-krona would be an example, to try to address those deficiencies in collaboration with each other. One example is the CBDC coalition created by the Bank of Canada, the Bank of

16 See Bergman (2020) for a more elaborate discussion.

England, the Bank of Japan, the European Central Bank, Sveriges Riksbank and the Swiss National Bank, together with the Bank for International Settlements (BIS).[17] The group will assess potential areas where a CBDC could make a useful contribution economic, functional and technical design choices, including cross-border interoperability; and the sharing of knowledge on emerging technologies.

If CBDCs can contribute to making international payments more efficient and affordable, that would contribute to minimizing the risk that some form of private cryptocurrency or stablecoin would gain a large share of the domestic payment market. It is therefore important that central banks cooperate in setting standards and so on, so that cross-currency payments are facilitated by the introduction of CBDC.

5 Conclusions

In this paper, we have argued that a well-functioning and trustworthy means of payment should be viewed as a public good that warrants the ongoing direct involvement of the public sector. We have stressed that the current monetary system is the result of incremental change, as policymakers in the past have acted to fulfill the fundamental government responsibility of ensuring an efficient monetary system. Currently, there are a number of potential risks facing the Swedish monetary system. As before, it is the role of the government to ensure that the system is sufficiently safe, inclusive and efficient and, ultimately, that trust in the monetary system is maintained. This will contribute towards protecting the role of the Swedish krona as the store of value and unit of account in the face of competition from private digital currency initiatives from Big Tech firms. Furthermore, it will give individuals the possibility to pay using a public alternative that ensures that the data generated by their purchases is not stored and commercialized.

We have also discussed the main potential policies through which the government can continue to fulfill the role of maintaining an efficient and robust monetary system that is accessible to all in the face of changing technology: regulatory updates and continued public money provision to the public, i.e. issuing an e-krona. Both have advantages and disadvantages, and the question of design is crucial to both.

Given the analysis of the current monetary system, our conclusion is that an important explanation for its durability is that it has relied on several different policies rather than just one. This would suggest that the best course of action is, again, to rely on more than one policy. Our main conclusion is that a suitably designed e-krona, provided to the public through a partnership between the central bank and supervised private payments service providers, could be an important tool, in combination with updated regulation, for the Swedish government to ensure an efficient Swedish monetary system in the future.

17 The Federal Reserve has now also joined the coalition.

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Is central bank currency fundamental to the monetary system?

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In this article, we discuss whether the ability of individuals to convert commercial bank money (i.e., bank deposits) into central bank money is fundamentally important for the monetary system. This is a significant question since the use of cash – the only form of central bank money that the public currently has access to – is declining rapidly in many countries. The question is highly relevant to the discussion around whether central banks need to issue a retail central bank digital currency (CBDC). We conclude that depositors' need for control could be a reason why cash or a CBDC is essential, even in countries with strong measures safeguarding commercial bank money.

'. . . you need as much public money as needed to anchor the trust in the currency.'
Cœuré (2019)

1 Introduction

Cash is often considered fundamental to the national monetary system. For instance, some theories of money suggest that a monetary system needs cash or some form of 'outside money'. Similarly, many authors assume that convertibility into cash – that is, the fact that you can convert your bank deposits into cash whenever you want – underlies both the store of value function and the acceptability of commercial bank money.[1] The convertibility function also allows one form of money to replicate the store of value and unit of account properties of another and therefore supports the 'uniformity of money'.[2]

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1 Money comes in different varieties. The most common are 'central bank money' and 'commercial bank money.' Central bank money is money issued by the central bank. It is a liability of the central bank and typically takes the form of physical cash and reserves. Anyone can hold cash, while mainly banks can hold reserves. In the future, the general public may also hold balances at the central bank. We follow standard terminology and call such balances, including electronically tokenized balances, retail central bank digital currencies (CBDC). Commercial bank money is money issued by commercial banks. It is a liability of a bank, and nowadays it takes the form of balances held at commercial banks, i.e., commercial bank deposits. Throughout the article, we use the terms 'deposits' and 'commercial bank money' interchangeably. Inside money is issued from inside the private financial sector by intermediaries in the form of a debt or liability (e.g. demand deposits at commercial banks). Conversely, outside money is a money which is not a liability of a private sector entity (e.g. central bank cash and settlement balances, gold and silver coins).

2 See, e.g., Andolfatto (2009, p. 14), who writes that 'the demandability clause makes bank money more widely acceptable as a means of payment.' Brunnermeier et al. (2019) presuppose that the safety of private money that is convertible into cash (or CBDC) is independent of the issuer. Brainard (2019, p. 3) writes, 'Commercial bank money […] is widely used in part because people are confident that they can convert it on demand to the liability of another commercial bank or the central bank, such as physical cash.'

However, the use of cash is declining in many countries, and cash is on the verge of becoming marginalized in Norway and Sweden. If this development continues, the general public will no longer have access to central bank money.

In this article, we discuss whether central bank money that is available to all – for instance, cash – is fundamentally important for the national monetary system. Our focus is mostly on the need for convertibility between commercial bank money and publicly available central bank money. The question is very important for countries where cash is becoming marginalized. If convertibility is fundamental and physical cash is disappearing, central banks might have to issue a modern electronic version of cash – a central bank digital currency (CBDC).[3]

Our discussion proceeds in three steps.

We start by looking at what the literature has to say about the issue. Essentially, this literature suggests the government has to take measures to ensure that money is safe and trustworthy. However, these studies do not say that the government (or the central bank) necessarily has to issue its own money but suggest that it can just as easily strengthen measures that safeguard privately issued money.

In the second step, we therefore look at the measures that countries have put in place to protect – and to signal the intent of protecting – commercial bank money. Many countries have instituted such measures and have proven willing to protect deposits and the payment system in times of crisis. In those countries, commercial bank money is safe – at least up to the amount of the deposit insurance.

In the third step, we look for other reasons why cash or a CBDC can be fundamental to the monetary system. We introduce a (novel) mechanism that may make cash or a CBDC fundamental even if commercial bank money is safe: people who do not trust commercial bank money may still choose to hold it as long as they can easily convert it into central bank money. This mechanism finds support in the psychology literature, where it has been documented that people are more willing to take risk if they feel they are in control. This mechanism may also offset some of the bank-run risk that many associate with a CBDC.

In order to avoid misunderstandings, we would like to emphasize what we do not analyze in this article:

- We do not analyze whether cash or a CBDC is needed to promote resilience and competition in the payment market.
- We do not evaluate whether central banks are necessary. We are only looking at the implications of lack of general public access to central bank money. We assume that commercial banks can still hold reserves at the central bank. Thus, our analysis differs from the literature on completely private monetary systems.
- We do not analyze the physical aspect of cash.
- We do not discuss currency competition. Our focus is on monetary systems based on commercial bank money denominated in the same currency.
- We do not analyze whether a system with deposit insurance and implicit guarantees to the banking system is better than systems that have no need for deposit insurance, for instance, the Chicago plan.

We have structured the article as follows. In Section 2, we look at what the literature has to say about our questions. In Section 3, we look at instituted measures that protect commercial bank money. In Section 4, we discuss reasons beyond safeguarding commercial bank money for why public access to central bank money might be fundamental. We summarize and conclude in Section 5.

3 In another article in this issue of the economic review, Armelius et al. (2000) propose other reasons why a CBDC may be needed.

2 The literature

In this section, we focus on studies that formulate and test theories about money in formal models. Economic theory provides many models of money, but only some are useful for the analysis of our questions. Also empirical studies would be useful for our purposes, but unfortunately we are not aware of any empirical literature that casts light on our questions.

Within the New Keynesian class of models, money sometimes enters directly as an argument in the utility function. We often call these 'money-in-the-utility-function models' (see, e.g., Walsh 2010). These models are useful for studying monetary policy and other macroeconomic issues, but they are not useful for our question. This is because they do not distinguish between private and central bank money and they assume that money is accepted and used.

A somewhat older class of models uses a 'cash-in-advance constraint' (see, e.g., Lucas and Stokey 1987). These models have two forms of money: cash and credit. A key assumption in the models is that agents need cash to buy certain goods. Thus, the public needs access to cash by assumption. However, these models also simply assume that agents trust and accept both forms of money.

The models that are useful with regard to our question are instead those that endogenously explain why a specific form of money is accepted and used. These are typically models where money is essential in the sense that it helps overcome some friction so that higher welfare can be achieved with a specific form of money than without. A common label for models with these features is 'monetarist models' (see, e.g., Williamson and Wright 2010, Lagos, Rocheteau and Wright 2017).

These models point to two reasons why central banks may need to give the general public access to central bank money – that is, why they need to issue cash or a CBDC. Both reasons involve a lack of trust in private money:

1. Private credit, which can work as money, comes with credit risk. If this risk were too high, private credit would not work as money and the government would have to step in and offer safe money.
2. Private issuers of money may have incentives to issue more money than needed. This could create inflation that undermines the value of money. The government would therefore have to offer money that keeps its value.

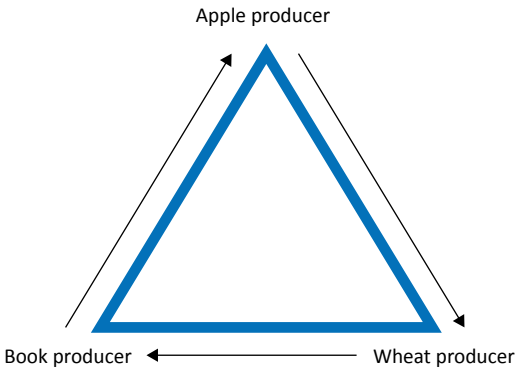
We will now take a closer look at the mechanisms behind the two reasons why we might need cash or a CBDC. We will also explain why public protection of private money can be an alternative to general public access to central bank money. The exposition below is intuitive, informal and quite cursory. Our aim is to portray the main arguments in a simple way.

2.1 Credit as money or the basis for money

If all agents in the economy could be trusted to honour all of their promises, then there would be no need for money. It would be sufficient to have a common bookkeeping system. However, in reality people cannot always be trusted to honour their promises, and bookkeeping is difficult when there are many agents. Therefore, we might need money in some form.

To explain how credit can work as money or can form the basis for money, we use what is sometimes called 'Wicksell's Triangle', named after the Swedish economist Knut Wicksell (Andolfatto, 2009). Suppose that an apple producer wants to consume wheat, a wheat producer wants to consume books and a book producer wants to consume apples (see Figure 1). Obviously, if there is no money and none of them can be trusted to keep their promises, trades will be hard to achieve unless all of them can meet in the same place at the same time. However, do we need central bank money (or some other form of outside money) for trades to take place?

Figure 1. Wicksell's Triangle



First, suppose that one of the agents, for instance the wheat producer, issues a credible IOU stating, 'I owe you one kilo of wheat.' The book producer then accepts this IOU as payment for a book, knowing he/she can hand it to the apple producer in exchange for apples. The apple producer wants the IOU because it can be exchanged for a kilo of wheat. In this case, the IOU – which is in fact a credit given to the wheat producer – serves as money. Thus, in this situation there is no need for outside money. All welfare-enhancing trades take place using the IOU, and central bank money is not necessary. This simple example illustrates that measures that render the IOU trustworthy are sufficient and eliminate the need for cash or a CBDC.

An alternative to the IOU is to introduce a bank (see, e.g., Cavalcanti and Wallace 1999). The bank could issue a loan denominated in some unit of account to the wheat producer. The wheat producer could then use the borrowed money to buy books. The book producer accepts the money, because it can be used to pay for apples. This is because the apple producer knows the wheat producer will accept the money, since the wheat producer needs it to pay back the loan. Thus, in this case all welfare-enhancing trades also take place using the money issued by the bank based on the credit. Therefore, central bank money is not necessary. This simple example illustrates that measures that safeguard credit repayment render bank credit trustworthy and useful.

In the examples above, agents trade only once. If agents make trades more than once and their previous behaviour (histories) can be observed, then trust in private money may arise endogenously. If agents want to trade repeatedly, they might prefer not to default in order to be able to trade in the future. The reason is that a previous default on an IOU or a credit can destroy future IOUs or credits. This illustrates that when people want to trade repeatedly, they – and thereby the money created inside the system – endogenously become trustworthy. However, the literature also shows that this mechanism is weakened in the presence of other frictions, for instance, the time it takes to verify whether an agent has honoured previous promises. Kocherlakota and Wallace (1998) and Mills (2007), for example, show that if there are lags in updating histories, contracts cannot be enforced. Their models reveal a need for outside money such as central bank money. However, and similarly to other models, an alternative would be for the government to put measures in place that enforce contracts.

Sanches (2016) analyzes a model where banks themselves find it optimal to set up measures that protect deposits. In his model, there is no role for outside money at all. Thus, the private sector finds a solution that does not involve central bank money. Again, theory suggests that it is not essential that the general public has access to central bank money.

The examples above revolve around the need for money when people cannot meet in the same place: what the literature sometimes calls 'separation in space.' Other theories explain the need for money when there is 'separation in time.' Samuelson (1958) is a

prominent example. Regarding our question, these studies, like those on separation in space, also show that public central bank money is not needed if instituted measures can provide sufficient trust in private money. Examples include measures that keep inflation in check and ensure sufficient enforcement or commitment to honour debt obligations.

The mechanisms explained above tend to suggest an 'all-or-nothing' solution. Either central bank money is not needed and not used at all, or it is needed and agents use only central bank money. In reality, central bank money and commercial bank money co-exist and are in use simultaneously. In other theories and models in the monetarist literature, inside and outside money do co-exist. However, these theories are not relevant to our question, since they explain either why private money provides more flexibility than central bank money or why two types of money denominated in different currencies can co-exist and circulate in an economy.

For example, Bullard and Smith (2003) provide a model in which it can be welfare enhancing if private agents issue money in addition to the already-existing central bank money. This is because the amount of central bank money is fixed and independent of the needs of the economy. The model does not suggest that we need central bank money for private money to exist.

Another example is Kiyotaki and Wright (1989), whose paper forms the basis for much of the consequent literature. In their model, the two types of money that circulate have different properties: one type has a higher rate of return and the other is more liquid. Also note that in models where different types of money co-exist, they typically do not have one-to-one convertibility – and there is thus no uniformity of money. These models, and other similar ones, do not provide any mechanism whereby public access to central bank money (or outside money) is a necessary condition for private money. They do, however, highlight that the co-existence of two types of money implies that neither of them strictly dominates across all characteristics. Users trade off one characteristic dimension for another when making their portfolio choice of what monies to hold.

One of the most influential models of banking is developed by Diamond and Dybvig (1983). The model explains how banks can help the economy reach a first-best solution through their ability to create short-term liquidity. This model is not about money per se, but rather about the consequences of mismatching maturities in the banks' assets and liabilities. Nevertheless, an important conclusion from the model is that securing bank deposits through deposit insurance, or some other means, is crucial for the stability of the financial system.

What does all this say about our question? Basically, it says that central bank money that is available to all is needed if bank money is not trustworthy and therefore not accepted. A corollary is that the government and the central bank will have two options. They can issue central bank money that is available to the general public, or they can put measures in place that safeguard bank money. Therefore, the literature that argues that credit works as money or forms the basis for money does not suggest that cash or a CBDC is fundamental to the monetary system. It suffices to have strong measures that protect commercial bank deposits. In a later section, we take a closer look at these.

2.2 The temptation of private issuers to over-issue

We now turn to the second mechanism in the monetarist models that may lead to the need for general public access to central bank money, namely, the temptation for agents to issue more money than needed. The assumption behind this is that money-issuing agents make a profit on money issuance similar to seigniorage or net interest rate margins. They therefore have incentives to over-issue money, which can result in money losing value.

The mechanism is quite intuitive. Suppose two types of money are available: central bank money and private money. Furthermore, suppose they are not necessarily convertible at

par. If issuance of central bank money is under control and well managed, inflation in terms of central bank money remains in check and central bank money will keep its value. In this sense, central bank money is 'good money.' The mere existence of central bank money as a stable alternative, then, may induce private money issuers to not over-issue, and private money becomes trustworthy. Thus, central bank money's role as a competitor, rather than its convertibility, lends credibility to private money. Also note that the problem of over-issuance disappears if the money issuers can be sufficiently monitored: that is, if instituted measures are strong enough (see, e.g., Cavalcanti and Wallace 1999; Gu, Mattesini and Wright 2013). Hayek (1990) suggests that competition among private money issuers is enough to render private money safe.

We nevertheless conclude that these models do not directly relate to our question, for two reasons:

1. Under current (real-world) regulation and monetary policy arrangements, credit demand restricts commercial banks' money creation. Credit demand, in turn, is determined by the central bank's monetary policy. Thus, under the current monetary policy regime, the risk that banks over-issue money to the extent that it leads to high inflation is not a matter for concern. However, over-issuance in the sense that banks may extend too much credit can still be a concern, for instance, if banks' capital requirements are too low. Our point here is only that banks cannot extend more credit than what is demanded at a given rate of interest.
2. In these models, the two forms of money do not have one-to-one convertibility. Thus, they are more about two different currencies than about a monetary system with commercial bank money denominated in the same currency as central bank money.

3 Measures that safeguard commercial bank money

Having established that the government has to take measures to ensure that money is safe and trustworthy, it is natural to ask what measures there are to safeguard commercial bank money? To what extent are they in place? Are they sufficient to render commercial bank money trustworthy? In this section, we consider these questions.

3.1 Laws, regulations and supervision

Legal frameworks and practices that support contract enforcement make loan defaults less likely. That reduces the vulnerability of banks and increases the safety of bank money. Similarly, regulatory frameworks for banks make bank money safer. The frameworks typically prescribe minimum capital levels, accounting standards, disclosure standards and so on. Regulation also describes what measures will be taken and what will happen if a commercial bank becomes insolvent or runs into illiquidity or other problems. Finally, supervision is supposed to ensure that the banks comply with regulations. Member countries of the Organisation for Economic Co-operation and Development (OECD) and many other countries have these measures in place.

3.2 Facility of lender of last resort

Commercial banks can run into illiquidity even in countries where strong laws, regulation and supervision are in place. Seen in isolation, this may undermine the trust in commercial bank money. For this reason central banks have the facility to act as lender of last resort, whereby banks that run into a temporary liquidity shortage can borrow from the central bank against

collateral. This facility makes commercial bank money safer and thereby more trustworthy. It is a key function of all central banks.[4]

3.3 A focus on depositors and the payment system

Banking resolution frameworks specify how authorities will handle insolvent and bankrupt banks. If these frameworks focus on saving depositors' money and keeping the payment system up and running, that makes commercial bank money safer and enhances trust in commercial bank money.

The current legal framework regarding bank resolution in the European Union (the Bank Recovery Resolution Directive) states that responsible government agencies will make sure that when major banks are under resolution, their customers' accounts will remain open. When it comes to banking resolution, it is worth noting that government finances and the strength of the balance sheet of the central bank may matter. To see why, consider an insolvent bank. The central bank, or some other relevant national authority, will have at least two options if it wants to save the funds of the depositors in such a bank:[5]

1. It can restore the bank's balance sheet by injecting necessary new capital.[6]
2. If there is another solvent bank, it can liquidate the insolvent bank, sell the bank's assets, add sufficient capital and move the deposits to that other solvent bank.

In the unlikely event that all banks are insolvent, the central bank – or other relevant authorities – can use option (1) for all banks, or option (1) for some banks and option (2) for the rest of the insolvent banks.

The capital that is injected through such operations can come from two sources: either the central bank's equity capital or capital from the government. If the government finances the operation, it needs to be able to raise enough capital. If capital from the central bank finances the recapitalization, the central bank's equity capital falls. The funds needed might even be larger than the central bank's equity. Thus, for such a large recapitalization to be possible, the central bank may need to operate with low or negative equity, or the government must be able to raise enough capital.

Theoretically, central banks can operate very well with negative equity. One reason is that a central bank cannot run into liquidity problems because it is legally entitled to pay its bills with the money it creates. If not through physical cash or a CBDC, it will pay by issuing bank reserves. The other reason is that, unlike other financial institutions, central banks are not legally forced to implement recovery measures or go into administration ('go bankrupt') when their equity is negative. And indeed, several central banks operate or have operated successfully with negative equity. The Czech National Bank and the Central Bank of Chile, for instance, have operated for years with negative equity without experiencing any ill effects on their reputations or operations.

There could nevertheless be a limit to how low the negative equity can become before the situation becomes unsustainable, for instance, because it gives the central bank incentives to embark on inflationary policies or simply because the central bank will lose its reputation or room to manoeuvre. Thus, we conclude that in countries with relatively low government debt, a well-run central bank and institutional arrangements that keep inflation in check, it is reasonable to believe that deposits in failed banks can be protected even in a systemic crisis.

4 The lender-of-last-resort facility is dependent on the existence of neither cash nor a CBDC. As long as the central bank accepts a sufficiently wide set of collateral, it can bridge the bank's liquidity shortage by lending bank reserves. Central banks can create such credits 'out of thin air.'

5 According to current legislation, a central bank within the European Union cannot bail out an insolvent bank. However, in real life it is often hard to separate between liquidity and solvency problems during a crisis. Furthermore, the central bank is part of the state and this section gives a theoretical exposition.

6 Preferably, the central bank (or the relevant national authority) should also take ownership of the bank if the original equity capital has been wiped out by the losses.

3.4 Deposit insurance

Deposit insurance is a promise by the government to assure consumers that money held as deposits in commercial banks is safe, at least up to a certain amount. It is a powerful measure set up to communicate the authorities' intent to protect deposits. It enhances trust in commercial bank money, in particular in times of crisis.

Deposit insurance schemes are typically not fully funded. For instance the US Federal Deposit Insurance Corporation (FDIC) web page states, 'FDIC insurance is backed by the full faith and credit of the United States government.'[7] If the crisis is sufficiently large, the scheme cannot provide full compensation for all deposits covered without additional funding. However, as explained above, the authorities can guarantee deposits even if a deposit insurance scheme is absent or underfunded.

3.5 Is commercial bank money safe enough?

In most advanced economies, all of the measures mentioned above are in place. Furthermore, during past financial crises, public authorities have proven willing and able to protect commercial bank deposits in many countries, including in the United States in 2008–09. In both Sweden and Norway, countries where cash seems to be disappearing, the governments have also proven willing and able to protect commercial bank deposits in times of systemic banking crises. The payment systems have been up and running without interruptions and no depositor have lost any money.

Based on the discussion above, we can conclude that in countries with strong institutions and sound government finances and macroeconomic policies, commercial bank money is safe up to the limit of the deposit insurance guarantee – and in practice even above that. Thus, given this, and according to the theory described above, it seems that neither cash nor a CBDC are fundamental to the monetary systems in these countries. However, even if commercial bank money is safe, cash or a CBDC may be essential to the monetary system for other reasons.

4 Other reasons why public central bank money might be essential

In this section, we discuss two reasons beyond issues of the risks around commercial bank money for why public access to central bank money might be essential. These are uniformity and control.

4.1 Uniformity of money

A key feature of the current monetary system is that funds deposited in different banks exchange at par. This makes money issued by different banks uniform and is sometimes referred to as the 'uniformity of money.'

Cash is often considered fundamental to the uniformity of money. This is because when all commercial bank money is convertible into cash at par value, one commercial bank's money automatically becomes convertible into another commercial bank's money. Convertibility into a CBDC would support uniformity of money in the same way. Thus, if cash disappears, convertibility and the uniformity of money would be maintained by a CBDC.

However, cash or a CBDC are not the only mechanisms we can use to transfer money between individuals or to convert money issued by different commercial banks (or other money issuers) between them at par value. All commercial banks (and other money issuers) have access to central bank reserves, and all electronic payments are ultimately settled

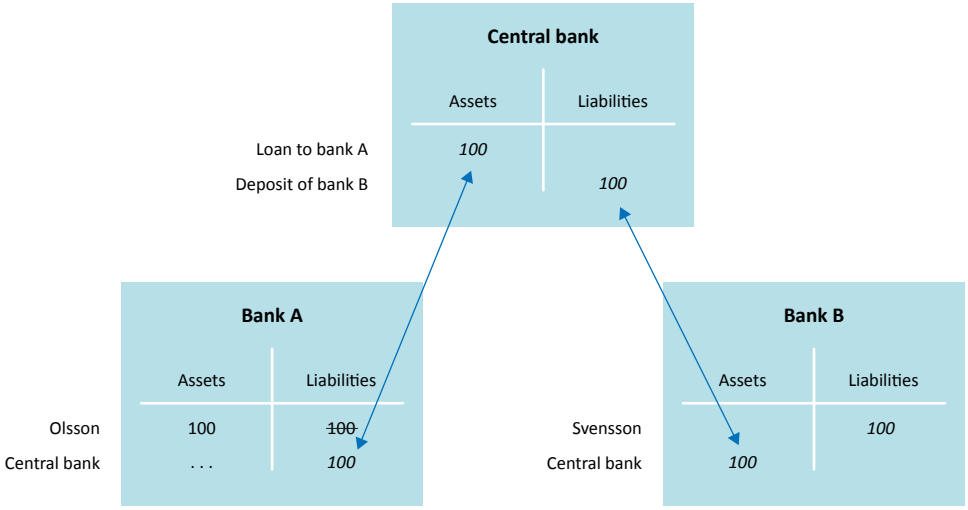
7 https://www.fdic.gov/

with central bank reserves. These facts are important parts of the mechanism to ensure the uniformity of money.

To see why, consider the example in Figure 2: bank A has given Mr. Olsson a loan of $100, so that he has $100 in his deposit account at bank A but also a debt of $100. Mr. Olson wants to use the loan to buy a house from Ms. Svensson, who has a deposit account at bank B. To settle the payment, bank A will borrow $100 in reserves from the central bank (or use $100 that it already has deposited at the central bank). This money will then be transferred to bank B's account at the central bank. Bank B will then credit Ms. Svensson's account at bank B with $100. Thus, in this case parity and convertibility between bank A's and bank B's money is maintained even though only the commercial banks, and not the general public (Mr. Olsson and Ms. Svensson), have access to central bank money.

Nothing in the example prevents bank B from crediting Ms. Svensson's account with only $80. Also, in this case parity would be maintained. The difference from above is that now bank B has charged Ms. Svensson a fee of $20. The $20 will appear on bank B's balance sheet as increased capital. This would be no different from a case where bank B charged a fee of 20 percent to customers depositing cash at bank accounts at the bank. It makes no difference for this argument if bank A charges the fee.

Figure 2. Settlement of a payment at the central bank



The mechanism outlined above describes how payments work in normal times when people are fully informed and have complete trust in the overall system. However, which parts of the mechanism are essential to restore uniformity in the case of a disequilibrium?

Suppose again that Mr. Olsson owes Ms. Svensson $100 but that Ms. Svensson believes bank A is close to failure. If Ms. Svensson is fully informed about deposit insurance, resolution programs and other aspects of the financial system and trusts that the government has the will and resources to ensure the safe and continuous functioning of the payment system, then she will accept Mr. Olsson's payment as described above without any problem. However, if Ms. Svensson is not fully informed about the financial safety net or does not fully trust the capacity of the government to solve the problem, then she might make demands that threaten uniformity.

In this scenario, Mr. Olsson has three options to pay off his debt to Ms. Svensson:

1. go to the bank, withdraw cash (or CBDC) and deliver it to Ms. Svensson;
2. write a cheque;[8] or
3. send money via, for instance, Swish in Sweden or Electronic Funds Transfer (EFT) in Canada.[9]

Since Ms. Svensson does not trust bank A, she might prefer option (1), because this puts the risk on Mr. Olsson of obtaining the cash from bank A to settle the debt. She is unlikely to accept option (2) because she knows it could take days for the cheque to clear and for her to be certain she had her money. If she trusts that the payment in option (3) is close enough to instantaneous and that it carries little risk, then she may accept that method. Ms. Svensson will likely accept $100 cash to settle the debt. But if Mr. Olsson chooses to write a cheque, Ms. Svensson may demand he add a premium to compensate her for the risk during the clearing period. Even if Mr. Olsson pays using option (3), some perceived greater risk might lead Ms. Svensson to demand a premium to compensate her for the risk. But the closer this electronic payment method is to the instantaneous settlement finality of cash, the lower the perceived risk will be of accepting a payment from Bank A.

The uniformity of money will only be broken if enough people begin to demand a premium from customers of riskier banks when using non-cash payment methods as described above. While cash, or a CBDC, does have a role to play in helping to ensure the uniformity of money, this role will diminish with the following:

- growth in the perceived and actual strength of the financial safety net,
- increased understanding of the safety net and financial system,
- greater confidence in the government's ability and willingness to quickly address systemic problems, and
- availability of payment alternatives that are instantaneous and fully understood to be so.

All of these components are important to the uniformity of money. Weakness in any of them could leave some role for cash or CBDC to help ensure the uniformity of different types of money. The importance of this role will depend on the national context. Even if cash or a CBDC is not needed for uniformity under normal circumstances, it could still be significant in extreme crises.

4.2 The importance of cash or a CBDC for control

Even if commercial bank money is safe, people might not believe it is. One reason could be that they see a risk that the measures instituted to support commercial bank money will be weakened in the future, in particular in times of stress. Other reasons could be that people are not aware of these measures or that they find it hard to assess how safe they can make commercial bank money. A case in point is that in Sweden only 52 percent of the population is aware of the existing deposit insurance guarantee (Riksgälden 2017). However, the declining use of cash seems to be at odds with distrust in commercial bank money. If people do not trust commercial banks, why do they not hold cash?

In this subsection, we provide a possible explanation for why cash or a CBDC may be fundamental even though people do not hold cash or hold it to a limited extent. The explanation builds on research on decision making in the presence of risk in the domain of psychology.

8 Cheques are still in use, although they have declined significantly in Canada and many other countries.

9 Swish is a real-time instantaneous payment system, while EFT in Canada can be very fast but it is not guaranteed to be instantaneous.

4.2.1 The need for control

Research in the field of psychology has demonstrated that control or perceived control is very important for a person's willingness to engage in a risky activity. If people think they have more control over the outcome of an activity, then they are more likely to participate in that activity. Conversely, they are less likely to participate in activities over which they have no control.

Evidence also shows that control can be broken down into control over the outcome of an event and choice about whether to participate in an event or activity. People are more willing to take risk if they believe they have some control over the outcome. Interestingly, however, when people have control over participation, they will tend to avoid risk. This seems to be because of anticipated regret. To avoid a bad outcome from an activity they chose to participate in, people will sometimes decide to not participate at all. However, once the decision to participate has been made, people feel more comfortable taking risk when they believe they can have some effect on the outcome.

Bracha and Weber's (2012) discussion of financial panics provides an example. They describe how investors gain a feeling of control through their belief that if they understand how financial markets work, they can predict market behaviour. They argue that 'events that destroy this sense of predictability and perceived control trigger panics, the feeling that crucial control has been lost and that the future is unpredictable, and hence, dangerous. Resulting behavior, including a retreat to safe and familiar options, aims to minimize exposure to such danger until a new model of how things work has been established' (Bracha and Weber 2012, p. 4).

4.2.2 How cash or a CBDC could support a sense of control

Access to cash or a CBDC can give people who distrust banks a sense of control. When individuals always have the option of converting their commercial bank money into cash or a CBDC, they are more in control of the outcome in the event of a banking crisis. Thus, even when people choose not to hold cash or CBDC, its mere availability may be necessary for some people to be willing to hold commercial bank money. Cash or a CBDC is especially useful for this because it is a method of exiting the entire banking system, not just a single bank. People may see this as particularly important.

As noted above, the literature also suggests that people will tend to avoid risk if they have control over participation. In our setting, this would mean that people who start out with cash might not want to put it in bank accounts. However, in advanced economies where income and transfers are payed in the form of commercial bank money, people start out with commercial bank money, not cash. Furthermore, in practice, interest payments, down payments, rents and most payments for big-ticket items have to be paid using commercial bank money – and people therefore simply have to hold it.

In practice, we see that in most circumstances people are willing to use commercial bank money to complete their transactions. This willingness may be due to the facts that instituted measures support commercial bank money, as described above, and that bank money can be converted into cash. However, the need for convertibility into cash or a CBDC may be particularly important in times of stress.

4.2.3 Access to cash or a CBDC in times of crisis

In a crisis, when mistrust in the banking system is at its highest, people become worried about the safety of their savings in banks. The easier it is for them to withdraw their money, the more in control they will feel about their financial well-being, which means they will be less likely to reduce their economic activity in terms of investment and consumption.

Roadblocks (e.g., withdrawal suspensions, banking holidays and quantity limits) designed to protect banks and stop a bank run will all take control away from the individual. This will exacerbate their loss of confidence and the resulting economic downturn. Being able

to withdraw their money from the bank may not completely keep people from losing confidence, but it does give individuals a certain amount of control and will reduce the damaging psychological effects of the crisis. Obviously, the central bank will still need to provide liquidity measures or act as lender of last resort to solvent but illiquid banks in crisis.

When individuals always have the option of using cash or a CBDC to get their money out of a financial institution, they are more in control of the outcome during a crisis. Cash or a CBDC is especially useful for this because it is not only a mechanism to exit a bank in trouble but also a method of exiting the entire banking system, which is particularly important during a system-wide financial crisis. The existence of cash or a CBDC thus serves as another line of defence to help maintain confidence in the banking system.

In discussions about CBDCs, it is often argued that a CBDC leads to a higher risk of runs on banks in times of stress, as it presumably would be easier to convert bank money into CBDC than into cash. However, the arguments above suggest that there may be offsetting effects – since depositors know that bank money can be moved quickly and easily into CBDC – that might make them less prone to run from banks in trouble.

Today, in most advanced economies, the share of cash is very small compared with bank deposits. The amount of cash available would definitely not be enough to cover demand should all depositors want to withdraw their money in the form of cash. There is therefore a risk that convertibility would have to be suspended in case of a bank run. As emphasized by the Diamond-Dybvig (1983) model, congestion effects may reinforce this problem and intensify a run into cash. If the ability to convert commercial bank money into central bank money is important for control, as argued above, a CBDC would be a preferable option to cash since the central bank can instantly create large amounts of CBDC.

5 Summary and conclusions

In this article, we have discussed whether the ability of individuals to convert commercial bank money into central bank money is fundamentally important for the monetary system. This is a significant question because cash, the only form of central bank money that the public currently has access to, is becoming marginalized in some countries. The question is highly relevant to the discussion about whether central banks need to issue a retail CBDC.

Theory suggests that commercial bank money is sufficient if it is safe. We have argued that instituted measures like deposit insurance, lender of last resort, regulations and supervision, together with sound government finances and macroeconomic policies, make commercial bank money safe up to the limit of the deposit insurance guarantee – and often beyond. Thus, to begin with, neither cash nor a CBDC seems fundamental to the monetary systems in countries with these measures in place.

We discussed two other potential reasons why cash or a CBDC might be fundamental. The first is the role of convertibility of bank deposits into cash or a CBDC for the uniformity of money. We argue that the uniformity of money can be maintained without cash or a CBDC if:

- institutions are strong,
- the government has the ability and willingness to quickly address systemic problems, and
- payment alternatives are instantaneous and fully understood to be so.

Weakness in any of these components may leave some role for cash or a CBDC to help ensure the uniformity of different types of money.

The second reason is the role of convertibility of commercial bank money into central bank money in giving a sense of control to economic agents that mistrust banks. Research has shown that individuals who feel they are in control are more willing to take risks. Thus, in this sense, one of the roles of cash, and potentially of CBDC, may be to promote a sense

of control for individuals. Furthermore, by extension this will support individuals' trust and confidence in their financial well-being and the financial sector.

Our overall conclusion is that the question of whether general public access to central bank money in the form of cash or a CBDC is fundamental to the monetary system is a judgment call and depends on the national context. In the two countries that are now experiencing the most rapid decrease in cash, Sweden and Norway, the governments have a proven record of protecting commercial bank money in times of crisis. People therefore have good reasons to believe their commercial bank money is safe should a new crisis come along. However, the perceived control provided by the ability to convert commercial bank money into cash or a CBDC may still be needed to make people willing to hold the former. We find that more research into this mechanism is needed before we can draw any definite conclusions.

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Competitive aspects of an e-krona

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This article evaluates whether the introduction of an e-krona can be justified on grounds related to market power and insufficient competition in the payment markets. It argues that an e-krona would i) increase competition in several banking services markets by facilitating the unbundling of services, ii) significantly facilitate regulation through a combination of government ownership of a critical asset and vertical separation, and iii) help forestall a situation in which an international private digital currency also establishes itself as the de facto standard currency for domestic payments.

A key argument is that standard economic regulation is highly complex and that government ownership of key bottleneck infrastructure in combination with more light-touch regulation is a good alternative. A higher level of flexibility and control and less need for extensive regulation will likely compensate for the presumably lower efficiency of government-owned entities. Furthermore, the Riksbank would be able to provide a level playing field and equal access for different types of payment service provider. Finally, relinquishing government control over a critical asset – currency in circulation – is a process that, for political and legal reasons, would difficult to reverse.

1 Introduction

Sweden has seen an exceptionally rapid fall in the use of paper currency for payments and in the ratio of the total value of outstanding paper currency in circulation to GDP. Against this background, the Riksbank is investigating the possibility of introducing an e-krona, a central bank digital currency.

This article evaluates whether the introduction of an e-krona can be justified on grounds related to market power and insufficient competition in the payment markets, today or in a future scenario where cash is absent. More precisely, its aim is to analyse competitive aspects of central bank currency's presence, or lack thereof, as a medium of exchange available to the general public in a digital future, while considering in particular i) the rapid decline of cash use in Sweden, ii) the strong network externalities that characterise the payment market and its associated tendency towards natural monopoly, and iii) the risks for monopoly profits and inefficiencies if the payment market becomes entirely private.

The pros and cons of different policy alternatives that address the above concerns are analysed. Two alternative policy approaches stand out: firstly, adjusted and strengthened regulation and more vigorous oversight and enforcement and, secondly, the introduction of a government-owned (central bank) digital currency (CBDC or e-krona). This article draws on the experience gained from past and current economic regulation of infrastructure-based

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markets, such as the telecom and electricity markets, as well as the experience of applying competition law to platform markets, such as payment cards and operative systems. It argues that the second policy alternative, the introduction of an e-krona, should be the preferred alternative.

The paper is organised as follows. Section 2 provides an overview of the Swedish payment market from a competition perspective, with a focus on those aspects of the market that are relevant for analysing the effects of an e-krona. Section 3 deals with the economic regulation of the payment market. Section 4 analyses the competitive effects the introduction of an e-krona may have and Section 5 concludes. Three appendices discuss A) how competition law has been applied to payment card networks, B) policies that have been applied to highly concentrated industries with market power based on the control of physical infrastructure and C) policies for industries where market power is derived from network effects.

2 The (Swedish) payment market

Retail payments can be analysed and categorised in many ways. One distinction is that between payments at the point of sale and remote payments. Examples of the former are cash and card payments (at the point of sale); examples of the latter are giro payments, credit transfers and direct debits. Cards are often used for remote payments, besides being used at the point of sale. Cheques were previously common in Sweden, mainly for payments at the point of sale, while in the United States cheques are still frequently used for remote payments.

Another distinction is that between three-party systems and four-party systems. In a three-party system, the payer and the payee have accounts with the same financial service provider (for example a single bank, the PG (Postgirot) or American Express) and a payment can easily be made within the system, for example within a bank, by transferring the agreed-upon amount from one account holder to another. In a four-party system, the payer and the payee have accounts with different financial service providers (for example different banks, BG, Visa, Mastercard or Swish) and then a clearing organisation needs to process the payment instructions and send information to a settlement system where both banks have accounts. The settlement system transfers the agreed amount to the payee's bank. Via the clearing organisation, the two banks receive information that allows the payee's bank to credit the payee's account and that verifies that the amount charged to the payer's account (less fees, if applicable) has reached its destination.[12]

So far, the processing stages of individual transactions have been described from a technical perspective, focusing on the relation between the seller and the buyer of a product and the financial intermediaries that connect the two. But payment systems constitute markets of their own, where providers of payment services compete for customers and where different types of need are met by different types of payment service. This is the perspective taken by competition authorities when analysing market power.[3] In the analysis, markets will often be distinguished according to where, along the value chain, they are located. The same market participant may be a buyer of inputs and intermediate services in upstream markets – and a seller of consumer services in downstream markets.[4]

1 See Sveriges Riksbank (2013) for a more detailed explanation.

2 Yet another distinction is that between push and pull transactions. Push transactions are initiated from the payer side of the transaction; pull transactions are initiated from the payee side.

3 When competition law is applied, the analysis of market power is based on markets being delineated or 'defined' as 'relevant markets'. A relevant market is a range of products that is broad enough, in terms of geography and product characteristics, that consumers of these products are reluctant to substitute to other products if faced with a 5-10 percent price increase. See Carlsson and Bergman (2015) or other competition law textbooks.

4 'Upstream' here means earlier in the value chain. For example, a manufacturer may buy inputs and business services in upstream markets and then sell to retailers in downstream wholesale markets; the retailers sell to final consumers in markets that are even further downstream.

When analysing debit and credit cards, the EU Commission's Competition Directorate has defined an upstream 'system' (or 'network') market, where different card systems (such as Visa and Mastercard) compete with each other, and the downstream 'issuing' and 'acquiring' markets, where banks and other financial institutions compete for individuals that carry cards and merchants that accept cards, respectively.[5] In its analysis, the EU Commission found that payment cards are sufficiently different from cash, cheques and giro and direct debit services for payment card services to belong to markets separate from those for cash, cheques and so on. It remains uncommitted as to whether there are separate markets for debit and credit cards, or whether there is one market for all payment cards.

Figure 1 illustrates the principle. Banks compete for individual customers in the issuing market and for merchants in the acquiring market (the downstream market), while banks and card networks interact in the upstream system market. The EU Commission describes the situation in the following way: 'The platform run by [a card network] is not a product offered jointly to cardholders and merchants. It is a vehicle for issuers and acquirers to offer distinct services to two groups of customers.'[6] In the system market, card networks such as Visa and Mastercard offer member banks a range of services, including transaction processing, a brand (card logo) recognised by individuals and merchants, system balancing via an interchange fee (see Appendix A) and technical standards and protocols, as well as clearing services. For these services, banks pay royalties, membership fees and payment processing fees.

The notion that there exists a distinct issuing market is a simplification, since individuals often buy bundles of services linked to the transaction account, including one or two different payment cards, credit transfers and direct debit services, a savings account and perhaps mortgage, insurance and long-term saving services.[7] To varying degrees, these different financial services can also be bought on a stand-alone basis. Three-party card networks, for example, tend to contract directly with individuals, as do many providers of insurance and mortgages. Besides cooperating with banks, four-party card networks offer their services on cards co-branded with large retailers. Still, for the present purposes, as well as when the EU Commission analysed the market for payment cards, the notion of an issuing market is useful.

Similarly, merchants buy a range of services linked to card acquisition from banks, but a distinct acquisition market is a useful concept for analysing payment services. The fourth relevant market illustrated in Figure 1 is the card services market. In this market, specialised subcontractors, such as payment processors and payment switch operators, sell their services to the banks. Technically, the subcontractors may be situated between the merchants and the banks, between the banks and the card networks or between the banks and the settlement system.[8] However, this further complexity can also be ignored for present purposes, since the subcontractors act on behalf of the banks and have little ability to influence the competitive situation, except by specialising and saving costs.

Even further upstream, card networks and central banks interact in the settlement market.

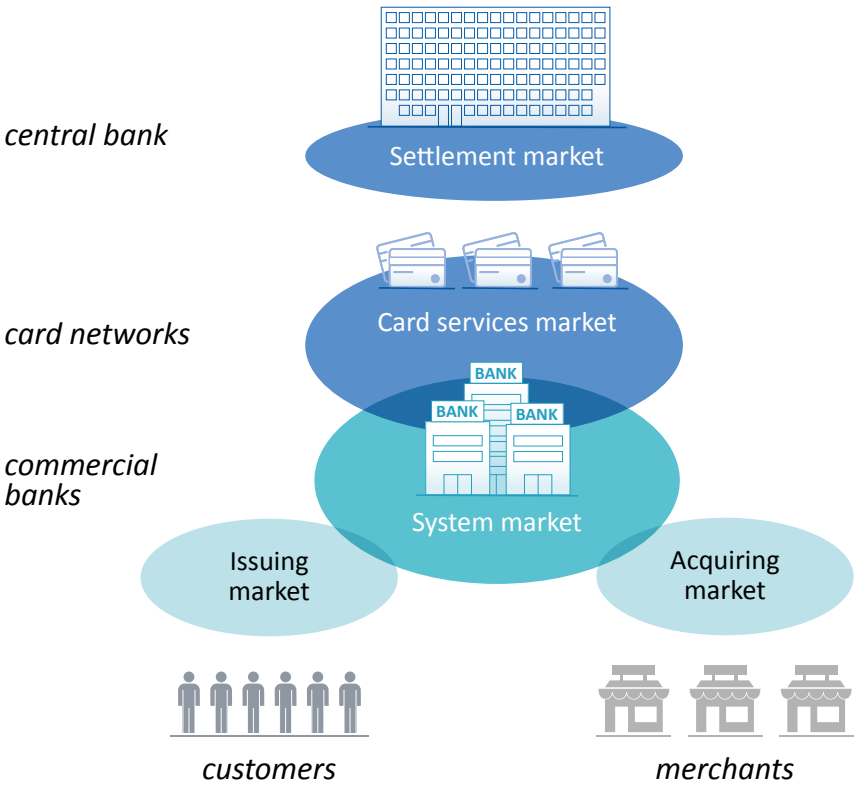
5 See, e.g., Mastercard I, COMP/34.579, at pp. 279.

6 Mastercard I, COMP 34.579, EU Commission's decision of 19 December 2007, at pp. 261.

7 These markets are sometimes referred to as cluster markets. See, e.g., the EU competition law case *EGL*, Judgment of the General Court in case T-251/12, 29 February 2016, at pp. 36. It might be more appropriate to say that banks compete in the cluster market that centers on the transaction account, than to say that they compete in the issuing market. It is widely accepted, however, that relevant markets to some extent do – and should – vary according to the question being analysed.

8 See Sveriges Riksbank (2013) for details.

Figure 1. Relevant markets in the card-payment value chain



Source: The Riksbank

The downstream system market is usually described as a two-sided market, with the two sides being individual customers and merchants, respectively. The benefits that the networks offer individuals and merchants increase with the number of merchants and individuals, respectively, that have joined the platform. However, except for these two-sided-network effects, the market positions of banks and card networks resemble those of retailers and manufacturers, respectively. Card services are, to a large extent, 'produced' upstream but mainly sold to individuals via downstream intermediaries (banks). The consumers have some freedom to choose between brands and can refrain from purchasing, but, if an individual customer wants a brand that his or her bank does not provide, the customer must turn to another bank. Typically, the platform is not offered directly by the card networks to final consumers; it is offered via banks that, in turn, are the card networks' customers.[9]

Finally, the card networks buy settlement services, often from central banks, in what could be called a settlement market. However, due to central banks often being the only providers of settlement services, this market has particular characteristics.[10][11]

Many other markets for retail payments have similar structures. Credit transfers and direct debit services are sold via banks, typically bundled with other products, to individual customers that are mainly payers, as well as to corporate customers that are both payers and payees. The transactions are processed and cleared by a systems operator, in the case of Sweden by Bankgirot (BG). Credit transfers, money orders and cheques (to the extent that

9 The fee structure used in card systems and the EU Commission's competition directorate's analysis of its anti-competitive effects are discussed in Appendix A.

10 Central banks are not the only providers of settlement services. Generally, the larger the transactions and the more systemic the associated risks, the more likely is it that settlements are made by a central bank. It will often be in the interest of commercial banks to settle in central bank systems, so as not to expose themselves to risks and so as not to have transactions settled by another commercial bank.

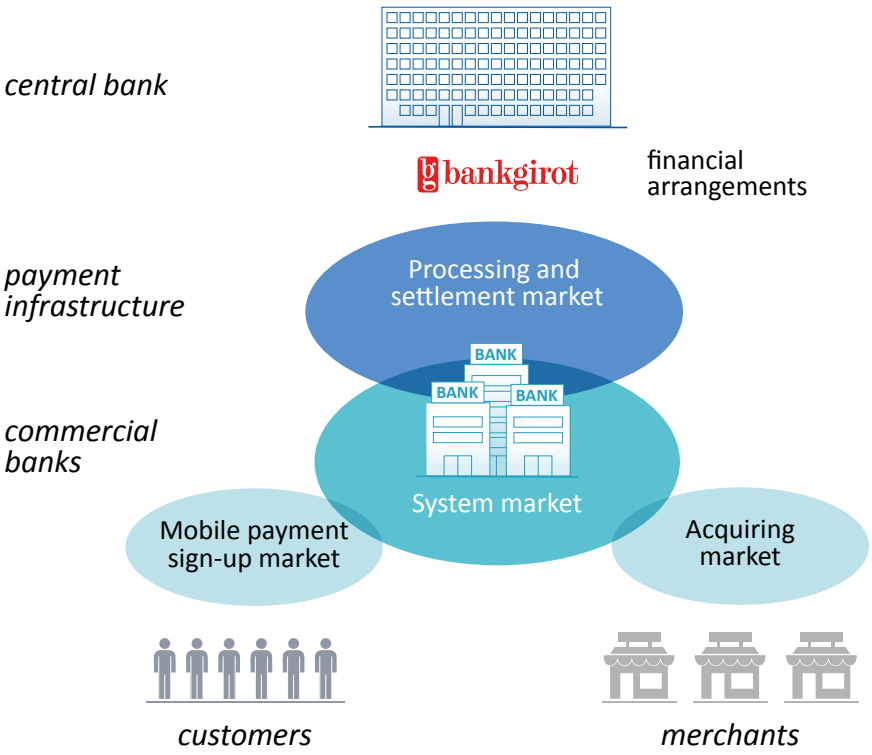
11 A similar three-layer structure is suggested in Arvidsson (2016) and repeated by the Swedish Competition Authority (2017).

they are still in use in Sweden) are processed by Dataclearingen (DCL); again these services are bundled with other products and sold to individual and corporate customers, while the banks buy services from DCL.[12]

BG is owned by seven Swedish banks, including the four largest banks, while DCL is owned by the Swedish Bankers' Association and is operated by BG. A financial institute can join DCL if it is a member of the association and if it participates directly or indirectly in RIX (see below).[13]

Innovations in the financial markets and the continuous development of IT technology have led to the introduction of new services that allow (near) instantaneous settlements. One example is the mobile payment service Swish, owned by the dominant Swedish banks. The instant payments that are made through Swish are settled directly in the system Betalningar i Realtid (BiR), owned and operated by BG. See Figure 2.[14]

Figure 2. Swish – instant mobile payments



Source: The Riksbank

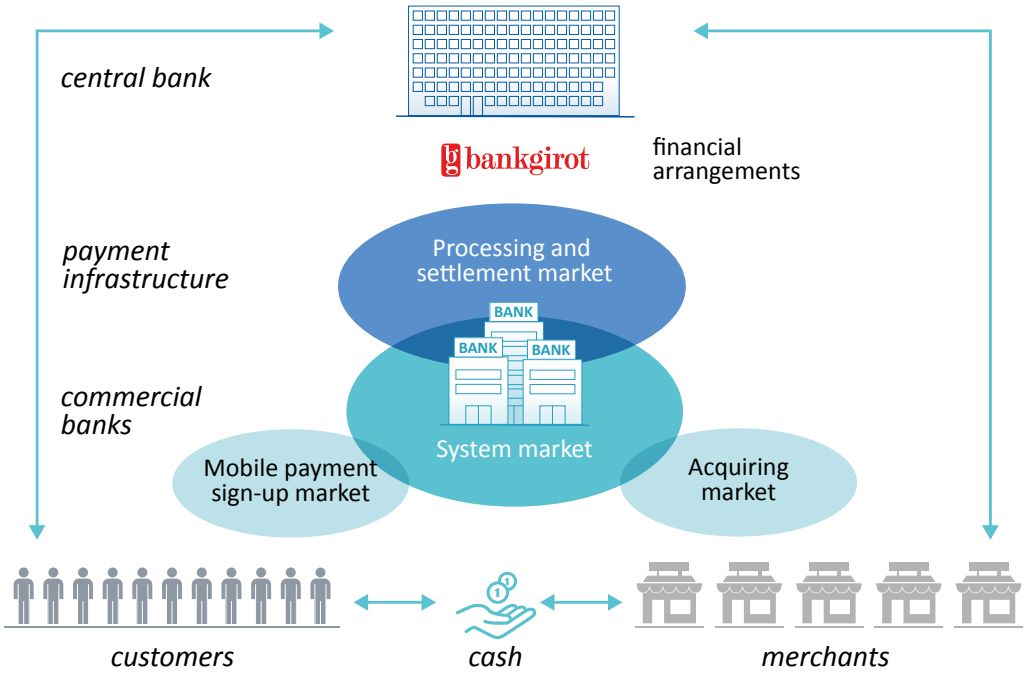
That a private company settles payments is an exception; usually large payments are settled individually by the central bank, while retail payments are aggregated and then net amounts are settled by the central bank. In Sweden, this is done by the Riksbank in its system RIX. BiR has a special arrangement with RIX that supports the atypical settlement in private bank money backed by central bank money. The European Central Bank has recently launched a platform for the settlement of instant payments, called TIPS, which can settle payments in

12 As mentioned in the discussion of the card market, technical service providers further complicate the picture. BG, for example, has outsourced most of the actual technical services to specialised providers, while retaining control over standards, customers, contracts, branding and strategic development. This vertical disintegration will be ignored in this report.
13 The banks in three Nordic countries are developing a pan-Nordic clearing organisation, P27, for cross-border payments within the Nordic region. Eventually, however, domestic transactions too will likely be processed by P27.
14 The initiative EMPSA, European Mobile Payment Systems Association, aims to link Swish to its sister organisations. Currently, Norway, Finland, Denmark, Germany, Belgium, Austria, Switzerland and Portugal are members, alongside Sweden, but the organisation expects more countries to join in the future.

euros as well as in other currencies. The Riksbank is planning to join TIPS in order to be able to settle instant payments in kronor in central bank money directly. When this happens, BiR can be devolved and the settlement stage can instead be done via the TIPS krona system.[15]

An e-krona would also require a platform for the processing of payment transactions, just as Swish or the international card networks do. However, since the accounts or digital wallets would hold central bank money, the transactions would be much less complex, with direct settlement between the payer's and the payee's accounts, as long as they both hold accounts in e-kronor.[16] This is similar to cash payments or payments within other three-party networks like American Express or the historic Postgirot. There is no need for a settlement separately from the transaction, neither for a cash payment, nor for an e-krona payment, as both involve central bank money. From the perspective of competition law and economics, and as established by the EU Commission in the Visa and Mastercard cases, cash is not considered as being on the same market as card payments. It does, however, exert a competitive pressure. This is illustrated in Figure 3.

Figure 3. Cash as a competitive constraint for Swish and card payments



Source: The Riksbank

When cash is used, notes and coins are paid to merchants as compensation for goods and services received – and debt previously owed by the central bank to the consumer is now owed by the bank to the merchant.

Cash constitutes a competitive constraint for the providers of card and Swish services, since consumers and merchants that are unhappy with the terms offered for card or Swish payments can opt to use cash instead. This option caps the banks' ability to charge high prices for their services, although, if cash is significantly more costly, is not often used, or is not seen as a close substitute, the competitive constraint may not be the one that binds. If competition is effective, it will instead be the competitive pressure from other banks that limits each individual bank's ability to set high prices.

15 Riksbank memorandum 4 June 2019 "Förstudie avseende användning av TIPS för avveckling av omedelbara betalningar' (Feasibility study concerning use of TIPS for settlement of instant payments).

16 A transaction between a holder of e-kronor and a payee that only has private bank money would need settlement through RIX Inst/TIPS.

This is in line with standard competitive analysis. A firm's competitive position is determined by rivalry within the market, by the competitive pressure from substitutes, but also by the firm's strength vis-à-vis suppliers and customers and by the threat of entry (see, e.g., Porter 1980).

Generally, competition tends to be insufficient in markets that are highly concentrated *and* where entry barriers are high. The Swedish banking market is not particularly concentrated in comparison to other industries and to the banking sector in western and northern Europe (Copenhagen Economics, 2018). However, the banking industry and, in particular, payment services are, to an unusually high degree, dependent on jointly owned assets, while network effects are important for payment markets. Entry barriers are so high that often the only realistic alternative for a new entrant is to seek access to existing systems, such as BG and DCL, while network effects make it essential to be able to process payments, directly or indirectly, to and from accounts in other banks.

The international market for payment cards *is* highly concentrated and characterised by strong network effects. In contrast, some markets for transaction processing services may be highly concentrated, but entry barriers are lower and network effects less important. In Sweden, as well as internationally, retailers have expressed concerns about high fees for payments with cards and competition authorities have taken actions against fee levels, as discussed in the appendix. Furthermore, entrant financial service providers have expressed concerns over charges for access to the jointly owned assets, such as BG.

The following section discusses pro-competitive regulation that has been introduced; regulation that centres on access for payments to and from accounts in other banks.

3 Pro-competitive regulation in the payment markets

The financial markets, including the market for payment services, is already extensively regulated, with some of the rules aiming specifically to promote competition. Other rules have other primary objectives but may still be relevant for the level of competition. This section will only briefly touch on some of the rules that have a clear relevance for the competitive situation in the payment markets.

The payment service directives (PSD and PSD2[17]) aim to harmonise rules for consumer protection and rules that regulate firms' right to provide payment services in the market. The PSD's purpose in regard to the payments industry was to increase pan-European competition with participation also from non-banks, and to provide for a level playing field by harmonising consumer protection and the rights and obligations for payment providers and users. In this context, it is also relevant to mention the Single Euro Payments Area (SEPA), a self-regulatory initiative by the European banking sector that aims to harmonise the infrastructure and the technical standards (Sveriges Riksbank, 2013).

PSD2 broadened the scope of the PSD1 regulation to include more types of services and market participants including, in particular, third-party providers that offer instant payment services for e-commerce customers, so called payment initiation services. These services do not rely on payment cards but instead use the payer's online banking module; one example of such a provider is Trustly.[18] Such services, which had begun to develop prior to the introduction of PSD2, now obtained stronger legal protection, as, under the new directive, banks are also required to provide access to their payment accounts for these service providers. Access should be provided under objective, non-discriminatory and proportional terms, in a way that does not block or hinder access to payment accounts. Under PSD2, a bank may not refuse to open accounts for a third-party provider. If it does, it has to have

17 Payment services (PSD 1) - Directive 2007/64/EC and Payment services (PSD 2) - Directive (EU) 2015/2366

18 https://ec.europa.eu/commission/presscorner/detail/en/MEMO_15_5793, accessed on 12 January 2020.

fair and reasonable causes and it has to notify the financial supervisor and explain those reasons.[19]

PSD2 also strengthens the position of consumers by requiring banks to release transaction data, at the request of the individual that made those transactions, to authorised or registered third parties.[20] For example, this would allow a consumer to reveal the complete financial history of his or her payment account to a stand-alone mortgage company or to a firm specialised in consumer credits. The UK implementation of PSD2 goes further, in that it requires standardisation of the format in which large banks release transaction data.[21] For example, the UK regulation requires banks to offer open APIs (applications programming interfaces), in practice through their enrolling in the Open Banking initiative.

While SEPA harmonises standards at the wholesale level, harmonisation at the level of end consumers is also needed for pan-European services to develop. Consequently, the EU Commission has initiated work to develop common standards for consumer interfaces. The payment services directives are likely to influence the markets for payments through several mechanisms. The EU Commission aims to facilitate cross-border payments so that, eventually, previously separate national payment markets will merge with the market for cross-border payments into a single EU-wide market. Also, promoting non-banks' participation will serve to increase competition for incumbents through new entry and by opening the market for competition between services based on different technical solutions (for example, payment cards versus payment initiation services). Finally, the regulation promotes vertical specialisation, potentially resulting in new financial services markets being established.

The tradition of setting up jointly owned systems (BG, DCL, the Swedish ATM system Bankomat, as well as the international card systems) makes payment markets more amenable to competition law than markets with individually owned assets.[22] A jointly owned system will often be considered as an agreement between firms and then competition law is applicable even if the system is not dominant. Following this logic, and also because it considered competition to be weak in the market for cross-border card payments, the EU Commission initiated a series of cases against the card networks. The cases are summarised in Appendix A. By applying competition law, the EU Commission achieved a resolution that has much in common with how an economic regulation of the sector may look. It capped prices in the upstream market (the interchange fee; see the discussion in the appendix) in the expectation that this would result in lower prices in the downstream acquiring market.

In fact, the subsequent 2015 Interchange Fee Directive follows the same logic as the competition law cases but goes a little further. It covers all four-party systems, not just Visa and Mastercard, and it covers domestic transactions, not only cross-border payments.[23] Four-party systems' MIFs are capped, but not those of three-party systems, such as American Express. However, while four-party systems are allowed to impose a ban on surcharges on merchants, three-party systems are not. This means that merchants are now in a better position to fight back if they believe merchant fees are unreasonably high. Similarly to what was achieved through the application of competition law, the card networks are required to specify fees, which makes it easier for merchants to unbundle the package of services the networks offer and to buy some services from third-party providers.

The Interchange Fee Directive is likely to have resulted in better competition and lower merchant fees, at least for large retail chains. It has established the principle of unbundling,

19 See Financial infrastructure 2016, Sveriges Riksbank, pp. 13–16; Payment in Sweden 2019, Sveriges Riksbank, pp. 7–8.
20 Depending on what service the third-party provider offers, it will need to be authorised or only registered.
21 https://www.wired.co.uk/article/open-banking-cma-psd2-explained
22 The international card networks were restructured in 2006-2007, from cooperative arrangements to regular listed corporations, possibly as a response to regulatory challenges from competition authorities, as discussed in Appendix A.
23 Since the member states are obliged to apply domestic competition law in conformity with how the EU Commission applies EU's competition rules, the payment card cases indirectly also had implications for domestic transactions.

with potential efficiencies due to specialisation and scale economies. The EU Commission is expected to publish a first evaluation in the summer of 2020.

Another set of rules comes with the Cross-Border Regulation, under which cross-border payments should be no more costly for consumers than domestic payments. The regulation initially applied only to the Euro zone and – following a voluntary Swedish initiative – to the krona. Following the 2019 revision, the regulation now applies to all EU currencies. It is noteworthy that the Cross-Border Regulation applies to consumer prices – the issuing market[24] in the terminology of Figure 1 – while the Interchange Fee Directive applies to prices at the wholesale level. The latter is more congruent with the perceived regulatory model.

Lastly, the Transaction Account Directive and the Settlement Finality Directive can be mentioned. Under the former, banks have to open accounts for EU citizens from other member states at fair prices, making it easier for consumers to unbundle financial services and, in that way, expose their domestic bank to competition from banks in other member states. The latter directive aims to create stable and uniform rules for settlements, in order to reduce systemic risks, but, in doing so, it requires non-bank payment-service providers to settle payments via banks, hence making entry more difficult (Górka 2016).

Overall, recent EU regulation of the payment markets follows the same logic as telecom regulation. Banks are increasingly required to provide access at fair prices in upstream markets to their downstream rivals. The presumption is that this will increase downstream competition due to new entry, due to previously national markets becoming more integrated, as well as due to unbundling and increased horizontal and vertical specialisation. This process is ongoing and it is still too early to say whether and to what extent it will be successful. However, the experience from telecom suggests that regulation must continuously be developed to accommodate market changes driven by technical innovations – and that an extensive array of regulatory measures is needed for complex and evolving markets.

4 Pro-competitive effects of an e-krona

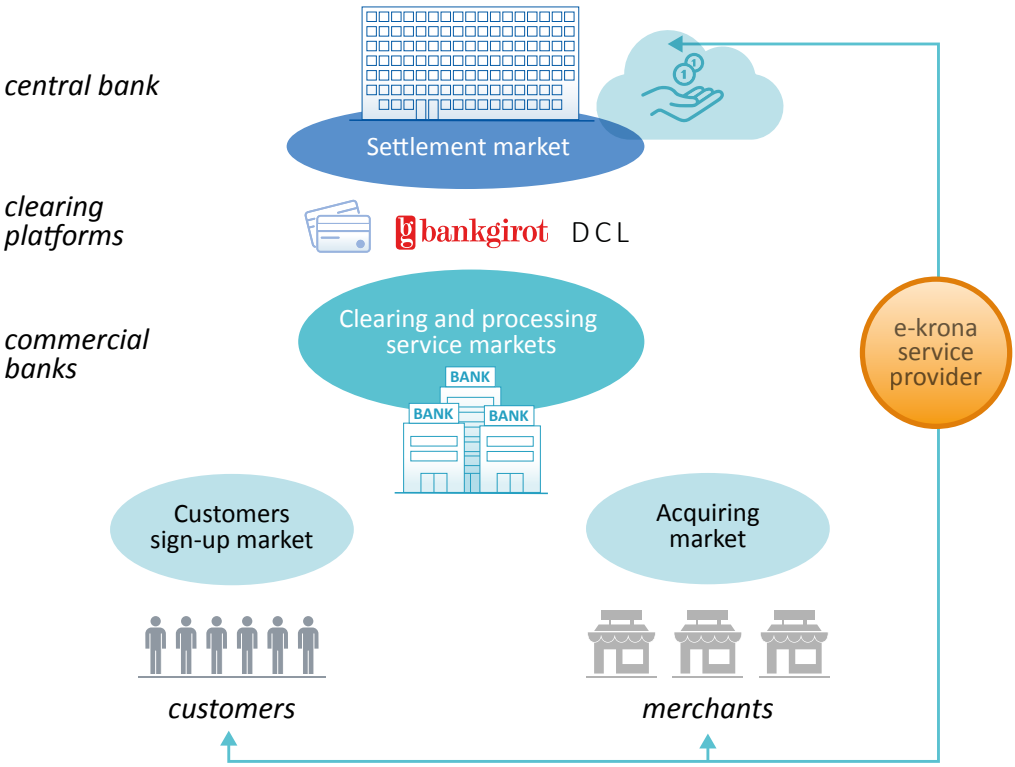
In the following, it will be assumed that the Riksbank will contract directly with individuals and merchants only rarely or not at all. As the e-krona will be digital, technical assistance will have to be provided by financial specialists such as banks. In terms of Figure 4, the Riksbank will continue to be the main seller in the settlement market and it will be active in a market where it provides wholesale access to e-krona accounts through a technical interface (API) that can be used by banks and other financial service providers. This market will be upstream, relative to the downstream market where e-krona accounts and linked services are provided to final consumers by financial service providers. That downstream market may develop into a relevant market of its own, or e-krona accounts and services may remain a product that is sold as part of a more general banking services bundle.

An extensive discussion of the technical differences between a value-based and an accounts-based e-krona (or CBDC) is outside of the scope of this report. A digital currency requires a ledger, distributed (as for Bitcoin) or not. The ledger can be linked to identified persons and the e-krona will then be based on accounts; it can be linked to potentially anonymous numbers or codes that can be transferred between individuals (like a pre-paid card for public transport or mobile telephony) and this can be interpreted as a value-based system. In the following, however, I will assume that an accounts-based and a value-based

24 Relevant markets are typically defined to be relatively narrow. It is possible that the EU Commission would find that the consumer market for cross-border payments with cards is a relevant market separate from that of the issuing market. This depends, among other things, on whether consumers would take the cost of cross-border payments into account when they choose payment cards and banks. Also, as discussed in the previous section, consumers may be active in a market for bundles of financial services.

e-krona system will be presented to the consumer in such a way that they would appear to be similar; in fact as accounts.[25] For that reason, in the following, I will be discussing accounts.

Figure 4. e-krona allows entrant payment-service providers



Source: The Riksbank

Under such a scenario, the launch of an e-krona system will shift part of the activities currently undertaken by BG (via BiR) or by DCL in combination with RIX to the e-krona system. Merchants and consumers will still be dependent on banks and other financial service providers for processing payment transactions. However, if the Riksbank offers an open API at the wholesale level, new payment transaction providers can enter and offer their services without having to depend on the incumbent banks and the existing payment infrastructure. That is, the introduction of an e-krona will not allow consumers and merchants to bypass financial service providers completely, as they (perhaps) can do with cash, but it could make it easier for new service providers to enter.

Seen from the perspective of an entrant financial service provider that wants to sell payment services, the extent to which an e-krona would facilitate entry also depends on whether the new firms would be dependent on accessing individual customers' and merchants' accounts with the old bank. If they are, the e-krona will likely not make entry much easier. Third-party providers of payment services already have access to bank accounts under the PSD2 regulation and consumers may not have strong incentives to open e-krona accounts. This is the chicken-and-egg problem that characterised two-sided markets. Consumers have little incentive to open e-krona accounts before there are useful services linked to such accounts; payment services providers have little incentive to develop services before there is a substantial customer base.

25 The underlying technologies may differ but will, presumably, be presented to the consumer in identical manners.

However, if a large fraction of the population has e-krona accounts and if these accounts can be accessed through an interface (API) provided by the Riksbank according to an open standard, then entry by rival payment providers *would* be facilitated.[26] It would then be possible to enter the payment market without being dependent on access to existing bank accounts via BG, DCL or the international card systems and without the entrant having to build its own customer base, customer by customer, as the card systems had to do when they were launched (Evans and Schmalensee, 2005, 2015). Also, new entrants would not be dependent on buying services from BG and other entities jointly owned by the incumbent banks. The availability of an attractive alternative for payments would increase competition throughout the relevant payment services markets. The direct effect may be most significant in the market for clearing and processing services, where competition is limited, but indirectly such a development may stimulate the unbundling of consumers' banking services more generally.

An e-krona in combination with the wide adoption of e-krona accounts would make it possible for an entrant payment service provider to bypass the clearing and processing services markets (at the same time, it obviates the need to settle the transactions, in turn reducing transaction complexity and hence, possibly, transaction costs). This is analogous to the scenario foreseen in the Microsoft case discussed in Appendix C, where the combination of Netscape and Java threatened (from the point of view of Microsoft) to develop into a substitute for Windows.

Even if the e-krona would not be widely used, its mere existence would introduce potential competition for the established payment systems. Retail chains and other 'merchants' would perhaps be able to obtain better deals, if they could more credibly threaten to launch their own payment system or to sponsor a new entrant. The prospect of entry may keep fees lower and induce the payment service providers to improve service quality.

In addition, the launch of an (accounts-based) e-krona would represent a way for the government to maintain control over an asset that is or could become key for controlling the payment system. This is in parallel to the government retaining control over the electricity market, by owning the transmission network, and over the rail market, by owning the tracks, even though the markets for power generation and train services, respectively, have been deregulated.

Another analogy is the telephone numbers system. A telecom network operator controls access to its own subscribers and enjoys a gatekeeper position. Even if the market becomes quite fragmented, each operator is the only one that can connect a call to its own customers, since it controls the terminating segment. Absent regulation, it would be able to extract monopoly profits by setting a high termination fee. If the originating network operator cannot set different prices for different terminating networks, the incentive to set a high termination fee actually becomes stronger the more fragmented the market is. The EU and its member states have an extensive bureaucracy that regulates access prices in the telecom market. Initially, fees were regulated for both the originating and the terminating segments, but, for the last few years, only the terminating segment has been regulated.

Government ownership and government regulation are substitutes, when it comes to controlling market power for key infrastructural assets. A vertically separated state-owned firm may not be as efficient as a private firm, but it has less incentive to favour certain customers over others and it is easier to regulate than a vertically integrated private company.

The history of market dominance and leapfrogging in the tech markets offers several lessons. When network effects are strong, dominance will arise and the dominant firm

26 The Berlin Group's API standard, NextGenPSD2 Access, is an example of an open standard. See further https://www.berlin-group.org/governance-and-structure

will do its best to erect entry barriers, in order to preserve its position as long as possible. Eventually, a new technology will emerge, surpassing and replacing an older technology and the entrenched dominance. However, even if such a challenge will eventually be successful, the process is protracted and meanwhile prices will tend to be too high, resulting in static efficiency losses. Given the increased globalisation of markets, a private solution that emerges as a substitute for cash is not likely to be Swedish; more likely it will arise out of the US market or possibly out of one of the major European markets.

To summarise, the introduction of an e-krona along the lines set out in this report would likely intensify competition on a number of banking markets, in particular relevant markets for payment services, but possibly more generally for banking services. Through a relatively limited government presence in the market, it would offer a structural mechanism for more intense competition. Generally, structural resolutions to impediments to competition are to be preferred over regulatory resolutions, as the former are more robust and more conducive to innovation and technical change, while, at the same time, they reduce the need for complex and costly regulation.

5 Conclusions

This article set out to analyse the competitive impact of introducing a central bank digital currency in Sweden, where cash use is falling rapidly. A maintained assumption is that strong network externalities characterise the payment markets and that, consequently, these markets are at risk of developing into monopolies or tight oligopolies if left unregulated.

The article provides an overview of policy alternatives that have been used in markets that share some of the payment market's characteristics and discusses existing pro-competitive regulation that applies to the payment markets. Against this background, it tries to predict the consequences for competition in the payment market of an e-krona.

The analysis suggests that there are at least five possible efficiency reasons for introducing an e-krona (and promoting wide adoption of e-krona accounts):

1. To increase competition for i) banks in the transactions account market by facilitating the unbundling of banking services, ii) providers of clearing and processing services, such as BG, Visa and Mastercard and iii) existing payment services, such as Swish, that depend on the existing clearing and processing service providers.
2. To combine government ownership of a critical asset – control over an e-krona system, including control of the ledger and the API necessary for financial intermediaries to access the e-krona accounts – and vertical separation, as a substitute for a bureaucratic regulatory system that sets prices for wholesale access to the payment system.
3. To avoid a situation where an international private digital currency also establishes itself as the de facto standard currency for domestic payments, with associated market power concerns.
4. To provide the foundations for a simpler routing of payment transactions, one that potentially dispenses with the need for separate clearing and settlement stages and that consequently may offer significant cost savings.
5. To provide a routing of payment transactions that does not depend on clearing and settlement systems based outside Sweden. This would improve the resilience and sovereignty of the Swedish payment system.

The validity of the first argument depends on the level of competition in the retail banking market and in the affected payment systems markets. The number of retail banks in Sweden is relatively large and, compared to many other services markets, the market concentration does not stand out as markedly concentrated. However, consumers' reluctance to switch

between banks weakens the effective competitive pressure and the Swedish Competition Authority has often held up retail banking as a market with relatively weak competition.

In the clearing and processing markets, BG's pivotal position and the fact that it is jointly owned by the dominant incumbents suggest that the introduction of another way to route payment transactions would be helpful, especially for new entrants. There is a history of complaints against the jointly owned systems, suggesting that incumbent banks try to prevent or at least limit new entry into the banking and payment markets by setting high access prices and otherwise impeding entrants' access to the systems. While the international card networks provide some competition and offer alternative routes for payment transactions, Visa and Mastercard are not direct competitors to BG and offer only imperfect substitutes.

However, the capability of an e-krona to intensify competition should be seen against existing regulation that aims to promote competition, such as the PSD2 directive that requires banks to provide access to accounts for payment initiation services. It should also be seen in the light of the chicken-and-egg problem this market shares with other two-sided markets: that consumers are likely to start using e-krona on a large scale only when useful payment services linked to such accounts have emerged – and payment service providers have weak incentives to develop such services before there are customers.

From a regulatory perspective, government ownership of a critical asset, especially in combination with a strategy of restricting the government entity to only those services that are best served by a monopoly – that is, a strategy of vertical separation – is a parsimonious alternative to an extensive regulatory machinery. This has been the model deployed for electricity markets, where governments often retain ownership of the (high-voltage) transmission network. The telecom market is an example of a complex system that has been successfully regulated without government ownership as a cornerstone of the regulatory regime. By and large, the interests of the owners of the networks and that of their access-seeking rivals have been balanced. However, it is an extensive regulation that is costly to maintain. Expressed differently, government ownership of key assets – and regulation – are, to some extent, regulatory substitutes. When the government controls infrastructural bottlenecks, regulation can be less comprehensive.

The third argument in the above list is concerned with the possibility that a private company will be able to obtain at least a temporary dominance over an international digital currency. Even if that company and its technology will eventually be superseded and even if that company is regulated, its ability to exercise market power will not be completely curtailed and it will do its best to deter rivals from challenging its position. This argument stands in addition to the possible benefits that may arise from a better ability to pursue monetary policy if the government controls the monetary base.

An evaluation of the validity of the final two arguments is outside of the scope of this article. They appear, however, plausible at first glance. Finally, it is worth repeating that a maintained assumption has been that the e-krona accounts ledger will be controlled by the Riksbank and made available to banks and other financial service providers (but not to end users) through an open API. Other solutions are possible. For example, the e-krona accounts ledgers could be maintained by commercial banks and then the competitive effects would be different; in this particular case, the pro-competitive effects of introducing an e-krona would be less pronounced.

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Appendix A. Competition issues for debit and credit card networks

A payment card system will need to attract both card holders (individuals) and merchants. A larger number of card holders will make a card more attractive for merchants; wide acceptance among merchants will make a card more attractive for potential card holders. This is known as a two-sided network effect and markets characterised by this phenomenon are often called platform markets.[27]

Card holders typically pay a monthly fee for their card, possibly as part of a larger bundle of bank services. Merchants pay a fraction of the transaction value and/or a per-transaction fee. In principle, each additional card holder adds a marginal cost to the system-wide cost of operating the card scheme, as does each additional card transaction. However, much of the costs will be fixed system costs that need to be allocated, either to the card holders or to the merchants, and this can be done in many ways, depending on the objectives. Typically, this entails adding a margin over and above the respective marginal costs.

It may be that card holders are more price sensitive (have a more elastic demand) than merchants, so that it is socially optimal to have a lower price-cost margin for card holder services than for acquiring services. If card holder demand is sufficiently elastic, the social value of the payment card system may, in principle, be maximised by setting a price below marginal cost, possibly at zero or even below zero. In fact, the card networks have argued that strong two-sided network effects and large differences in price elasticities between the two sides have made it optimal to subsidise cardholders and to surcharge merchants. Historically, credit cards have often been provided free of charge and often also promoted with loyalty schemes and cash paybacks for individuals that use cards heavily.

The card networks can balance the allocation of common costs between the two sides, the card holder side and the merchant side, by setting the fee paid by the acquiring banks to the (card) issuing banks, a fee known as the MIF (multilateral interchange fee). For example, if the acquiring bank has to pay 0.5 per cent of the transaction value to the issuing bank (the bank that has, as one of its customers, the card holder that makes the purchase), the marginal cost of the acquiring bank rises correspondingly and the latter bank will be incentivised to set the merchant fee 0.5 per cent points higher than it otherwise would. Similarly, the issuing bank will have incentives to lower its fee; for example, by introducing a loyalty scheme that awards 'points' or gives cash-backs in proportion to purchases.

Merchants have historically complained that merchant fees have been too high and that the banks (or the card networks) have exploited the fact that they are more or less compelled to accept card payments, so as not to lose customers, and also that fees are much higher than the benefits the merchants derive for receiving electronic payments rather than cash payments. The card networks have made the choice situation for merchants more challenging by adding rules that make it even more difficult for merchants not to agree to pay high merchant fees. One example is the honour-all-cards rule, which stipulated that a merchant that accepted (relatively low-cost) debit card payments from a particular brand (Visa, say) also had to accept (much more expensive) credit card payments. Another example is the no-discrimination rule, under which merchants are allowed neither to surcharge customers that use credit cards to compensate for the merchants' card fees nor to discount prices for customers paying with cash. Such price differentiation could otherwise be used to steer card holders toward the payment instrument that the merchant sees as the most cost effective.

While subsidising card holders and surcharging merchants may be a socially efficient way of increasing network effects, there is also another rationale for shifting revenues from

27 See further in Appendix C.

the acquisition market to the issuing market. If revenues are shifted from a more to a less competitive market, the banks' overall profits increase.[28] It seems likely that the acquisition market, with merchants as the buyers, is more competitive than the issuing market, where the customers are individuals.

In relatively small countries such as Sweden, banks have been able to negotiate the interchange fees bilaterally. Competition law views bilateral agreements as a normal and unavoidable consequence of doing business; hence the presumption will be that an agreement between a seller (for example, an issuing bank) and a buyer (for example, an acquiring bank) will be legitimate. However, when it comes to multilateral agreements, competition law takes a more restrictive view. By its nature, an MIF will be an agreement between multiple sellers and multiple buyers and hence the presumption will be that it is an illegitimate agreement, albeit an agreement that may, depending on the circumstances, ultimately be allowed. It will be tolerated if its positive effects are sufficiently strong and if its negative effects are small and no larger than they have to be.[29]

In large jurisdictions, such as the United States, and for cross-border card transactions, the number of banks is so large that it becomes impractical or even impossible to establish a system based on bilateral agreements. Consequently, MIFs have, in principle, been tolerated by competition authorities such as the EU Commission and its competition directorate. However, since the 1990s, the EU Commission has investigated the card networks' pricing and rule setting. While MIFs may be indispensable and while fees may be set to balance the two sides of the market and to optimise network effects, they may potentially also be used for anti-competitive reasons, as discussed above.

Initially, the EU commission focused on the rules that the merchants had to accept, including the honour-all-cards rule, rather than the MIF itself. In 1999, it informed Mastercard's predecessor Europay[30] that it had concerns that the specifics of some of these rules violated the competition rules. In 2002, it accepted Mastercard's revised set of rules but opened an investigation into the level of its (and Visa's) MIF. In 2007 it found that the MIF violated competition law, a finding confirmed by the Court of Justice in September 2014. In 2009, Mastercard reduced its MIFs to 0.2 per cent and 0.3 per cent for debit and credit card transactions, respectively, in order to comply with the Commission's findings. These caps were subsequently also applied to Visa, in decisions by the EU Commission in 2010 and 2014 and then, in 2015, further confirmed and extended to all card systems when the EU Parliament in April of 2015 adopted the Interchange Fee Regulation, IFR.[31]

The intervention by the EU Commission and the subsequent introduction of sector-specific EU legislation have had the effect that wholesale prices paid by acquiring banks for necessary services have been price regulated. The analogy to consumer prices, the merchant fees paid by retailers to the acquiring banks, have not been regulated. The new rules are intended to reduce upstream prices, after which downstream competition, in the acquisition market, is supposed to result in lower merchant fees. This is in line with the general principles for economic regulation that, since in the early 1990s, have become the established norm. Direct regulation of consumer prices, as in the Cross-border Regulation, is a contradiction of these principles.

To summarise, the international four-party card networks were organised so that they could effectively coordinate the pricing of the participating banks through the level of the MIF. This made it possible for the networks to optimise network effects, potentially increasing the social value of the payment cards – but it also made it possible to increase the

28 Notice that, under this hypothesis, the market elasticity of the issuing market is higher than that of the acquiring market, while each bank faces a (firm) elasticity that is higher in the acquisition market than in the issuing market.

29 This is a simplification of how agreements are analysed under competition law; for more extensive treatments, see standard textbooks.

30 In 2002, (the European) Interpay merged with (the American) Mastercard.

31 IFR, in addition, mandated other changes, intended to increase competition in processing and acquisition. See also Section 3 in the main text.

participating banks' profit at the customers' expense. Revenues could be shifted from the more competitive acquisition market to the less competitive issuing market, increasing the banks' overall profit.

Competition law is applicable, since an MIF by its nature is an agreement concerning prices between several firms. The MIF is the price banks charge one another for issuing services and its level is a main determinant of the fee that the banks charge merchants in the acquiring market. Competition law was used to cap the MIF but subsequently a sector-specific regulation has been adopted. The new regulation puts similar but stronger restrictions on the freedom of the banks and the card networks to set prices and other market conditions.

As a consequence of the new legislation, the pricing of payment card services has been rebalanced, so that (large) merchants pay less. Competition also appears to have become more intense in other respects, although, for heavy card users, the rebalancing of prices has, of course, resulted in less generous rewards from the loyalty programmes.

Competition law was effective since MIFs are agreements that involve multiple banks and affect banks horizontally; then competition law can be used to regulate or at least cap the price level. In contrast, bilateral interchange fees are much more difficult to challenge under competition law. The same goes for transaction and processing fees, which, by nature, are vertical payments from merchants via acquiring banks to the payment card networks. In 2006 and 2007, the corporate structures of Mastercard and Visa, respectively, were transformed from being jointly owned and controlled by a large number of banks, into normal listed corporations.[32]

32 Visa Europe, a membership association and cooperative controlled by several thousand European banks, was acquired by Visa in 2016.

Appendix B. Policy options for market power arising from physical infrastructure

Different policy options have been used at different times and in different markets to manage market failure due to market power. Often the root cause of the problem has been the existence of a physical infrastructure that is indispensable for firms that want to be active in the market and that is so costly that duplication is not a feasible option. This type of problem has long existed and special regulatory institutions have had time to develop. Examples include the transmission and distribution system for electric power, rail tracks and critical parts of the fixed-line telecom network. In some industries, technological developments have resulted in changes regarding which components of the physical network are natural monopolies and which components are not. Much of the telecom network was previously a natural monopoly; today it is mainly the wires or fibres that connect individual subscribers to a switch that remain regulated.[33]

The traditional European solution, used in many countries for electricity, rail and telecom services, as well as for other services, has been government ownership of much of the industry. As an example, the main-line Swedish rail tracks were built by the government and the Swedish Parliament nationalised the private rail tracks in 1939. Similarly, the entire telecom network was owned by the government agency Televerket, prior to liberalisation, incorporation of Televerket and the partial privatisation of Telia, as it is now known. The traditional American solution has, instead, been to regulate the prices of privately-owned firms in these industries, often called utilities.

Since the 1990s, the trend has been towards the liberalisation of previously regulated industries and towards the privatisation of previously government-owned firms (Sweden has seen relatively little privatization, but quite a bit of liberalization). Furthermore, an international consensus has developed that regulation should focus on key bottleneck infrastructural services, rather than on consumer prices. For example, instead of regulating the price of electricity delivered to consumers, price regulation is now restricted to the bottleneck distribution service, while the pricing of the relatively competitive electric-power generation industry has been deregulated in many countries. The Swedish high-voltage transmission network remains government owned, allowing a state-owned entity to be the TMO, the Transmission System Operator.

Ideally, firms active in the competitive segments should successively establish their own infrastructure and, over time, become less dependent on the old incumbent, allowing regulation to be devolved step by step. To a large extent, this is what has happened in the telecom industry, where entrants have invested heavily in proprietary infrastructure and, consequently, access regulation has become confined to the segments of the infrastructure where duplication remains infeasible.

In other industries, however, as infrastructure remains difficult to duplicate, it has not been possible to reduce the scope of the regulation (electricity is an example). At the same time, it has become apparent that it is not enough to regulate access prices; key quality characteristics often have to be regulated as well. A regulated firm that owns infrastructure, while also being active in the downstream market, will typically not be interested in selling to its rivals, particularly not if access prices are held down to a low level. The less access it provides its rivals, the better its own downstream competitive situation, the larger its market share and the better its own ability to charge premium prices. As rivals are hurt when the

33 Network operators' charges for call termination also remain regulated, as discussed below. See Commission Recommendation of 17 December 2007 (2007/879/EC); Commission Staff Working Document Explanatory Note Accompanying the document Commission Recommendation on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services; and Commission Recommendation of 9.10.2014 concerning the same document, at 25.

quality of access services is degraded, regulation must concern itself not only with prices, but also with the quality of access. This has made regulation quite complex, even when the regulatory scope has decreased. While it may be difficult enough to establish a fair access price, in most settings it is even more complicated to define quality standards for access.

In some markets, the critical infrastructure has been vertically separated from the competitive segments. A firm that owns infrastructure, but that is not active downstream, will not have incentives to distort quality. It will likely be willing to sell to all firms, without discriminating against some of them. Vertical separation has thus been seen as a means of achieving a fair and balanced situation. Sometimes, the government remains the owner of the critical infrastructure (for example, rail track, high-voltage transmission and terrestrial broadcasting networks in Sweden); sometimes, critical infrastructure is privately owned (for example, many of the Swedish electricity distribution networks, as well as critical parts of the telecom network). However, vertical separation is no panacea, for at least two reasons.

Firstly, vertical synergies may be lost. Secondly, and perhaps more importantly, price regulation tends to become laxer when every firm pays the same and no firm is competitively disadvantaged by paying too much. It appears that a regulatory authority, which has to balance the interests of an incumbent that wants high access prices against the interests of entrants that want low access prices, can achieve lower access prices than an authority that regulates an industry without such asymmetries. At least, this is the impression given by a comparison of the Swedish telecom market – with asymmetric ownership of key infrastructure and an adversarial position between the incumbent and the entrants – and the Swedish electricity market, with a much more symmetric situation and where the interests of the regulated firms are aligned.

Besides vertical separation and vertical integration, ownership of the key assets can be structured as an infrastructural club. This was the solution chosen for Visa and Mastercard, prior to 2006, and this remains the situation for critical parts of the Swedish payment system, notably BG, DCL and Swish. An infrastructural club combines some of the advantages of the two polar ownership configurations. It allows some vertical synergies; it creates a level playing field for its owners; and its owners can likely prevent access prices from inflating. However, dominant owners may discriminate against new entrants, or even block them completely. Infrastructural clubs are more open to challenges from competition authorities; this may have been a reason for the restructuring of the ownership of the card networks discussed above.

Two important aspects of the economic regulation of physical assets concern which assets to regulate and how to structure the ownership of the industry and its assets. A third aspect is *how* to regulate. A regulated access price should be set high enough that the owner of the asset has incentives to invest, yet low enough that consumers can benefit from low prices. From an economic point of view, two main principles for calculating such prices are, respectively, rate-of-return regulation (also known as cost-plus) and price-cap regulation.

Rate-of-return regulation caps the (access) price that can be charged at a rate that reflects the sum of the per-unit operating expenditures and capital costs. At its core, the latter is calculated as the permissible rate of return plus the depreciation rate times the asset base. In practice, rate-of-return regulation tends to be complex. All cost components can be contested – and are contested. Is it, for example, up to the regulated firm to determine what capital expenditures to include in the asset base? Or does a new investment need regulatory approval for it to be included in the asset base?

A fundamental concern with rate-of-return regulation is that high costs justify high prices, hence blunting the incentives of the regulated firm to be efficient. As an alternative, therefore, price caps based on historical prices in combination with projected productivity gains have been proposed. If the regulated firm can reduce costs faster than predicted, it can keep the difference as profit. In order to reduce risks, cost components that are not controlled by the regulated firm, such as world-market prices of inputs, can be factored into the price cap.

In principle, price-cap regulation creates strong incentives for cost reductions. In practice, however, the price cap will eventually have to be re-aligned to match actual costs. This means that the difference between rate-of-return regulation and price-cap regulation is really the length of the revision period. Long revision periods make the incentives to cut costs stronger, for capital costs too. Consequently, price-cap regulation tends to give weaker incentives for investment. Conversely, rate-of-return regulation may create excessive incentives to expand the asset base. In 2012, a new regulatory model for electricity distribution in Sweden was introduced, based on rate-of-return regulation, although somewhat misleadingly called a revenue-cap regulation. The previous regulatory model, based on price-cap regulation, was discontinued in 2009, following a debate about underinvestment in the distribution networks, as well as the regulatory authority losing a series of court cases. Since the new model's introduction, investments have risen sharply – as have prices.[34]

From a legal point of view, an important design feature of the regulatory model is whether regulation is retrospective or prospective. Under prospective regulation, the regulatory authority sets the maximum price before the regulatory period begins. If a regulated firm is dissatisfied, it must initiate legal procedures to overturn the regulator's decision. Under retrospective regulation, the regulated firms set prices first and the regulator will have to challenge excessive prices in court. Naturally, the party that is allowed to act first will have an advantaged position; the party that initiates a legal challenge will have to satisfy the evidentiary requirements of the court. Table A1 provides examples of how prospective and retrospective regulation have been combined with price-cap regulation and rate-of-return regulation in Sweden.

Table A1. Combinations of regulatory models; examples from Sweden

	Time dimension of regulation with implications for burden of proof		
		Prospective	Retrospective
Basis for calculating maximum permissible price	Price cap	Telecom access regulation[35]	Electricity networks, prior to reform
	Rate-of-return regulation	Electricity networks, after reform	Competition law applied to access pricing

Competition law's main thrust is to prevent market power from arising in the first place. By contrast, (economic) regulation aims to limit an already dominant firm's ability to use its market power to set high prices. In some situations, however, competition law can be used to regulate access prices. Technically, a dominant firm's refusal to provide access at reasonable prices can be construed as (illegal) abuse of dominance. The strength of competition law is its flexibility. In principle, it can be used to regulate the behaviour of any sufficiently dominant firm. Its weakness is that the 'regulation' will be weaker – and sometimes much weaker – than an economic regulation tailored for that industry. Competition-law-as-regulation will be applied retrospectively, although a retrospective decision will have forward implications.

The application of competition law to MIFs, as discussed above, is a typical example. Through the application of competition law, the MIFs of the two dominant card networks were capped. When economic regulation was introduced in 2015, the cap was extended to all card networks and the scope of the regulation became more extensive.

34 https://www.villaagarna.se/globalassets/dokument/resultat-sammanstallning.pdf; Nätföretagens drivkrafter för investeringar, Rapport till energimarknadsinspektionen, 2017-06-16.

35 Telecom regulation is multi-faceted and contains elements of rate-of-return regulation.

Appendix C. Policy options for market power arising from intangible assets

So far, the discussion has focused mainly on tangible assets; expensive physical infrastructure such as rail track or fibre networks. However, network effects and other intangible assets are becoming increasingly important. Especially prominent are the platforms that dominate the digital markets.

Around the year 2000, the concepts 'two-sided markets', 'two-sided network effects', the 'platform business model' and digital (or online) 'matchmaking' became widely used to describe markets where different types of agents meet and interact and where this is facilitated by a set of assets that constitute a 'platform' controlled by a third party. The platform provider and the platform itself facilitate the interaction, while either or both sides of the market are charged for the services received. Platforms can be digital, but they can also be physical. Sometimes the platform inserts itself in the transaction chain, so that parties on both sides contract with the platform; sometimes the platform just provides the opportunity for parties to contract directly. See Table A2 for examples.

Table A2. Examples of platforms

	Nature of the platform's role: matchmaking only or transaction party		
Nature of the platform's key assets: physical or digital		Matchmaking only	Party to transactions
	Physical	Shopping mall; night club	Telephone networks
	Digital	Blocket (Internet classified ads)	Credit-card network, Amazon

Besides the platform itself, the number of customers or clients on one side of a two-sided market will be critical for its value to the other side of the market. As discussed above, a credit card network is valuable to card holders in proportion to the number of merchants that accept the card; it is valuable to merchants in proportion to the number of card holders that are inclined to use the card. If the network effects are strong enough, if it is costly to use more than one platform and if customers' preferences do not vary too much, there may be a tendency for platform markets to 'tip' – that is, for all customers on at least one of the sides to adopt the dominant platform, once it becomes dominant enough.

Politicians have so far been less willing to regulate platform markets than the owners of physical infrastructure, even when a single platform has become dominant. The 2015 EU regulation of the credit card industry, as discussed above, is an exception. Another exception is the regulation of termination access in telephone networks. Even small network operators are mandated to provide access for incoming calls to their own customers and are not allowed to charge the originating operator more than the maximum rate, as set by the telecom regulator.

Competition authorities, however, have used their tools to intervene in some platform markets. The EU Commission's competition directorate's actions against the international card networks are discussed above. The Swedish Competition Authority has also acted against card networks and it has used competition law to challenge hotel booking platforms.

In special situations, competition law can be used to achieve de-facto access regulation to physical infrastructure. It will not be as forceful as sector-specific regulation and it will only be effective against dominant companies and against agreements between firms, but it requires no sector-specific legislation and can be applied in contexts and situations not anticipated by the legislator. In contrast, economic regulation can apply to relatively small companies that have local monopolies or that act as gatekeepers to particular assets to which other firms need to connect.

Another early example of how competition law has been applied to network industries and platforms is the interest the US antitrust authorities took in Microsoft's operative system Windows and the emerging internet browsers in the 1990s. The operative system was a platform that attracted software developers on one side of the market and individuals and enterprises that owned desktop and laptop computers on the other. Windows was an attractive choice for consumers, as numerous applications had been developed to run on Windows; it was attractive for developers because Windows had a large customer base.

In 1998, the US Department of Justice (DoJ) sued Microsoft for tying the internet browser Internet Explorer (IE) to Windows, in violation of an earlier settlement. Microsoft argued that IE was a feature, not a separate product tied to Windows.[36] According to the so-called theory of harm proposed by the DoJ, the rival internet browser Netscape, in combination with the software Java, represented a threat to Microsoft's dominance on the market for operative systems for desktop and laptop computers – and Microsoft tried illegally to thwart that threat. As Netscape and Java became ubiquitous, software developers would increasingly have incentives to design software that could run on Netscape and Java, hence threatening to make Windows dispensable or, at least, threatening to break Microsoft's near monopoly in the market for operative systems.

Microsoft used a series of anti-competitive practices to stop the growth of Netscape and to boost the market share of its own IE. Although Netscape, initially the market leader, could offer similar features as IE, it failed to overcome the strong network effect created when IE was tied to Windows and the pressure of a range of anti-competitive actions. The first court instance established that Microsoft had used illegal practices and ordered the break-up of Microsoft into two entities, but this was overturned by the appeals court. In a settlement, Microsoft agreed to share so-called applications programming interfaces with third parties but was allowed to continue providing IE for free. The efficacy of this measure for curbing Microsoft's dominance and market power has been debated.

Subsequently, however, Microsoft's grip on the market has been weakened. It is now down to about 75 per cent from about 90 per cent five years ago, although this is mainly due to a technological shift towards smartphones and tablets.[37] Considering all platforms (desktops, laptops, smartphones and tablets), Microsoft is far behind Google's Android operative system and also behind Apple's IOS.

The evolution of the computer and software markets shows that new technologies will eventually leapfrog old monopolies: IBM's hold on the market was superseded by Microsoft and the rise of desktop computers, which, in turn, was challenged by Google's Android system and Apple's IOS. Although these companies are now, in turn, under scrutiny for anti-competitive practices, it is likely that they will eventually be challenged by new rivals building their strength on new yet-to-emerge technologies.

However, it is also apparent that significant competition problems can persist for many years before a new technology emerges. The companies that have replaced Microsoft as the new dominants in the tech market – Facebook, Google and Apple – are accused of stifling competition in the markets they have come to dominate and are now attracting the attention of competition authorities.

36 Tying is an arrangement where, in order to buy one product, the consumer must purchase another product that exists in a separate market. One way to achieve a tie is to bundle two products, so that one (the tied product) comes with the purchase of the other (the tying product). Tying by a dominant firm can be a violation of competition law.

37 https://www.statista.com/statistics/218089/global-market-share-of-windows-7/

The Riksbank's seigniorage and the e-krona

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Seigniorage has historically been an important source of profits for the Riksbank. In recent years, the use of cash in Sweden has declined rapidly, and a future possibly cashless society could have important consequences for the Riksbank's financial independence. This article contains a discussion and some numerical examples of how the introduction of an e-krona could affect the Riksbank's ability to generate profits. Several factors affect the results: whether the e-krona would be regarded as a substitute for cash or bank deposits, how high the demand for the e-krona would be, and the level of the interest rate. As a final part of this article, we address the question of how high the demand for an e-krona would have to be to cover the Riksbank's current expenses.

1 Background

Seigniorage has historically been an important source of profit for the Riksbank, being instrumental in securing the Riksbank's financial independence. In recent years, the use of cash in Sweden has declined rapidly and a cashless society no longer appears distant. The decline is a result of both technological advances and agents preferring other means of payment, where physical cash has been substituted for private account-based services. If no measures are taken to secure the Riksbank's profits in an environment with low or no seigniorage, the financial independence of the Riksbank could eventually be threatened.

The role of seigniorage in generating profits for the Riksbank is discussed in detail in Kjellberg and Vestin (2019), henceforth K&V (2019). Using their analysis as a starting point, this article contains a discussion and some numerical examples of how the introduction of an e-krona could affect the Riksbank's ability to generate profits.

2 A cashless society might require new ways of funding the Riksbank

In principle, seigniorage could be defined as the share of the Riksbank's interest income that is financed by the issuance of cash. As discussed in K&V (2019), historically, the Riksbank's balance sheet has been constituted of a foreign exchange reserve financed by cash and, to a smaller extent, equity. However, the balance sheet has changed in recent years, partly by a considerable amount of government bonds, following the Riksbank's QE programme, and partly by the recent large asset purchases during the Corona crisis. In both cases, the purchases have been financed by bank reserves; see Sveriges Riksbank (2020). The fact that equity has remained roughly unchanged and demand for cash is lower implies that the Riksbank has less access to interest-free funding than before, lowering its seigniorage.

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Earlier official inquiries into the Riksbank's balance sheet and financial independence, known as the Bonde (SOU 2007:51) and Flam (SOU 2013:9) inquiries, primarily investigated the amount of equity necessary to secure financial independence, taking a certain demand for cash as given. These inquiries were less concerned with the consequences of lower demand for cash and its effects on the Riksbank's ability to generate profits.[1] The Riksbank Committee, which consisted of representatives of all the parties in the Riksdag (the Swedish Parliament), presented its final report, 'A new Riksbank Act', to the Government in November 2019; see SOU 2019:46. Chapters 28–31, 'The Riksbank's institutional and financial independence' discuss issues regarding the Riksbank's balance sheet and financial independence. Once again, the focus is on the amount of equity. One of the proposals is the introduction of an indexed target level for the Riksbank's equity, meaning profits are only transferred to the Treasury if the target level is exceeded. Further, it is proposed that a procedure is prescribed in law for restoring the Riksbank's equity if it falls below a certain level.

According to recent annual reports from the Riksbank, cash is now a very small part of the balance sheet and seigniorage constitutes a minor share of the Riksbank's annual profits. This can largely be explained by the Riksbank's purchases of government bonds for monetary policy purposes in recent years. These bond purchases have led to a rapid growth in the balance sheet and, as the bond portfolio has been financed by central bank reserves, the relative role of cash in financing the Riksbank's assets has decreased. Thus far, the bond portfolio has generated higher-than-expected profits as the repo rate has turned out to be lower than was expected at the time of the bond purchases. As a consequence of the Corona crisis, the Riksbank has purchased additional government bonds, in combination with other securities, such as covered bonds and commercial paper, and the purchases have been financed by central bank reserves. Future profits from the asset portfolio are uncertain, which may affect the relative importance of seigniorage.

If the trend of declining cash demand continues and demand approaches zero, the lack of seigniorage would then raise the question of how the Riksbank should be funded in order to preserve its financial independence. K&V (2019) conclude that it may be difficult for the Riksbank itself to accumulate sufficient equity and discuss different sources of earnings in detail. These include (i) return on equity, (ii) return on long-term bonds financed by monetary policy debt and (iii) bank fees, such as revenues from interest-free reserve requirements.[2]

If the Riksbank decides to introduce an e-krona, another potential source of earnings arises. The importance of this source depends on numerous factors. In the rest of this article, we will look more closely at this issue.

3 How would the introduction of an e-krona affect the profits of the Riksbank?

At this point in time, no decision has been made to introduce an e-krona. This means that little is known about its specific design and features. When assessing the potential consequences for the Riksbank's profits of introducing an e-krona, it is necessary to consider both the potential level of demand and the profit per issued e-krona. The exact determinants of the demand for an e-krona are of course highly uncertain, but are likely to involve several

1 In SOU 2013:9 (2013), it is stated (our own translation from Swedish): 'Should the amount of outstanding cash become so small that the targeted level of cost-free capital is not achieved, this should be regulated by profits being withheld at the Riksbank and transferred to equity.'

2 The financing model of reserve requirements is currently used by the Bank of England. Banks that benefit from central bank services such as liquidity supply are obliged to hold a certain amount of interest-free reserves at the BoE, increasing the central bank's amount of interest-free capital. Fees are differentiated on the basis of the risk the bank poses to financial stability. Seigniorage is passed on to the government.

factors related to its design. On the one hand, demand could be expected to depend positively on the return on the e-krona. On the other hand, regarding the profit per issued e-krona, an interest-free e-krona gives a profit similar to that of cash, while it is lower for an interest-bearing e-krona. In this section, we define seigniorage as profits from issuing cash or e-krona, interest-bearing or not, contrasting slightly to the traditional definition.

If e-krona were easier to transfer than regular cash, it would be reasonable to expect the same amount of transactions to require fewer e-krona, thus increasing the velocity of money. However, in the following examples, we assume that the introduction of the e-krona will not affect velocity. According to the quantity theory of money, this leaves the total money stock unchanged.[3]

3.1 Would the e-krona replace cash, deposits or both?

The current demand for cash amounts to about SEK 60 billion. As a baseline for the analysis, we therefore consider the following, extremely simplified Riksbank balance sheet, before the issuance of the e-krona. This could also be viewed as the 'seigniorage-generating part' of the balance sheet.

Assets		Liabilities	
Government bonds	60	Cash	60

First, assume that the nominal return of the Riksbank's assets is 3 per cent. This would yield a baseline seigniorage of 60 × 0.03 = SEK 1.8 billion. In the examples below, we assume that the Riksbank issues 60 billion e-krona, roughly equal to the outstanding value of cash.

Example 1: Assume that the introduction of the e-krona would cause agents to substitute all of the outstanding cash (SEK 60 billion) for e-krona.

Assets		Liabilities	
Government bonds	60	E-krona	60

In the case of an interest-free e-krona, seigniorage is unchanged at SEK 1.8 billion. If, in contrast, we assume an interest-bearing e-krona with an interest rate 0.5 per cent lower than the return on the Riksbank's assets, i.e. the government bond yield, this would see seigniorage fall by 60 × (0.03 – 0.005) = SEK 1.5 billion, eliminating more than 80 per cent of the seigniorage.[4]

Example 2: A fundamental question concerns the motivation for holding e-krona. For illustrative purposes, we could make the extreme assumption that the introduction of an e-krona would not affect the demand for cash, with agents instead viewing the e-krona primarily as a substitute for bank deposits. The question then arises why agents would be willing to switch from bank deposits to the e-krona. If the e-krona is interest-free or has an interest rate lower than the bank deposit rate, this could be motivated by agents wanting to pay a premium to avoid costs associated with future bank defaults, or agents viewing the

3 According to the theory, M × v = P × Y, which means that M = P × Y/v.

4 Alternatively, we could assume that money velocity increases and agents substitute cash amounting to SEK 60 billion for 40 billion e-krona. In this case, the balance sheet shrinks by SEK 20 billion and seigniorage decreases even more than if money velocity were to be unchanged. The introduction of an interest-free e-krona would, in this case, cause seigniorage to decrease by (60 – 40) × 0.03 = SEK 600 million. If the e-krona instead were to yield interest, seigniorage would fall by (60 × 0.03) – (40 × 0.005) = SEK 1.6 billion.

e-krona as a more convenient and safe form of money than bank deposits, for example. If agents substitute SEK 60 billion of their bank deposits for the same amount of e-krona, the balance sheet of the Riksbank would be expanded to 120 billion.[5]

Assets		Liabilities	
Government bonds	120	Cash	60
		E-krona	60

In the case of an interest-free e-krona, seigniorage would double compared to the baseline as it increases by 60 × 0.03 = SEK 1.8 billion. If the e-krona instead were to yield interest, the additional seigniorage would amount to 60 × 0.005 = SEK 300 million.

Example 3: Assume instead that agents substitute *equal amounts* (SEK 30 billion) of their cash and bank deposits for e-krona. In this case, the balance sheet of the Riksbank would be expanded to 90 billion.

Assets		Liabilities	
Government bonds	90	Cash	30
		E-krona	60

In the case of an interest-free e-krona, seigniorage would increase by (90 – 60) × 0.03 = SEK 900 million compared to the baseline. If the e-krona instead were to yield interest, seigniorage would decrease by (30 × 0.03 + 60 × 0.005) – (60 × 0.03) = SEK 600 million.

3.2 How high would the demand for an e-krona be?

Segendorf (2018) has estimated the potential demand for the e-krona, in order to meet the need for transactions, to be in the region of 1–2 per cent of Swedish GDP, roughly equal to the outstanding value of cash, in line with the stylised examples above. Juks (2018) estimates the potential demand from a savings and investment perspective, and arrives at a number amounting to approximately 2.5 per cent of GDP. Adding these numbers together, an estimation of the total demand for the e-krona would be higher than in the previous examples and amount to about 3.5–4.5 per cent of GDP.

Example 4: As a sensitivity analysis, one could assume that the demand turns out to be twice as high, i.e. 7–9 per cent of GDP. The mid-point of this interval, 8 per cent of GDP, corresponds to about SEK 400 billion. For simplicity, assume that agents substitute *equal shares* of their cash and bank deposits for e-krona. As the total value of household bank deposits currently amounts to roughly SEK 1,500 billion and the total value of cash amounts to 60 billion, the sum of the two is about SEK 1,560 billion. This means that the share of cash and deposits replaced is 400/1560, which is about 25 per cent. The remaining cash demand would thus amount to 75 per cent of current demand, i.e. SEK 45 billion.

5 This is similar to a QE programme where an expansion of the government bond portfolio is financed by the issuance of an e-krona instead of central bank reserves.

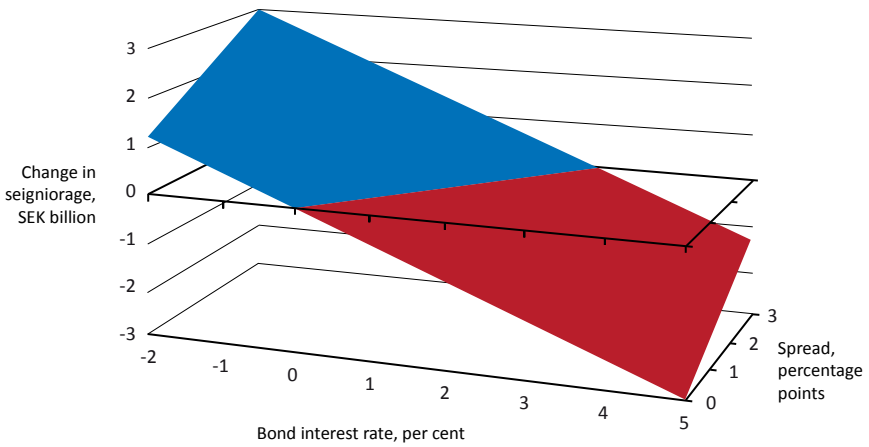
Assets		Liabilities	
Government bonds	445	Cash	45
		E-krona	400

In the case of an interest-free e-krona, seigniorage would increase by (400 + 45 – 60) × 0.03 = SEK 11.6 billion compared to the baseline. If the e-krona instead were to yield interest, seigniorage would increase by (45 × 0.03 + 400 × 0.005) – (60 × 0.03) = SEK 1.6 billion. A very high demand for the e-krona would thus mean a considerable increase of the Riksbank's balance sheet and the holdings of government bonds. If the Riksbank is assumed to provide the amount of e-krona demanded by the public, this is an inevitable consequence. Nevertheless, the interest rate risk on the balance sheet would increase, which is a factor that needs to be recognized. Flodén (2018) discusses this issue in relation to the Riksbank's large purchases of government bonds in recent years. If a significant portion of bank deposits is being substituted for e-krona, there will also be consequences for the banks' funding models; deposits will be substituted for market funding. See Juks (2018) for an analysis of this question.

3.3 How would e-krona seigniorage depend on the interest rate?

Example 1 above illustrates the broad question of how much the Riksbank's seigniorage would be reduced if all cash were to be replaced by e-krona with interest. We have assumed a bond interest rate of 3 per cent and interest differential or spread of 0.5 percentage points between the bond and e-krona rate. Figure 1 contains a sensitivity analysis, illustrating the effect on seigniorage in SEK billion for different levels of the interest rate and spread. The red and blue areas correspond to the change in seigniorage being negative and positive, respectively. The line dividing the red and blue areas denotes the introduction of an interest-free e-krona without any change in seigniorage. For an interest-bearing e-krona, the most negative impact on seigniorage would take place in an environment with high interest rates and a low spread. This is because cash, with an implicit interest rate equal to zero, would constitute much cheaper financing than the e-krona. In contrast, if the e-krona were to be introduced in an environment with negative interest rates, an increase in seigniorage could occur, as cash would constitute relatively expensive financing compared to the e-krona. A higher spread would amplify this effect.

Figure 1. Change in seigniorage if cash is replaced by an e-krona for different levels of the interest rate



Source: Own calculations

3.4 How high demand for e-krona is necessary to cover the Riksbank's current expenses?

Another question regarding the replacement of cash by an e-krona is the following: Given the current funding model and demand for cash, what demand for the e-krona would be needed to maintain stable, long-term funding for the Riksbank? According to K&V (2019), assuming a steady-state nominal interest rate of 3 per cent, the cash demand required to generate a revenue roughly corresponding to the Riksbank's costs (SEK 900 million), amounts to approximately SEK 30 billion.[6] If the e-krona were to be interest-free, the necessary demand would be the same as for cash, that is, SEK 30 billion. If we maintain our initial assumption of an interest rate differential between the bond rate and the interest-bearing e-krona of 0.5 percentage points, the demand required to cover the costs would amount to 900/0.005 = SEK 180 billion. This represents three times the value of today's outstanding cash of approximately SEK 60 billion, but only about a tenth of household bank deposits.

4 Conclusion

Given that very little is known about the specific features of a future e-krona, its effects on seigniorage are thus uncertain. Relying on a set of simple assumptions, we have arrived at some preliminary conclusions. One conclusion is that it is important to understand whether the public would view the e-krona as a substitute for cash or bank deposits. If an interest-bearing e-krona were simply to replace cash, a significant reduction of seigniorage would be likely. However, varying the assumptions of the level of the interest rate and the spread of the bond rate over the e-krona rate could yield different results. Naturally, an interest-free e-krona replacing the current cash would leave seigniorage unchanged.

If cash demand instead remains the same as today and agents substitute a fraction of current bank deposits for the e-krona, additional seigniorage could be extracted, even if it is interest bearing. However, all things being equal, this would require an expansion of the Riksbank's balance sheet.

K&V (2019) estimate that the necessary cash demand to secure the long-term financing needs of the Riksbank amounts to half of the currently outstanding cash. Our calculations indicate that, under the baseline assumptions, demand for an interest-bearing e-krona needs to be in the order of three times current outstanding cash, representing about 10 per cent of households' current bank deposits and just over 3 per cent of GDP.

6 A more detailed discussion is provided in section 4.4 in K&V (2019).

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Central bank digital currencies, supply of bank loans and liquidity provision by central banks

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A frequently voiced concern about a central bank digital currency (CBDC) is its potentially adverse effects on the supply of bank loans. We explore this concern in a setting where banks can create unlimited amounts of loans and deposits in their own books but must satisfy customers' outflows to other banks and cash. We show how the current stickiness of retail deposits allows banks to create lending volumes that are 10 or more times their own liquidity reserves. The CBDC may reduce the stickiness of these retail deposits and reduce the lending capacity of banks. However, central banks have tools to offset the effects of CBDC on the lending capacity of banks if so is deemed necessary.

1 Introduction and preliminaries

A frequently voiced concern about the issuance of a central bank digital currency (CBDC) is its potentially adverse effects on the supply of bank loans and thereby macroeconomic activity.[1] Some have therefore suggested that the demand for CBDC should be managed, for instance, via a time-varying interest rate spread between CBDC and the policy rate.[2]

This paper studies the effects of CBCD on the supply of bank loans in a setup where the demand for CBDC is not managed. CBDC is modelled as cash in an electronic form: it is non-interest-bearing and depositors can at will exchange their bank deposits for CBDC, exactly as they can exchange their bank deposits for physical cash in the current system.

The paper builds on a model of bank loan supply that is based on the actual practice of banking. In the model, banks can create potentially unlimited amounts of loans and deposits in their own books.[3] When banks give out loans and create deposits, they must also make sure that they can satisfy customers' outflows to other banks, cash or CBDC. To satisfy these outflows, banks need central bank reserves. For this purpose, banks hold a portfolio of central-bank-eligible collateral which can be exchanged for central bank reserves at the central bank's lending facility.

It is worth emphasising that the paper is conceptual in nature. No sharp policy conclusions on the actual effects of a CBDC on the supply of bank loans can be drawn from the paper. The sole purpose of different examples provided in the paper is to illustrate the underlying mechanisms. The paper also ignores the benefits of issuing CBDC and no attempt is made to weigh pros and cons of issuing a CBDC.

The rest of this paper is organised as follows. We start with a model that relates banks' supply of loans to potential outflows. Potential outflows are then linked to the savings rate,

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1 This concern is especially well reflected in a speech by the general manager of BIS: 'Central bank digital currencies at the retail level have very serious consequences, and they are not easily tackled', see Carstens (2019).

2 See, for instance, Kumhof and Noone (2018). When the demand for CBDC is managed, the effects of CBDC on banks would be modest, see Juks (2018) and Bindseil (2020).

3 For an accessible primer for how banks create credit, see McLeay et al. (2014).

size of cash withdrawals and the magnitude of runs. CBDC is then introduced and its effects on potential outflows and hence on the supply of bank loans are discussed. Next, banks' measures to deal with increased outflows are discussed. Finally, it is discussed how central banks can offset potentially adverse effects of CBDC on the supply of bank loans.

2 Banks' loan creation with and without CBDC

2.1 A model of bank loan supply

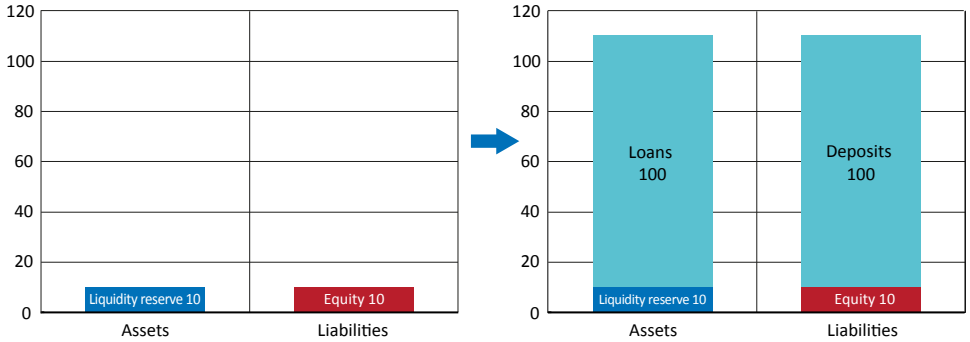
Consider a typical bank that is about to start its operations. The bank has some amount of own funds held in a liquidity reserve, that is, a portfolio of central-bank-eligible collateral. The bank can create unlimited amounts of loans and deposits in its book in a digital form.[4] However, when deposits are used for payments, outflows to other banks and to cash or CBDC, if available, may occur. These outflows can be only met in central bank reserves, giving rise to banks' demand for central bank reserves. The bank can lend and borrow reserves via interbank markets, but only on a secured basis using central-bank-eligible collateral.[5]

The central bank supplies central bank reserves against eligible collateral via its lending facility and exchanges reserves for cash or CBDC, if available, whenever the demand for these central bank liabilities arises.[6] The central bank also maintains the system of electronic payments, where banks can make payments between themselves in central bank reserves. Payments between banks arise whenever the clients of one bank make payments to the clients of other banks.

The setup outlined above allows the calculation of a bank's lending capacity as a function of its liquidity reserve and the size of potential outflows. To illustrate the mechanism of the model, consider a bank that has 10 units in its liquidity reserve (see Figure 1). The bank is assumed to operate in an environment where the size of potential outflows is estimated to be up to 10 per cent of deposits. In this environment, the bank has a capacity to create 100 units of loans. When the bank issues 100 units of loans, it simultaneously creates 100 units of deposits. These deposits can give rise to a potential outflow up to 10 units. Since the bank has 10 units in its liquidity reserve, it can borrow reserves from the central bank against its liquidity reserve and meet potential outflows stemming from deposits.

Figure 1. A stylised example of a bank's lending capacity if the size of potential outflows of deposits is 10 per cent

Units of money



4 Digital loan and deposit creation by banks nowadays can be compared with the issuance of banks' own notes and bills in 19th century Sweden. For more information on banks' issuance of notes and bills, see Sveriges Riksbank (2020). Note also that banks must comply with capital and many other regulations, something that is ignored in this model.

5 In practice banks can also borrow to some degree via unsecured interbank markets, but this source of borrowing is not available during times of distress.

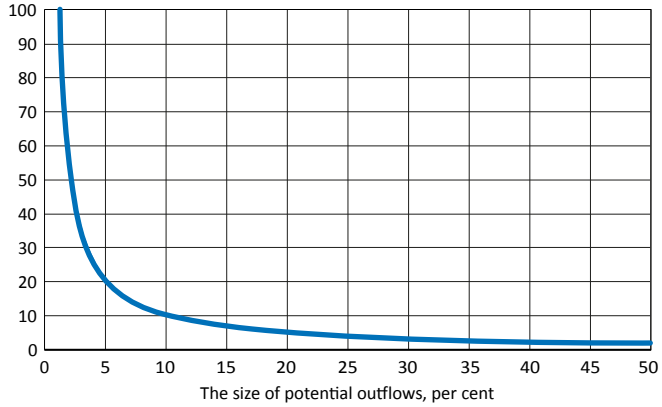
6 By applying interest rates on their deposit and lending facilities, central banks can influence the interest rates that banks apply on their deposits and loans.

A bank's lending capacity can be also expressed as a multiple of its liquidity reserve. For the bank in Figure 1, the lending capacity would be 10 meaning the bank can lend out 10 times its liquidity reserve. When the lending capacity is expressed as a multiple of the bank's liquidity reserve, the only remaining parameter that determines the bank's lending capacity is the size of potential outflows.

As illustrated in Figure 2, banks' lending capacity increases (decreases) exponentially as the size of potential outflows decreases (increases). When the size of potential outflows is below 5 per cent, banks' lending capacity is at least 20 times their liquidity reserves. When the size of potential outflows is between 5 and 10 per cent, banks' lending capacity is between 10 to 20 times their liquidity reserves. As the size of potential outflows approaches 100 per cent, banks' lending capacity reaches one. This case corresponds to a situation where banks lend out cash, but none of this cash ever returns to banks in the form of saving deposits.[7] We return to this case in the next section.

Figure 2. Banks' lending capacity as a function of the size of potential outflows

Lending as a multiple of liquidity reserve funded by equity



Note. Banks' capacity to lend is calculated as the inverse of the size of potential outflows.

2.2 Understanding the size of potential outflows from retail deposits

When banks create deposits by granting loans, all deposits are initially held for transaction purposes. Yet, after initial borrowers have used their deposits for various payments, other economic agents receive these deposits as an income. This income can be either consumed or saved. When income is consumed, deposits are used for transaction purposes. When income is saved, deposits are used to make financial investments. Below we explain in detail how outflows occur when deposits are used for either consumption or savings. Our focus is on retail deposits, that is, deposits held by households and small and medium-sized enterprises.

2.2.1 Outflows from retail deposits that are held for transaction purposes

When deposits are consumed and thus held for transaction purposes, depositors can choose between electronic demand deposits and physical cash. When depositors use cash as means of payment, outflows will occur. Banks will then need to buy more cash from the central bank against their liquidity reserve.

7 This case is similar to the loanable funds model where banks are assumed to be pure intermediaries rather than liquidity creators. For more information on the loanable funds model, see e.g. Jakab and Kumhof (2019).

When depositors use demand deposits for electronic payments, payments will occur between different banks. Whenever a client of one bank makes a payment to a client of another bank, the bank of the paying client sees an outflow while the bank of the receiving client sees an inflow. In other words, payments with demand deposits redistribute liquidity reserves between banks: banks that have more outgoing payments than incoming payments during a day see a daily outflow and hence reduction in their reserves while banks that have more incoming payments than outgoing payments during a day see a daily inflow and hence an increase in their liquidity reserves.

The amount of liquidity reserve that is needed to facilitate payments with demand deposits is small in relation to the stock of demand deposits. This result is partly driven by the fact that income is consumed gradually over time and only a fraction of all demand deposits held for transaction purposes are actually used every day. Another reason for this result is that incoming and outgoing payments during a day tend to be equal resulting in zero outflows for individual banks. This result holds naturally in a banking sector where banks are identical in terms of size, customer base and new lending. When banks differ in business models, structural outflows may occur for individual banks. Yet, these outflows are likely to be temporary in normal times since both reserve-losing and reserve-winning banks have incentives to actively adjust their activity.[8] Banks that experience frequent daily outflows see their liquidity reserves go down. To manage future potential outflows, these banks have clear incentives to reduce outflows for instance by temporarily slowing down new lending. Similarly, banks that experience frequent daily inflows see their liquidity reserves increase. Since holding more reserves than are needed weighs negatively on banks' profitability, these banks have an incentive to increase outflows, for instance, by increasing their new lending. In the end, these active choices reduce any structural imbalances between banks, allowing both groups of banks to achieve lending volumes that are large in relation to their liquidity reserves.

Even if demand deposits held for payment purposes generate close to zero daily outflows on average, individual banks would still need to hold some liquidity against demand deposits for two reasons. First, there is always some random volatility in outflows even if outflows on average are close to zero. Due to the law of large numbers, this volatility is naturally low when demand deposits are held by a large number of small retail clients, such as households and small and medium-sized enterprises. Second, demand deposits are subject to run risk. The amount of liquidity required to deal with runs is substantial even when referring to retail deposits. When mistrust against a bank or banks occurs, retail depositors may choose to move their funds away from the troubled banks. An outflow from retail deposits that is typically close to zero can in this case increase significantly for the banks concerned. In practice, it is this possibility of runs that makes banks hold a considerable amount of liquidity reserves against demand deposits held for transaction purposes.

2.2.2 Outflows from retail deposits that are used for savings

Some income that is received via deposits is saved rather than consumed. Depositors can use liquid demand deposits for savings, but most likely they would look for more attractive savings opportunities.[9] Typically, individual retail depositors use intermediaries to allocate their savings. When a few large asset managers receive a large pool of retail deposits, a large part of banks' retail deposit stock is converted into wholesale deposits controlled by a few actors. These wholesale deposits require larger liquidity reserves than retail deposits. However, instead of holding larger liquidity reserves, banks can manage outflows from these wholesale deposits by offering savings in term deposits and bonds. When these

8 In normal times, unsecured interbank markets may also work to some extent, reducing the need for banks to hold liquidity against random imbalances between incoming and outgoing payments.

9 If demand deposits are held for savings, banks would need to hold some liquidity against these demand deposits due to run risk.

wholesale deposits are invested in long-term funding instruments issued by banks, these wholesale deposits are stabilised and no outflows occur during the maturity of these funding instruments. In sum, banks have good opportunities to minimise outflows from saving-oriented retail deposits by offering them suitable saving products.

2.2.3 A numerical illustration of potential outflows from retail deposits

As explained previously, retail deposits are held for either transaction or saving purposes. Banks need to hold some liquidity against transaction deposits to cover potential outflows due to cash withdrawals and the risk of runs. To manage outflows from the saving part of retail deposits, banks can offer investments in stable funding instruments. Outflows from these deposits can therefore be considered to be zero since the maturity of stable funding instruments can be matched with the maturity of loans.[10] The total outflow factor for banks, in our example, can therefore be calculated as a product of the share of transaction deposits (i.e. the non-saving part of deposits) and the outflow factor attached to transaction deposits.

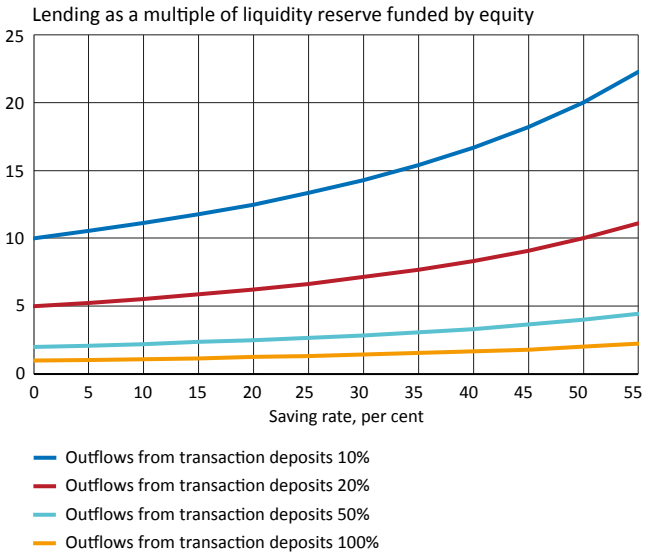
Figure 3 illustrates what different saving rates and outflow factors from transaction deposits (which themselves are driven by cash withdrawals and the risk of runs) mean for banks' lending capacity. The increased saving rate naturally increases banks' lending capacity since outflows from deposits held for saving purposes can be managed without holding any liquidity reserve, that is, these outflows can be managed via the issuance of long-term funding instruments (all lines are upward sloping in Figure 3). Increased outflows from transaction deposits naturally decrease banks' lending capacity for any given saving rate. As the risk of runs or withdrawals to cash increase, more liquidity must be held against every unit of deposits that is held for transaction purposes (see the downward shift in curves as outflows from transaction deposits increase).

There are two interesting cases presented in Figure 3 that are worth explaining in more detail. The first one is when outflows from deposits held for transaction purposes are 100 per cent and the second one is when the saving rate is zero.

The first case describes a world where loans are granted only in central bank money such as cash and where central bank money is used as the only means of transaction. In this world, banks' capacity to lend would entirely depend on the saving rate. With the saving rate of zero, banks will have 100 per cent outflows and banks' capacity to lend will be 1 (see the yellow line at the point of zero saving rate). In this world banks lend out cash, but none of this cash ever returns to banks in the form of transaction or saving deposits. Hence, banks cannot lend more than they have in their liquidity reserves. With the saving rate larger than zero, banks' lending of cash also generates an inflow of cash which in turn can be used to make additional lending so the total amount of bank lending will exceed that of banks' initial liquidity reserves.

10 This is a simplification. In practice, banks may not entirely match the maturity of their market funding with the maturity of loans. Also, some demand deposits may be held for saving purposes, which exposes them to the risk of run, thereby requiring the holding of liquidity reserve.

Figure 3. Banks' capacity to lend for different combinations of saving rates and outflows from transaction deposits



Note. The saving rate is used to divide deposits into two: saving and transaction deposits. The total outflow factor for all deposits can then be calculated as a weighted average of outflow factors for two types of deposits. The outflow factor for saving deposits is assumed to be zero, while the outflow factor for transaction deposits varies between 10, 20, 50 and 100 per cent. The total outflow factor is then used to calculate lending capacity as an inverse of the outflow factor, just like in Figure 2.

We can illustrate the lending process with the saving rate of 50 per cent (see the yellow line at the point when the saving rate of 50 per cent). In this case, banks' capacity to lend is 2, that is, banks can have a lending volume that is twice the amount of their own liquidity reserve. This lending can be created in a following way. First, banks lend out the amount of cash that is equal to their entire liquidity reserve. This initial lending then generates the need for savings that banks can satisfy for instance via term deposits. This means that after the initial lending, there will be an inflow of cash to banks that corresponds to 50 per cent of their initial lending. This inflow can be used for the second round of lending, which in turn generates an inflow of cash corresponding to 50 per cent of the second lending. The process continues until banks reach lending volumes that are twice the amount of their initial liquidity reserve. All these loans would be funded by 50 per cent of banks' own funds and 50 per cent of term deposits representing savings that were created in the economy.

The second case corresponds to a world where no depositor is willing to save in illiquid claims. In this world, all deposits created via lending will be held in the form of liquid demand deposits. In such a world, banks can still achieve high lending capacities provided that outflows from transaction deposits are relatively low. For instance, when the risk of runs and withdrawals to cash are estimated to be 10 per cent of these deposits, banks can still create illiquid bank loans that correspond to 10 times their liquidity reserves (see the interaction of the blue line with the y-axis). This case is a vivid illustration of how banks can fund some illiquid investments even when no-one in the economy is willing to hold illiquid claims.

2.3 The impact of a CBDC on the supply of bank loans

In the model, it is the size of potential outflows that determines banks' capacity to lend. Since banks can offer long-term funding instruments for retail deposits held for saving purposes, outflows stem mainly from retail deposits held for transaction purposes. While these deposits do not create any significant outflows in normal times, outflows can become significant in times of distress due to bank runs.

The introduction of a CBDC can affect banks' outflows in both normal as well as stressed times. In normal times, a CBDC can act as a natural competitor to a part of retail deposits held for transaction purposes. In stressed times, a CBDC can cause larger outflows than are possible currently, as a CBDC is more attractive competitor to bank deposits than physical cash is in times of systemic stress.

In this section, we consider the effect of a CBDC on outflows in distressed times. Our focus is on stressed times for two reasons. First, while a CBDC can also affect outflows in normal times, the effect of a CBDC on banks in normal times is likely to be insignificant. This is because bank deposits are interest-bearing, while a CBDC is not, giving banks a crucial advantage over a CBDC in normal unstressed times. Second, outflows in stressed times are larger than outflows in normal times. It is therefore the size of outflows in stressed times that is a binding constraint for banks. This result holds irrespective of whether there is a CBDC or not.

2.3.1 The current estimates of deposit outflows in stressed times

Banks' current holdings of liquid assets are regulated by the liquidity coverage ratio regulation (LCR). This regulation refers to a combined scenario of idiosyncratic as well as market-wide stress lasting for the period of 30 days. According to this stressed scenario, the cumulative net outflows of retail deposits under the period of 30 days are estimated to be between 3 per cent and 10 per cent of the stock (see BIS 2013). Therefore, banks must currently hold a liquidity reserve that is up to 10 per cent of their stock of retail deposits.

While it is not explicitly stated in the LCR regulation, there are good reasons to believe that the current estimates of outflows of retail deposit stem primarily from the actual cases of idiosyncratic rather than systemic runs. The reason is that a bank run in case of an idiosyncratic stress situation is straightforward: depositors can simply transfer their funds from a troubled bank to a healthy bank. This can be compared to a bank run in case of a systemic stress situation, when all banks are deemed risky. A bank run where depositors change banks makes little sense in this case. Depositors can buy government bonds or foreign currencies but the current owners of any safe assets will sell if they are appropriately compensated for exchanging these safe assets for risky bank deposits. In other words, the limited supply of these safe assets will leave any marginal depositor indifferent to buying or not buying these safe assets. While cash is supplied elastically by central banks, cash can be an inconvenient asset to run to due to its physical form.[11] A general lack of suitable assets to run to in systemic stress situations is likely to limit the actual magnitudes of runs of retail deposits in the existing financial system.

Note that retail deposit outflows in an idiosyncratic stress situation are lower than 100 per cent. One potential explanation is that some depositors are simply not informed. Another potential explanation is that depositors do not bother to run in the presence of a credible deposit guarantee scheme.

2.3.2 The change in deposit outflows when a CBDC is introduced

The introduction of a CBDC introduces an attractive run asset that allows retail depositors to run banks even in systemic crisis situations. If the potential size of runs in systemic stress situations is larger than the size of runs currently observed mostly in idiosyncratic stress situations, then a CBDC leads to an overall increase in potential outflows.

There are good reasons to believe that the magnitude of stress in systemic stress situations is likely to exceed the magnitude of stress observed in idiosyncratic stress situation. First, shocks may get more easily magnified via spillover effects in systemic stress situations as compared to idiosyncratic stress situations. Second, systemic crisis situations

11 In addition, the physical form of cash can make the actual supply of cash inelastic in the short-term. Banks may also have limits to how large daily withdrawals from deposits to cash can be.

typically persist longer than idiosyncratic crisis situations. This may increase media coverage, which in turn may increase the share of informed depositors in case of systemic as compared to idiosyncratic crisis situations. Finally, the credibility of any deposit insurance system may be weaker in case of systemic as compared to idiosyncratic crisis situations.

All in all, a CBDC may reduce the current stability of retail deposits by increasing the potential outflows of demand deposits during systemic stress situations.

3 Adjustments by banks in a world with a CBDC

In the previous sections we looked how the supply of bank loans depended on potential outflows and how CBDC affected the size of potential outflows. The size of banks' liquidity reserves and central bank policies for eligible collateral were taken to be given. In this section we allow banks to adjust to a world with a CBDC. Before the launch of a CBDC, banks can adjust their balance sheets in advance so that they are able to meet the new level of potential outflows.

To make the setup as concrete as possible, we assume that banks operate initially in the environment where the size of potential outflows is 10 per cent. This initial environment means that banks have created lending that is 10 times their liquidity reserve (see Figure 1). We then assume that the introduction of a CBDC is announced and the size of potential outflows is estimated to increase from 10 to 20 per cent.[12]

3.1 Balance sheet adjustments by banks with unchanged lending

We start by considering adjustments that banks can undertake without affecting their initial level or composition of lending. To achieve this, banks have essentially two choices in the new environment:

- find investors willing to exchange their central-bank-eligible securities for stable funding instruments issued by banks;
- find real sector depositors willing to convert their demand deposits into stable funding instruments issued by banks.

The first way banks can adjust is to increase their liquidity reserve so that the new increased level of liquidity reserve supports the initial level of lending[13] (see the upper graph in Figure 4.) Such an adjustment can be achieved by finding investors that are willing to exchange their central bank eligible securities for stable funding claims issued by banks.[14, 15] In practice, banks will first need to buy central-bank-eligible securities from willing investors. As a payment for these securities, investors will receive newly issued demand deposits. Banks can then convert these demand deposits into stable funding instruments when investors buy these funding instruments and pay with their demand deposits.

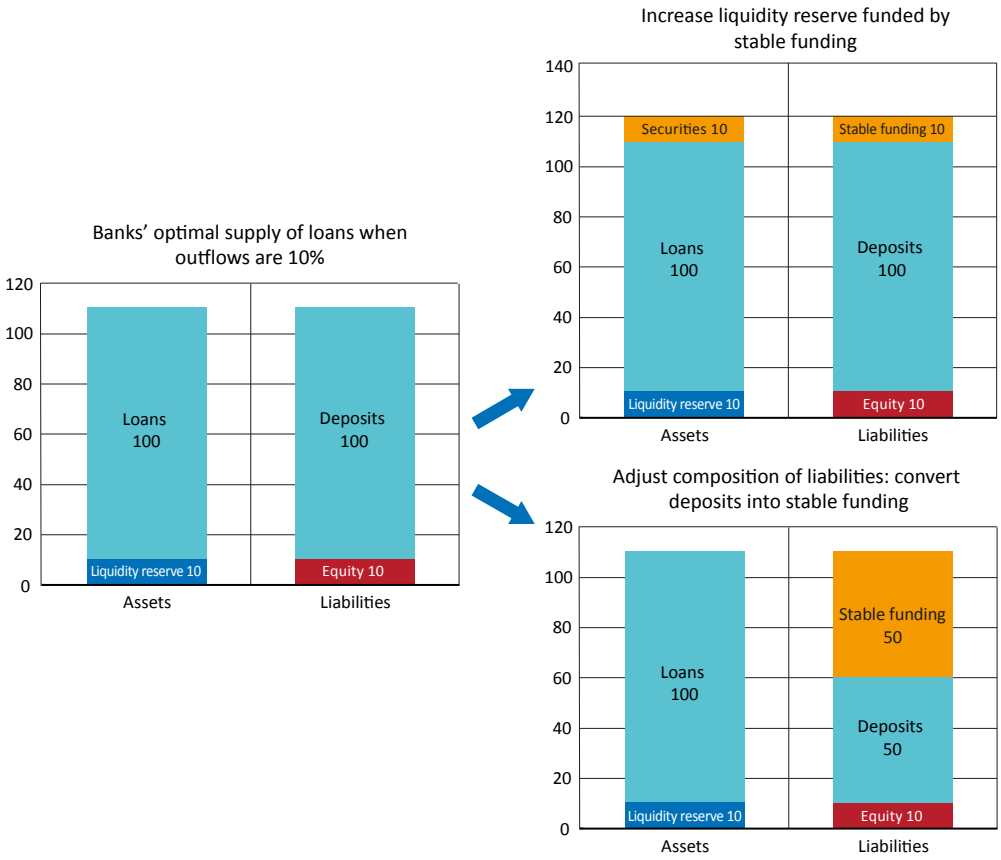
12 This increase in outflows can be motivated in many different ways. One possibility is to assume that all retail clients hold retail deposits even for saving purposes. Then, the size of potential outflows stems simply from the fact that a CBDC increases the size of bank runs from 10 to 20 per cent of demand deposits.

13 Here we keep the supply of central-bank-eligible collateral such as government bonds fixed. In practice, the supply of government bonds typically increases as the economy grows. When the government aims to keep its debt to GDP ratio constant over time, it must run a small deficit as the economy grows. When the government spends more than it receives, it funds this deficit first by borrowing overnight from the banks. Banks' balance sheets therefore increase as a result of the increased deficit: on the asset side, there is a larger loan to the government and on the liability side, there are increased deposits held by economic agents that received more than they paid to the government. The government can then exchanges its overnight bank loan for newly issued government bonds by selling these securities to banks. This natural increase in banks' liquidity portfolio facilitates the natural growth of banks' own supply of loans as the economy grows.

14 For an individual bank, it does not have to be central-bank-eligible collateral. If some non-central-bank-eligible collateral is accepted in money markets, the bank can draw in central bank reserves with this collateral from other banks. But looking from the perspective of the entire banking sector, outflows to a CBDC would create an aggregate shortage of central bank reserves in the banking sector. To manage this shortage, banks must acquire central-bank-eligible collateral.

15 Stable funding claims could also be in the form of equity. If so, banks would also become better capitalised and better capitalisation could in turn reduce the size of potential outflows from demand deposits. This second round effect is for simplicity ignored. It is also unclear to which degree can capital offset the risk of outflows from retail deposits.

Figure 4. Banks' adjustments that keep banks' lending the same when outflows increase from 10 to 20 per cent



As a result of these transactions, banks' liquidity reserves increase by the amount required to meet increased outflows. In our example, outflows increase from 10 to 20 per cent. This means that the liquidity reserve needs to increase by 10 units of central-bank-eligible collateral and on the liability side, there will be newly issued stable funding instruments in the amount of 10 units. With the help of these transactions, banks can adjust their balance sheets without affecting their initial supply of loans and deposits to the real sector.

The second way banks can adjust is to reduce the amount of potential outflows, for instance, by converting some demand deposits into stable funding instruments (see the lower graph in Figure 4). In practice, this means that banks will try to convert some of their existing demand deposits into term deposits. In our example, banks will need to convert half of their demand deposits into term deposits to survive in the new environment. Banks still have the same level of liquidity reserves as initially, but these reserves will be enough to meet outflows that fall due to a conversion of some demand deposits into term deposits.

Comparing the two adjustments presented above, it is clear that both adjustments imply an increase in illiquidity of the real sector. In the first adjustment, this increase in illiquidity takes place indirectly via intermediaries that become less liquid. These intermediaries may be willing to exchange their liquid assets against less liquid assets only if they are appropriately compensated for it. How much compensation they require depends on their own need for liquidity. In the second case, the increase in illiquidity is direct since some demand deposits held by the real sector are converted into term deposits. If the real sector holds these demand deposits for saving purposes, the cost of conversion will probably be low. However, if the real sector holds these demand deposits for transaction purposes, the cost of conversion will be high since the real sector will be unwilling to hold illiquid term deposits which cannot be used for transaction purposes.

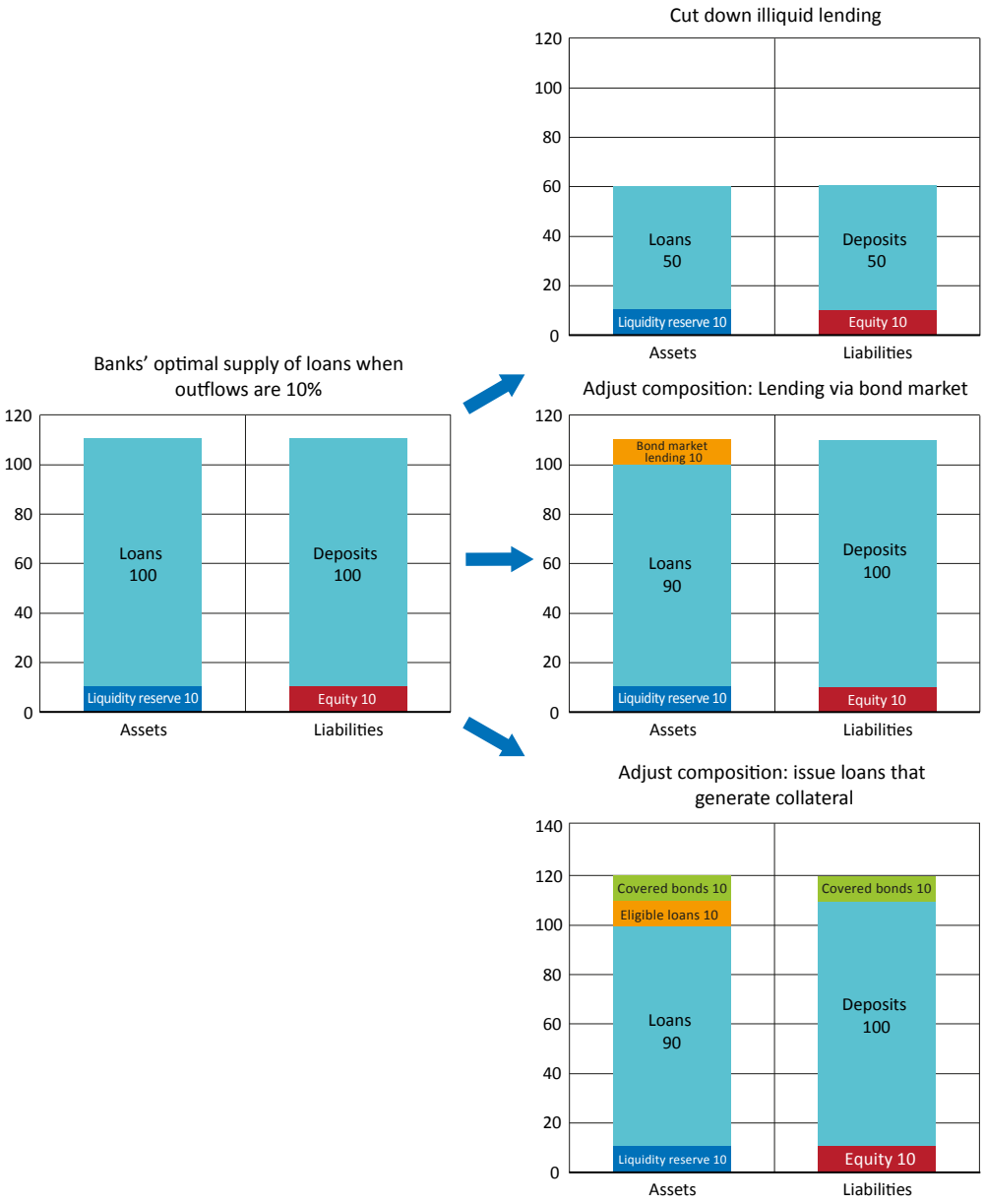
Both adjustments, even if feasible, will add to the cost of bank lending. The increased cost, once laid over to the initial stock of loans, will likely affect the demand for loans, leading to a lower level of bank loans in equilibrium. As a back-of-envelope calculation, assume a spread between government and senior unsecured bank bonds to be equal to 100 basis points. Then, an increase of outflows from 10 to 20 per cent implies an additional cost of existing bank loans of 10 basis points, if banks exchange their newly issued senior unsecured bonds for central-bank-eligible collateral in the form of government bonds.

3.2 Balance sheet adjustments by banks: level and compositional changes

In addition to the adjustments that allow banks to keep their initial level and composition of lending, banks can also respond by adjusting the level and composition of lending. The level adjustment can take place by banks not rolling over some of their maturing illiquid loans (see the upper graph in Figure 5). In our example, banks need to half their existing stock of loans to be able to adjust to the new environment. In practice, banks can also reduce illiquidity of loans by simply reducing the maturity of loans. In an extreme case, the maturity of loans may match that of the maturity of demand deposits. In the event of increased risk of deposit withdrawals to a CBDC, banks can simply call in loans which in turn will destroy deposits that can run to a CBDC.

Compositional adjustments can take place by banks cutting down the type of lending that cannot generate collateral and replacing it with loans that generate collateral. For instance, banks may start lending more via bond markets instead of issuing traditional illiquid loans (see the middle graph in Figure 5). By doing this, some illiquid real sector loans on banks' balance sheet are substituted for tradable bonds. This change in lending would enhance banks' liquidity position in case these tradable assets were accepted as central-bank-eligible collateral.

Figure 5. Banks' adjustments via the level and composition of lending when outflows increase from 10 to 20 per cent



Compositional adjustments can also take the form of banks tilting their lending policy towards loans that can be securitised (see the lower graph in Figure 5). In some countries retail mortgages with certain loan-to-value properties are eligible for cover pools that in turn can be funded by covered bonds. In case of an increased need for a traded security, banks can include loans currently funded by demand deposits into their covered pools and issue additional covered bonds. These newly issued covered bonds can then be retained by banks and used in central bank borrowing facilities as long as these traded securities are accepted as central-bank-eligible collateral.

Any changes in the level or composition of bank lending will lead to quantitative rationing of bank credit to some sectors. Credit rationing will lead to a contraction in macroeconomic activity in these sectors. In addition, there may be adverse effects on the prices of real assets that are heavily used in sectors that see their supply of banks loans decrease.

All the adjustments discussed above imply a reduced role of banks as liquidity creators for the real economy. Banks' adjustments will either increase the cost of existing bank loans or lead to a reduction in absolute level of bank lending to some sectors. The changed supply

of bank loans will in turn affect macroeconomic activity. The magnitude of macroeconomic effects will depend on the following factors:

- The size of a necessary adjustment. The larger the size of a necessary adjustment, the greater the macroeconomic cost associated with the adjustment. Banks are likely to follow a pecking order of adjustments starting with the least expensive: Banks may initially try to keep the existing volume and composition of their lending and work with acquiring more central-bank-eligible collateral and rolling-over demand deposits into term deposits. These first adjustments may however have their natural limits. If the supply of central-bank-eligible collateral is limited, finding willing investors to swap these securities for illiquid claims issued by banks will at some point be increasingly costly. Similarly, as banks try to roll over their liquid deposits into term deposits, they may at some point reach the point where no more existing depositors are willing to engage in trade, irrespective of the price offered. If these thresholds are hit, banks will need to cut their supply of illiquid loans which will have an increasing impact on macroeconomic activity.
- The length of an adjustment period. The longer the time period for banks and their borrowers to adjust, the lower potentially adverse transitory effects would be. Borrowers whose loans are not rolled over will need enough time to complete their investments. For instance, manufacturing companies will need to complete their production cycles and be ready with the sales of their final products before they can actually repay their maturing bank loans. Any rapid adjustment will inevitably increase stress for these firms, which in turn may lead to more adverse macroeconomic activity.
- Monetary policy response. When the adjustments go via rates rather than via quantities, central banks can reduce the macroeconomic impact via standard monetary policy tools. The necessary adjustments that go via costs will either increase bank lending rates in relation to the policy rate (e.g. lending margins) or reduce banks' profitability. If banks tried to increase their lending margins, monetary policy could react to offset increased margins. This policy measure is however limited if there is a natural limit in the form of a lower bound on the policy rate.

It is worth emphasising that other non-bank actors such as asset managers have only a limited capacity to compensate for the decreasing supply of bank loans. When the supply of bank loans contracts and bank loan rates increase, it may become more attractive for these other actors to step in and supply more credit. However, unlike banks, these other actors cannot increase their lending unless they first acquire more funds from existing depositors.[16] When existing depositors provide funds to these non-bank actors, they exchange their liquid demand deposits for less liquid claims. The end result is the re-distribution of liquidity from depositors to non-bank actors. Therefore, the capacity of non-bank actors to offset the decreasing supply of bank loans is directly comparable to banks' own ability to roll over their own demand deposits into term deposits or other forms of stable funding instruments. As explained above, there are natural limits to how much illiquidity can be pushed into the existing stock of demand deposits.

16 The only exceptions are non-bank actors that manage to create liabilities that are widely accepted as a means of payments by the general public.

4 Adjustments by central banks in a world with a CBDC

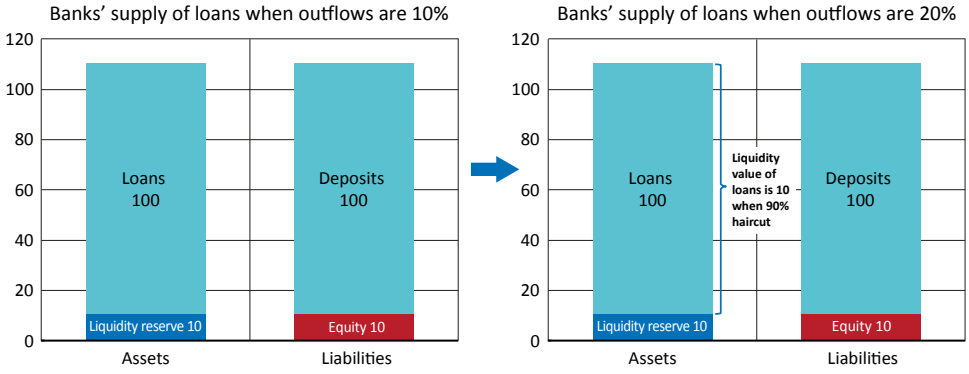
4.1 Adjusting the set of central-bank-eligible collateral

As described previously, the introduction of a CBDC may lead to increased outflows and thereby increase the demand for central bank reserves, especially in systemic stressed situations. When central banks accept only (high-quality) tradable securities as eligible collateral, the supply of central bank reserves may become constrained unless banks adjust their balance sheets ex ante. Adjustments by banks may however have adverse effects on the supply of illiquid bank loans, with potentially adverse effects on macroeconomic activity.

In this section we show how central banks can offset adverse effects of a CBDC on the supply of bank loans by accepting illiquid bank loans or simply raw loans as eligible collateral. When the extra liquidity value that stems from the eligibility of raw loans is large enough to cover an increase in potential outflows due to a CBDC, then banks' lending capacity can be kept unchanged even in the presence of CBDC.

To illustrate this result, consider the typical bank we have used throughout the paper (see Figure 6). Due to the issuance of a CBDC, the size of potential outflows increase from 10 to 20 per cent. It can be easily verified that if raw loans have a liquidity value of 10 per cent in central bank lending facilities (i.e. a haircut of 90 per cent), then the bank can still sustain its initial level of lending of 100 units. Lending out 100 would generate 100 units of demand deposits. When 20 per cent of these are converted into CBDC, the bank can use its initial liquidity reserve of 10 units plus the extra liquidity value of bank loans, which is 10 units, to meet the outflow.

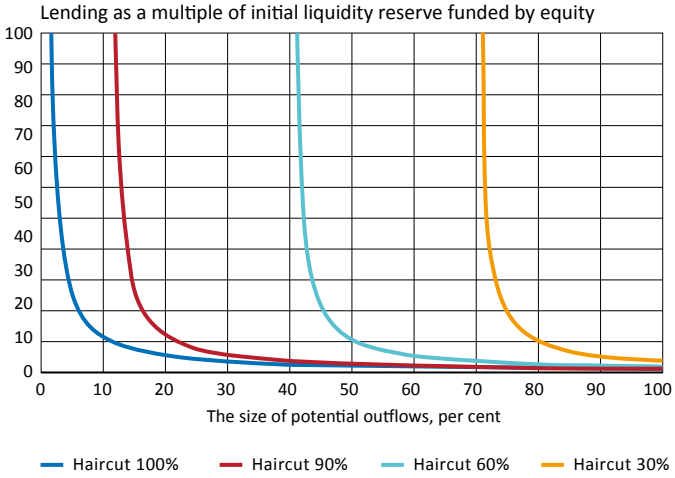
Figure 6. An example of a bank's capacity to lend when raw loans are accepted as eligible collateral



More generally, we can calculate banks' lending capacity by taking into account the eligibility of raw loans. This is illustrated in Figure 7. The dark blue line illustrates the initial situation where raw loans are not eligible. We can see that high levels of lending capacity can be achieved even in the environment with large potential outflows. For instance, banks would still be able to lend out 20 times their liquidity reserve when the size of potential outflow is 75 per cent. This would be possible if haircuts on raw loans were up to 30 per cent.

Figure 7. A banks' capacity to lend as a function of the size of potential outflows when loans are eligible collateral

Lending as a multiple of initial liquidity reserve funded by equity



The inclusion of raw loans to the set of eligible collateral is by no means an extraordinary step for central banks. The Federal Reserve, ECB, Bank of England and Bank of Canada have already collateral frameworks that allow pledging of raw loans in their credit operations. Haircuts that are applied vary from 5 per cent for low-risk loans such as high-quality retail mortgages to 80 per cent for high-risk loans such as unsecured consumer loans.[17] Some central banks do not accept raw loans directly, but they do so indirect by accepting asset-backed securities (e.g. Reserve Bank of Australia).

4.2 Increasing central bank reserves via outright purchases of assets from investors

In previous sections we looked at changes to the set of eligible collateral by central banks as a potential measure to manage adverse effects of a CBDC on the supply of bank loans. In this section we consider an additional measure that can be taken by central banks: the outright purchase of assets from investors (AP). The question we are interested in is whether AP can enhance banks' capacity to lend in an environment where banks' capacity to lend is hampered by the introduction of a CBDC.

To understand AP in the presence of a CBDC, we need first to specify who can hold central bank reserves. To ensure consistency with the rest of the paper, we stick to our initial assumption that only banks can hold central bank reserves but depositors can at will convert their deposits to the CBDC. This assumption allows us to think of AP as it is currently conducted in practice.

In this setup, AP will first lead to the creation of new central bank reserves as central banks need to pay for the purchased assets. These new central bank reserves will be held by banks, even if it is investors and not banks that sell the assets. Investors who sell their AP assets receive bank deposits as a payment for the assets sold. The investors can, however, convert their deposits into the CBDC, just like any other depositors.

To illustrate the setup, consider a case where the central bank buys 10 units of illiquid assets from investors. As a result of AP, banks experience an increase in central bank reserves that are funded with deposits held by the investors that sold their assets into AP (see the left graph on Figure 8). Investors are likely to take further steps. It is these additional steps taken by the AP investors that determine the impact of AP on banks' capacity to lend.

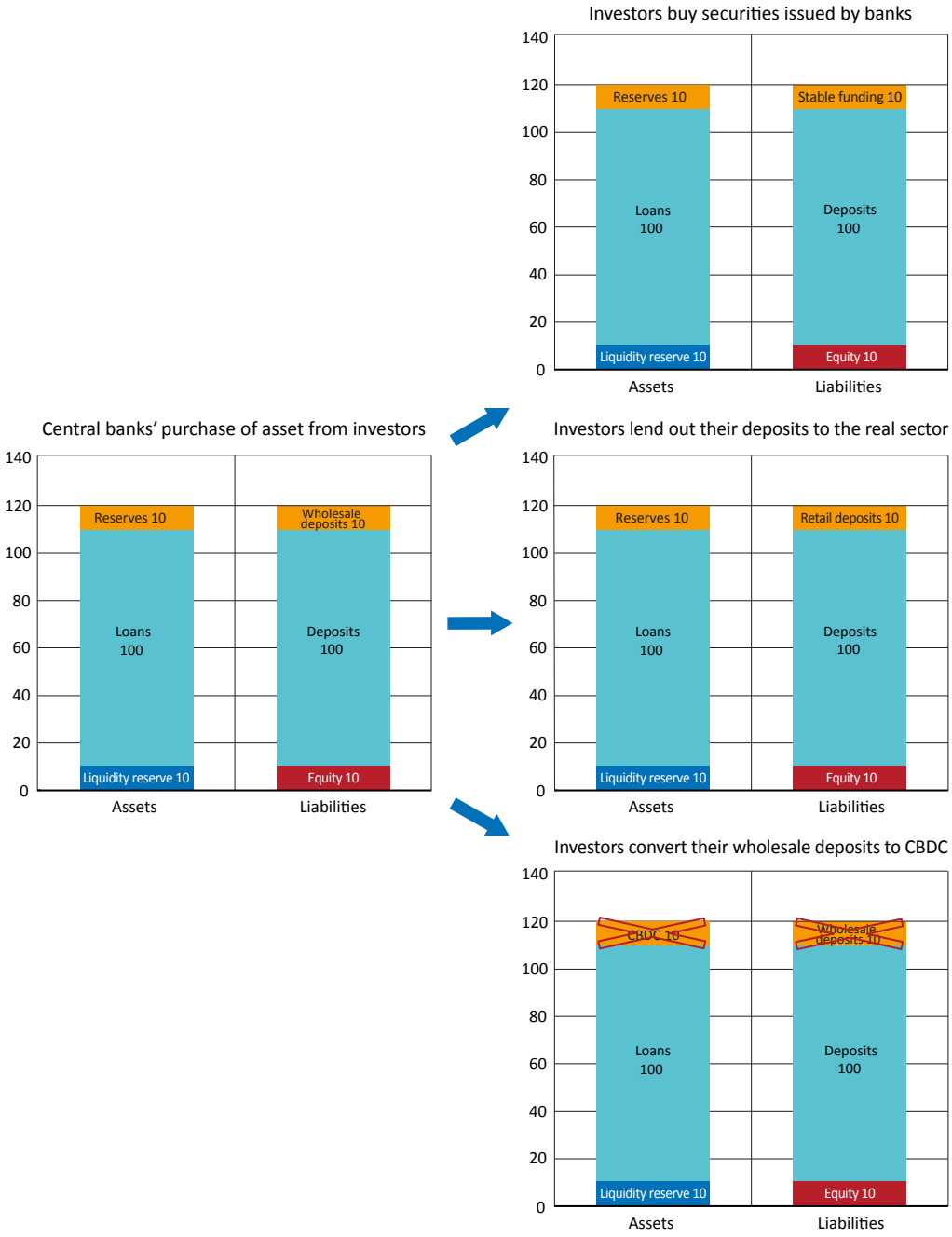
17 The Federal Reserve, ECB and Bank of Canada publish haircuts on individual loan types on their websites. Bank of England does not publish haircuts on individual raw loans, but states in its annual Report on the Bank's official market operations 2018–19 that haircuts in raw loans stayed in the interval of 14–52 per cent (see Bank of England 2019).

In non-stressed situations, investors would re-balance so that their exposure to illiquid assets was the same as it was before AP. In our context this means that investors would lend out their demand deposits at term, via either illiquid bonds or loans. The borrowers of these funds would be either banks via stable funding instruments or the real sector via illiquid loans (see the upper and middle graphs on the right-hand side in Figure 8). Irrespective of whether the funds were lent out at term to banks or to the real sector, banks' lending capacity would be enhanced as explained in more detail below.

If investors lent out funds directly to banks, AP would lead to an increased demand for stable funding instruments which in turn would mean reduced costs of term funding for banks. AP therefore reduces the cost that banks bear when they push illiquidity to investors in an attempt to adjust their balance sheets to the world of a CBDC (see also Figure 4).

If investors lent out funds to the real sector, AP would enhance banks' lending capacity by reducing the size of required adjustments that banks must take to manage the presence of a CBDC. As investors lent out their demand deposits to the real sector, deposits would move from investors to the real sector. If the retail deposits have an outflow factor than is lower than 100 per cent in the presence of CBDC, then the increase in central bank reserves due to AP is larger than the increase in outflows stemming from the increased retail deposits. All in all, this dynamic reduces the magnitude of adjustments that banks need to make to be able to cope with the world of a CBDC.

Figure 8. Outright purchase of illiquid assets by central banks



To illustrate this last point, consider again the setup where CBDC increases outflows from 10 to 20 per cent. Without AP, banks would need to find investors willing to swap 10 units of central-bank-eligible collateral with 10 units of stable funding instruments issued by banks (see also Figure 4). With the AP of 10 units, banks would obtain 10 units of extra central bank reserves. If investors rebalanced by lending out the received demand deposits to the real sector, banks would see an inflow of 10 units of extra retail deposits. These extra retail deposits would increase banks' outflow by 2 units. Thus, AP has given banks 10 units of extra central bank reserves, while outflows have increased by only 2 units. The extra 8 units of central bank reserves means that banks need only 2 units instead of the initial 10 units of central-bank-eligible collateral obtained via swaps from investors.

As shown above, AP can help banks to adjust to the world of a CBDC if investors do not themselves demand liquidity that is created by AP. However, there may be situations when

the demand for liquidity is high and investors absorb the extra liquidity created by AP. In such cases, investors would simply keep their extra liquidity in demand deposits (if they had trust in banks) or convert them directly into the CBDC (if they did not have trust in banks) (see the lowest graph on the right-hand side of the Figure 8). In these cases, AP would boost the overall supply of funds to the real sector via investors, but the effect of AP on banks' lending capacity would be weakened considerably.

In sum, AP represents an additional tool through which central banks can stimulate the supply of bank loans should the introduction of a CBDC lead to a contraction in the supply of bank loans. This tool however has its limits, especially when it is used in distressed times when the general demand for liquidity is high.

5 Conclusions

The introduction of a CBDC is often perceived to have an adverse effect on the supply of bank loans. We study this concern with the help of a model that is based on the actual practice of banking. In the model, banks can create unlimited amounts of loans and deposits in their own books. However, they must also satisfy customers' outflows to other banks and cash, and in the presence of a CBDC, also to the CBDC.

Banks can currently create lending volumes that are at least 10 times their own liquidity reserves. This lending capacity is possible because deposits created by lending generate only modest outflows. The two main drivers of outflows for retail deposits are withdrawals to cash and the risk of bank runs. In the current system, sizeable bank runs mostly take place in times of idiosyncratic stress situations when depositors can easily move their funds from a troubled bank or banks to healthy banks. In times of systemic stress, all banks may be deemed risky but outflows may nevertheless be limited. This is so because physical cash, the only available run asset with elastic supply in the times of systemic stress, is an unattractive asset to hold in the digital era. Since CDBC is digital, it can become superior to bank deposits, especially in times of systemic distress. CBDC can therefore expose banks to larger potential outflows than are currently observed.

To cope with larger potential outflows in the presence of a CBDC, banks can take different measures. Banks can for instance buy more central-bank-eligible collateral and fund these purchases by issuing stable funding instruments to the sellers. Banks can also try to convert some demand deposits into term deposits. Adjusting the composition and the supply of illiquid lending is another way for banks to adjust to a world with a CBDC. All these measures, especially if large enough, tend to reduce the supply of illiquid bank loans to the real sector, with potentially adverse effects on macroeconomic activity.

To offset the adverse effects of a CBDC on the supply of bank loans, central banks can increase the supply of central bank reserves. When raw loans are included into the set of eligible collateral, the issuance of new loans increases banks' liquidity reserves. When an increase in banks' liquidity reserves matches an increase in the size of potential outflows due to a CBDC, the effect of the CBDC on banks' lending capacity is neutralised fully. Central banks can also conduct an outright purchase of illiquid assets to stimulate banks' supply of illiquid loans. As central banks buy illiquid assets from investors, new central bank reserves will be created for banks. Investors who sell their illiquid assets are then likely to rebalance their portfolios, increasing the demand for illiquid assets and reducing the cost of illiquid term funding for banks.

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E-krona design models: pros, cons and trade-offs

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In this article we sketch out four different design models for supplying an e-krona to the Swedish general public. We discuss advantages and disadvantages of the different models, using the policy goals identified by the Riksbank for the payment market as our point of departure. Possible trade-offs involve weighing the advantages of more minimalistic approaches against performance as regards enhanced competition and resilience, and the amount of decentralization versus control over data and privacy.

1 Introduction

The reasons for introducing an e-krona, the Riksbank's retail CBDC, have been thoroughly described in previous reports and in another article in this issue of the Economic Review (see Sveriges Riksbank 2017, 2018 and Armelius et al. 2020). However, no description of how an e-krona would be designed and actually work has so far been forthcoming.

As soon as we leave physical cash and enter the digital world, we need to think of an e-krona not only as the instrument used for making payments but also as the infrastructure that allows the transfer of e-kronor between different stakeholders. Several questions therefore arise: What roles should the different stakeholders play? How will end-users access the e-krona? What is the best technology to use? And so on.

In this article, we discuss how the e-krona and the related payments infrastructure could be designed in order to fulfil the Riksbank's mandate of promoting a safe and efficient payment system in Sweden as we move towards a cashless society. We discuss four different models and then proceed to evaluate these. We would like to stress that these are not the only conceivable designs, but are the ones that currently seem the most relevant for the Riksbank. The designs we present are also stylized, but it would of course be possible to consider combining different models.

The provision of central bank money plays a pivotal role when the Riksbank strives to promote a safe and efficient payment system. Currently, the Riksbank provides central bank money to the public in the form of cash and reserves to the participants in the central system for settlement of payments. Furthermore, the Riksbank acts as overseer and a catalyst for change towards private payment providers and infrastructures. When considering design, we need to evaluate not only how different options deliver with respect to the policy objectives. Equally important is to minimize potential negative side effects on the Riksbank's responsibilities within other areas, such as monetary policy and financial stability.

The article is structured as follows. In Section 2, we briefly present the policy objectives that will guide our design evaluation. We describe four alternative models in Section 3. Section 4 presents a concluding evaluation of how well the different models fulfil the policy goals and also identifies some trade-offs between these goals. Section 5 presents some economic design objectives that need to be considered regardless of the choice of model. Finally, section 6 concludes.

* We would like to thank Carl Andreas Claussen, Björn Segendorf and Gabriel Söderberg for useful comments. Any views presented in this article are those of the authors, and not necessarily of the Executive Board of Sveriges Riksbank.

2 Reasons for introducing an e-krona and policy objectives

The starting point for the e-krona-analysis at the Riksbank has been the marginalization of cash. The policy goals that could be achieved by introducing an e-krona are rooted in a desire to uphold some of the functions that cash has had in the Swedish economy, and that we risk losing if it is marginalized further. These policy goals have been identified in, for instance, E-krona Report Number 2 (Sveriges Riksbank 2018). Most of these policy goals are directly related to the Riksbank's mandate of maintaining a payment market that is both safe and efficient and there is often a trade-off involved between efficiency and safety. Higher demands for safety will often lead to increased costs, limits on the number of participants, and so on. It is therefore impossible to find an objectively optimal solution, since the trade-off will depend upon the subjective consideration of different aspects.

Ideally, an e-krona would emulate the best properties of cash, such as user friendliness, universal access, instant and final settlement and peer-to-peer capabilities, while at the same time avoiding its drawbacks. The latter include such aspects as scope for illegal usage, but also the use of a paper-based technology that is not adaptable to changing circumstances. Therefore, desirable features of an e-krona as a means of payment would be to provide the following:

Risk-free money to the public, accessible to all

Central bank money can be considered the safest form of money as it is a claim on a central bank. Central banks can always meet their obligations in the national currency as they have unlimited capacity to create new money. Central bank money is thus a risk-free asset and means of payment. Other forms of money, like commercial bank money, are claims on a private entity that can have liquidity shortages or go bankrupt.[1] If these risks are not fully offset by regulations, lender of last resort and bank resolution facilities, deposit insurance schemes and so on, these private forms of money are more risky than central bank money.

Giving the general public access to the safest form of money may be important for several reasons. Some claim that it is simply a duty of the state to provide 100 per cent safe money (see e.g. Armelius et al. 2020). Others suggest that convertibility into safe central bank money can be important for there to be trust in commercial bank money (see Armelius, Claussen and Hendry, 2020).

Finally, it is imperative that everyone has access to a reliable means of payment, and not only groups that are considered profitable by the private sector. Groups with special needs therefore also have to be taken into consideration when designing an e-krona regardless of the model adopted.

Enhanced competition

In order to keep the cost of payments down, it is useful if there is competition and innovation in payments. However, this may not come naturally in payment markets as they exhibit economies of scale and strong network effects. For this reason, payment markets tend to become concentrated, especially on the wholesale side. Concentration hampers competition and innovation. Sveriges Riksbank (2018) and Bergman (2020) argue that an e-krona could enhance competition and innovation in payments.

1 Some forms of 'money', like bitcoins, are not claims on anyone. These forms of money are even more risky and may not even be described as money because they do not fulfil the basic functions of money as unit of account, store of value and (generally accepted) means of exchange.

Resilience and crisis preparedness
Cash has traditionally served as a back-up payment method to electronic systems. If electronic payments did not work, people could resort to cash payments. However, the more marginalized cash becomes as a means of payment, the less useful it also becomes as a back-up method if the need arises. Sveriges Riksbank (2018) argues that an e-krona may serve as a back-up payment method.

Privacy and personal integrity
There is value in data about preferences, purchasing habits, etc. that is generated when we pay since it can be used for marketing and surveillance. There are therefore incentives to compete using means of payment with low or no fees where the business model relies on collecting and selling consumer data to retailers. Individuals may not always be aware of this since details are sometimes hidden in complex user terms. In China, for instance, people largely pay using payment apps that collect detailed data. Providing a public alternative, which is not based on a commercial interest to collect personal data, could be important in Sweden where it is becoming increasingly difficult to pay with cash.

Efficient cross-border payments
Payments outside of Europe are often slow and expensive compared to domestic payments. Making cross-border payments cheaper and more efficient is an urgent concern for policymakers and central banks worldwide, in particular after the rise of global private monies initiatives. If central banks cooperate and construct CBDCs that are similar in construction or interoperable and surrounded by standardized legislative frameworks, it could facilitate international payments. Common international standards would reduce the costs for operation in different countries (or currency areas), which could promote more institutions to operate in more jurisdictions.

3 Some models for an e-krona

As mentioned previously, an e-krona is not just a means of payment but also a payment infrastructure.[2] The design of this infrastructure needs to be carefully considered against the Riksbank's policy objectives that are relevant for payment infrastructures. Different design models need to be evaluated and trade-offs need to be identified. Some properties, such as security, are essential, while others such as low costs are desirable, but could be ranked lower in case there is a trade-off involved. One obvious example is the trade-off between resilience and cost. If the Riksbank were to set up a separate settlement system, where e-kronor would flow completely separated from RIX (the RTGS-settlement system at the Riksbank) and commercial bank money, it would probably be more resilient but it could also be costly for the central bank to operate. A judgement would then have to be made to assess whether the resilience of the current system is good enough against the desire to keep costs low. Basic aspects against which any e-krona model needs to be evaluated include how well the proposed design performs in terms of the overarching policy objectives: universal access to a risk-free asset and means of exchange, enhanced efficiency and resilience in the payment market, and protection of privacy and integrity of consumers. When evaluating a concrete proposal, we need to transpose these objectives into concrete design properties that also need to be operationalized in measurable goals. This is not the objective of this article.

Lately, in part as a response to the rise of private digital money, more central banks are exploring the necessity to issue a CBDC. Thus, the issue of interoperability and

2 Payment infrastructure here is interpreted in a wide manner. It could range from just a rule book and set of technical standards to a whole payment system.

standardization between jurisdictions has become increasingly important and is therefore something to consider when evaluating designs.

There are many ways of designing an e-krona, and the options are continuously growing as technology evolves. We have chosen to focus on four different stylized models that we judge would be possible to implement using existing technology. Combinations of the models are also possible. However, all of the models would require adjustments to existing legislation in Sweden. The Riksbank has asked the Riksdag (the Swedish parliament) to start an inquiry to, among other things, look into the scope for the Riksbank to issue an e-krona. The models presented in this section are sketches of possible designs assuming that some adjustments to the legislation can be implemented. The aim is to give a general overview of various options. In case a decision is taken to implement an e-krona, a much more thorough analysis will be needed. We look at design options for the 'provision' of an e-krona. By provision, we mean choices about who should do what in the supply of the e-krona.[3]

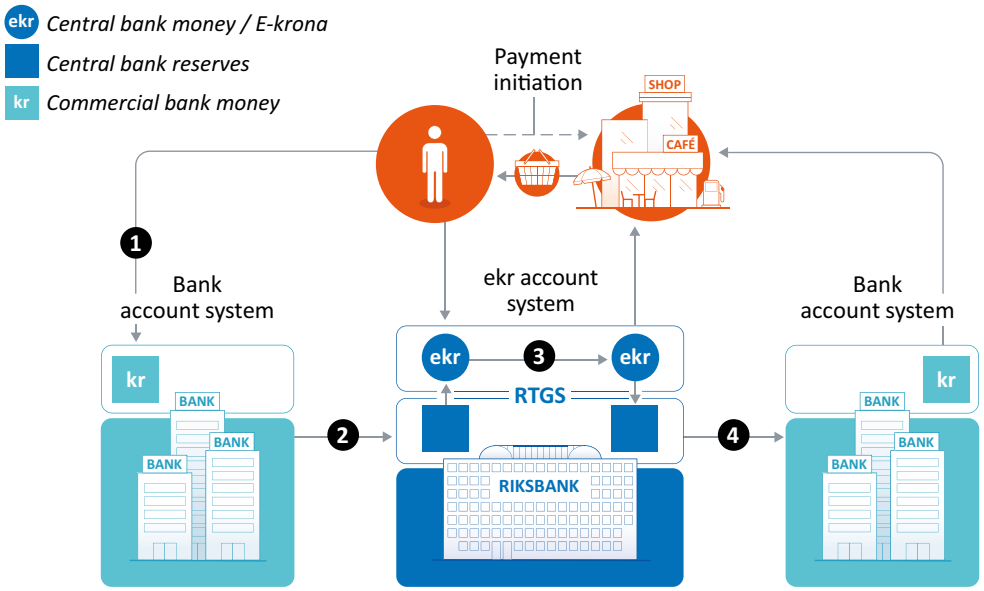
3.1 Centralized e-krona provision without intermediaries

Provision of an e-krona without intermediaries is an option where the Riksbank takes the responsibility for the whole distribution chain for the e-krona. The Riksbank has a direct contractual relationship with end-users of the e-krona and provides a technical platform with a register containing information on users of the e-krona and their e-krona transactions. In addition, and importantly, the Riksbank provides traditional payment services such as cards, apps, payment information to consumers, businesses and authorities, authorization of payments, customer service, etc. This 'holistic' solution would be similar to the one the commercial banks currently provide for their depositors except for credit lines, etc. The distribution model can also serve as a settlement system operated by the Riksbank. E-kronor stored on the platform constitute central bank money and are thus a claim on the Riksbank.

In this model, end-users need to open e-krona accounts or wallets at the Riksbank.[4] They have to instruct their bank to transfer the desired amount of commercial bank money in exchange for e-kronor (step 1 in Figure 1). The transfer between commercial bank money and e-kronor is executed between the bank's account at RIX and the e-krona account on the e-krona platform (step 2 in Figure 1). The merchant that desires to accept e-krona payments also needs to open an account at the Riksbank. Then payment between the end-user and the merchant in e-kronor involves a simple credit transfer between two accounts on the Riksbank's e-krona platform (step 3 in Figure 1). As long as both payer and payee want to transact with e-kronor, there is no need for intermediaries. The merchant may also want to do the opposite transaction and decrease their e-krona holdings in exchange for commercial bank money. Then the merchant instructs the Riksbank to withdraw the desired amount of e-kronor from their account and deposit the same amount in their commercial bank account (step 4 in Figure 1). If a holder of e-kronor wants to pay to a recipient who does not have e-krona accounts or who does not wish to increase their e-krona holdings, there is a need to exchange e-kronor for commercial bank money, i.e. to go outside the e-krona accounts. This requires settlement in RIX (steps 2 and 4 in Figure 1).

3 See Bank of England (2020) for the division of e-krona design into (i) provision, (ii) functional design and (iii) economic design.
4 This model does not preclude e-kronor from being issued in the form of tokens and stored on e-wallets provided by the Riksbank.

Figure 1. Centralized solution without intermediaries



Source: The Riksbank

In the international literature, such models are called 'full-fledged' (Adrian and Mancini-Griffoli, 2019) or 'Direct CBDC' (Auer and Boehme, 2020). In the first e-krona report, this model was called 'register based e-krona with significant Riksbank commitment', see Sveriges Riksbank (2017).

This would entail a completely new role for the Riksbank, which would be similar to the role of a large retail bank. The model would entail substantial costs for staffing customer support functions for potentially millions of users, as well as IT-support. Moreover, it implies that the Riksbank would compete with private payment service providers at the retail level, in the direct provision of payment services to end users, and in the wholesale sector in the provision of infrastructure that handles these payments. Thus, the Riksbank may end up having too large a footprint in the payment market.[5] It could also be possible to implement a small-scale version of this model where the Riksbank would provide a basic supply of services that could for instance be catered to the needs of vulnerable groups.

3.2 Centralized model with intermediaries

Models that resemble the current financial infrastructure are those based on a partnership between the Riksbank and private service providers. In such models, the Riksbank maintains its prominent role at the wholesale level of the payment market but does not have an operational role in the distribution chain. Between the Riksbank and the public there is a layer of intermediaries offering payment services for the e-krona. However, the e-krona is still a direct claim on the Riksbank.

There are different variants of this design. Here we distinguish between designs using centralized ledgers of transactions and those using decentralized ledgers.

In the centralized model with intermediaries, the Riksbank has a direct contractual relationship to the end-user and provides a core ledger where all holders of the e-krona have accounts or digital wallets in which all transactions are recorded, depending on whether the Riksbank uses a token-based approach or conventional account-based technology. The model is therefore similar to the completely centralized mode (3.1) presented above

5 This could however, be solved by having design features that limit the size of the e-krona (see Section 5).

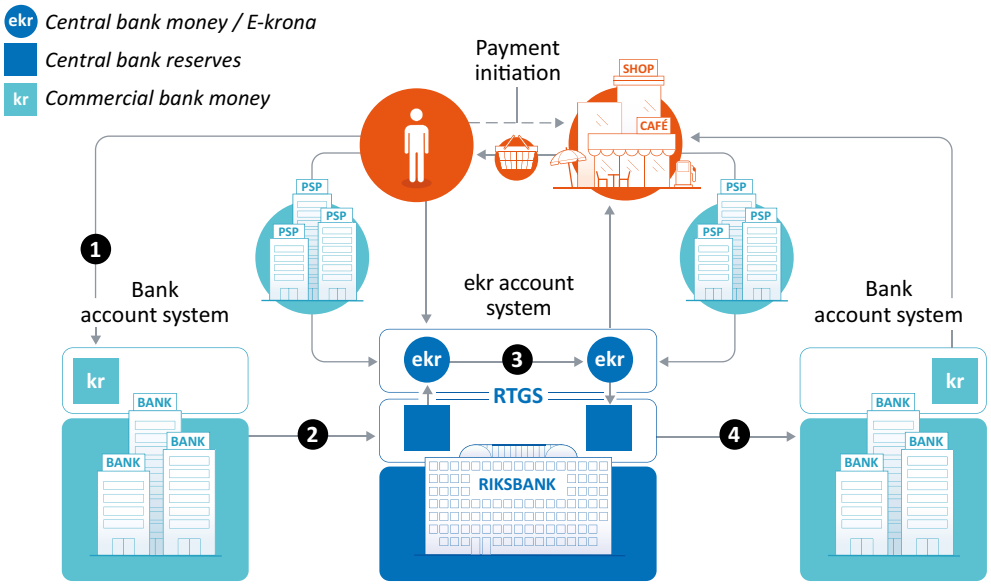
at its core, the difference being that the Riksbank is not directly involved with the users. The commitment of the Riksbank will still be high since it will be ultimately responsible for dispute resolutions and related services as well as the operation of the infrastructure with risks of cyber-attacks, etc. There could be a reputational risk for the Riksbank if the system runs into problems (as suggested by Auer and Boehme, 2020).

This design would be in line with the spirit of the new Payment Services Directive (PSD2), which gives authorized payment service providers the right to offer payment initiation, account information and card-based payment instruments linked to accounts held at another payment institution.[6] The role of the Riksbank would in this model be limited to issuing e-kronor, and providing a technical platform with the core ledger onto which payment service providers who have a contractual relationship with the Riksbank for the provision of e-krona to end users can connect. This model therefore also has more potential to allow the private sector to innovate and thus continuously develop user-friendly solutions, something which central banks might be less well placed to do.

Even though the Riksbank has a contractual relationship with all account holders, it is the payment service providers who are responsible of onboarding e-krona holders or terminating their accounts, distributing e-kronor and providing holders with the desired devices to access and use the e-krona, mobile applications or online solutions.[7] To increase their holdings in their e-krona accounts, customers need to instruct their bank to debit their commercial bank money account and credit their e-krona account at the Riksbank (step 1 and 2 in Figure 2). The exchange between commercial bank money and e-kronor is done through the bank's account in the Riksbank's settlement system RIX. As in the previous model, payments between e-krona holders, for example between a customer and merchant, can simply be described as in-house credit transfers within the core ledger (step 3 in Figure 2). Since the e-krona itself is central bank money, the transfer of e-kronor from one holder to another settles the payment with finality, much in the same way as the exchange of physical cash. However, when a holder of e-kronor wants to pay to a recipient who does not have e-krona accounts or who does not wish to increase their e-krona holdings, there is a need to exchange e-kronor for commercial bank money, i.e. to go outside the e-krona accounts. This requires settlement in RIX (steps 2 and 4 in Figure 2).

6 A prerequisite for external PSPs to benefit from access to accounts in accordance with article 66 in Directive (EU) 2015/2366 on payment services in the internal market is that the e-kronor are considered to be stored on a payment account held by a PSP.
7 Under the assumption that the PSP has required authorization according to Swedish implementation of PSD2.

Figure 2. Schematic view of the centralized model with intermediaries



Source: The Riksbank

The payment service providers conduct the required 'Know-your-customer' (KYC), 'Anti-money-laundering' (AML) and 'Counter-terrorist-financing' (CTF) policies. However, due to the fact that the Riksbank has a direct contractual relationship to the end-user, it is not clear that the Riksbank can renounce responsibility on these issues – these legal aspects need to be investigated further.

The centralized account/wallet system can be developed by the central bank itself or a system can be bought off the shelf. Furthermore, the central bank can choose to operate the system or to outsource operations. It is worth noting that both solutions require substantial investment compared to the current RTGS-systems since the former would involve supporting accounts for potentially millions of users. For the Riksbank, operating such a system would require a substantial increase in IT and support staff.

Technology is not a decisive factor in this model. Both a conventional account-based and a token-based e-krona are possible. A token-based model where each digital e-krona is uniquely identifiable would essentially replicate the current cash distribution model but in digital format. See the box 'Token- vs Account-based models' below for a distinction between the two technologies.

BOX Token- vs account-based models

In the debate around CBDC projects, there has been much emphasis on whether an account-based model, also called register-based, or a token-based model is preferable not least in terms of potential risks for disintermediation of the banks. This is a mistaken focus for the discussion since the difference between an account- and a token-based model is only a matter of technology and legal definitions. Tokens are bearer instruments and represent in themselves ownership of a monetary value. Thus, a token-based e-krona is similar in this sense to physical cash or checks. An account-based e-krona indicates ownership of a monetary balance in some form of financial intermediary or the Riksbank itself, i.e. conventional financial technology, and can be compared to deposits.

Another difference between tokens and accounts is in their verification: a person receiving a token will verify that the token is genuine, whereas an intermediary verifies the identity of an account holder (BIS, 2019). However, this difference does not always hold completely. In some DLT token-based models, there is still the need of verification through a central node in the system, a so-called notary node which could be operated by an intermediary.

However, despite being bearer instruments, a token e-krona is digital and thus requires all transactions to be recorded in a register or a ledger to avoid the risk of fraudulent use or double spending. The ledger is in all relevant senses also a form of account. This is a contrast to other bearer instruments like cash which, once withdrawn, can circulate from user to user outside the banking system with no records of what it has been used for or by whom. The risks associated with bearer instruments regarding double spending lies primarily on the payee in the absence of a register (e.g. checking security details like a watermark).

In short, the distinction between a token-based or account-based e-krona has no bearing on the potential implications of the e-krona on the monetary system by itself.

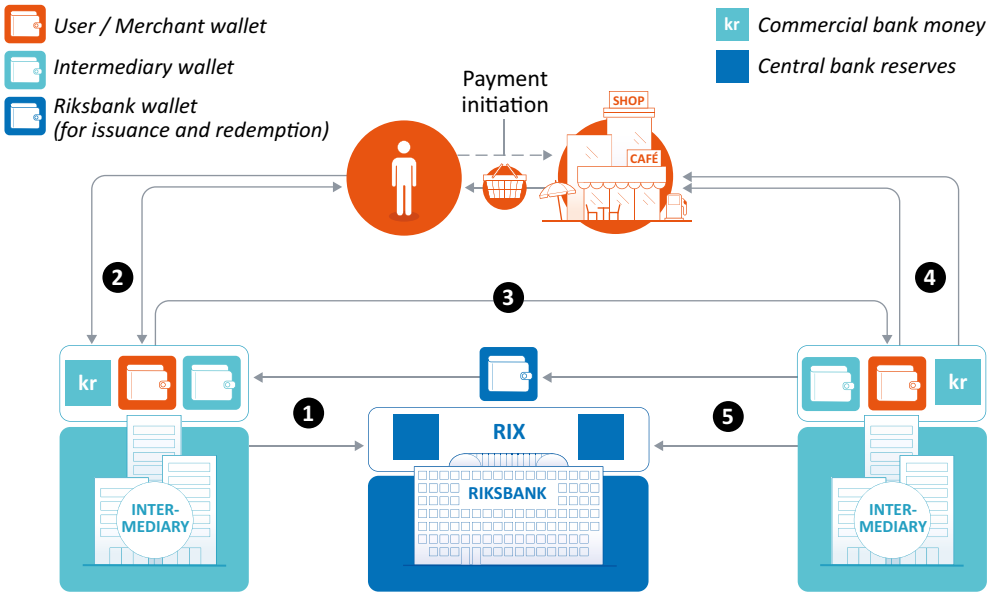
There are, however, certain advantages of token-based models inherent in in the technology used. Modern digital tokens are based on advanced cryptography that allow for the use of 'smart money' and 'smart contracts through atomic swaps'. This makes it possible to have desired conditional requirements built into the tokens. With the use of so-called 'atomic swaps', it is possible to automatize conditions for exchange and for the exchange to occur only when these conditions are fulfilled – notably for simultaneous exchange of currencies (payment vs payment) eliminating so-called Herstatt risk and simultaneous exchange of the security and the liquidity leg in securities trading (delivery versus payment). Similar use can also be transfers of ownership in the payment swap when buying a car. However, due to the novelty of smart money technology, there are still challenges associated with alteration and revocation of smart contracts.

For account-based models, these important principles for secure exchanges require the existence of a trusted third party such as a continuous linked settlement (CLS) for currency exchange or central securities depository (CSD) for trade in securities.

3.3 Decentralized solutions with intermediaries

Similar to the model with a centralized ledger of transactions above, the e-krona would be a direct claim on the Riksbank and intermediaries would handle the provision of e-kronor to end users. The difference is that there is not a single core ledger of transactions owned by the Riksbank and that there is no direct contractual relationship between the Riksbank and the end-user of e-krona. Instead, all intermediaries have their own part of the ledger and a direct contractual relationship with the end-user. This setup is simply a decentralized database of all e-kronor in circulation at any given moment, where the Riksbank verifies all transactions before completion. There is currently an ongoing pilot project at the Riksbank, which falls into this category. In this article, we will not be discussing that particular model, but rather decentralized models in general. For more information about the pilot project, readers are referred to the Riksbank's website. Figure 3 depicts the interaction between the flow of e-kronor and the rest of the financial system.

Figure 3. Flow of e-kronor in a decentralized ledger system



Source: The Riksbank

Intermediaries, called nodes in the network in the distributed ledger technology (DLT) terminology, exchange central bank reserves in their RIX accounts for newly issued e-kronor assigned to their wallet/vault (step 1 in Figure 3). End-users exchange the desired amount of e-krona through an intermediary by decreasing the same amount in their commercial bank deposits followed by a deposit onto their e-krona accounts/wallets (step 2 in Figure 3). The customer pays for goods or services from a merchant with e-kronor and thus the customers e-krona account/wallet is decreased by this amount while the merchant's e-krona holdings increase by the same amount (step 3 in Figure 3). If the merchant does not want to increase their e-krona holdings, they can exchange the received amount of e-krona for increased bank deposits through their intermediary (step 4 in Figure 3). The intermediary can either accept the increase of e-krona holdings or exchange these for central bank reserves at the central bank through RIX. In that case, the Riksbank redeems e-kronor in the same way as currently is done with physical cash (step 5 in Figure 3).

In this case, technology matters. The use of a token-based (DLT) approach might have advantages over conventional technology. With a DLT-based approach, the Riksbank could create one singular common infrastructure among all intermediaries, each of which represents a node in the network having a copy of the ledger. However, each node only contains information regarding the intermediary owning and operating the node and the end-users/customers of that intermediary. If conventional account-based technology were to be used in a distributed setup, all intermediaries would have a full copy of a traditional deposit ledger which would be more expensive than a traditional centralized trusted third-party model (e.g. an automated clearing house, ACH) eliminating the economies of scale advantages.

In the DLT-based approach, there is still a need for centralized services by the Riksbank such as 'issuing/redemption' of e-kronor and verification of legality of the transaction against 'double spending'. Intermediaries distribute e-krona to end users, and the latter can load the e-kronor onto their e-krona accounts/wallets in the intermediary's node. Similar to the model with a centralized ledger, an exchange between e-krona and commercial bank money needs settlement outside the e-krona network in the Riksbank's settlement system.

Different variations of this kind of technology are possible – a permissioned DLT network open only for participants approved by the Riksbank or an open DLT network open for

everyone. However, from a central bank perspective, the permissioned option is the only admissible one.[8] Admission to the network as an intermediary would be granted by a rule-book that the Riksbank decides on and owns. There are two different possibilities:

- Licensed proprietary technology requires intermediaries to acquire and run a specific software solution. Requires license fees and builds on specific technology. A potential weakness is vendor lock-in. An example of licensed technology is the operating system Windows from Microsoft.
- Specific open source technology requires intermediaries to run the solution provided by the designated open source community for the specific solution. A potential weakness is the risk of the community being abandoned or the build-up of dependence on open source consultants. The code is public and requires no license fees. An example of open source in operating systems is Linux.

Although the model is decentralized, it still entails a high degree of involvement by the Riksbank. The model requires the Riksbank to invest in some type of infrastructure with the potential to support millions of users where the Riksbank issues and redeems e-kronor and prevents 'double spending'. Furthermore, there is a reputational risk involved for the Riksbank if parts of the system should fail. Users' accessibility to their e-krona wallets would most likely be dependent on the intermediary systems being up and running. The fact that the model is decentralized could increase resilience since there would be copies of ledgers available, but most likely to a much lesser degree than with permissionless DLT-solutions. The Riksbank would therefore need to provide a contingency solution if one or several intermediaries fail in order to prevent a situation where substantial numbers of end-users are unable to make e-krona payments. In contrast to the previous model, the Riksbank has no contractual relationship with the end-user and therefore the responsibility for ensuring anti-money-laundering (AML), know-your-customer (KYC) and counter-terrorist-financing (CTF) policies would primarily rest with the intermediaries.

3.4 Synthetic e-krona

The final model is a version of the design of the 'Synthetic CBDC' coined by Adrian and Mancini-Griffoli (2019) at the IMF. Similar proposals have also been discussed by Kumhof and Noone (2018) and Auer and Boehme (2020) at the BIS. In this model, e-kronor are issued and provided through intermediaries who hold 100 percent reserves at the Riksbank to back their value. *One fundamental difference from the other models is thus that a synthetic e-krona will be a claim on the intermediary and not directly on the Riksbank.* Some would argue that the most important contribution of an e-krona would be to continue the provision of central bank money to the public in a digital future, something that this alternative actually does not really do (only indirectly). Therefore, it is not clear if this should really be considered to be a CBDC, but we have decided to include it in this article since it is an alternative that has received some attention internationally.

The proposal is similar to what is sometimes called a '100 per cent reserve banking', which has been discussed by, for instance, Tobin (2008). One additional ingredient in the set-up with a synthetic CBDC is that the model involves more institutions than just banks. According to Mancini-Griffoli (2019), e-money providers would also have the possibility to hold reserves at the central bank in order to be able to issue synthetic CBDC.

8 An open DLT network is associated to several disadvantages; every transaction must be verified by every participant (cf. blockchain) in a time and resource consuming manner. The responsibility for the Riksbank regarding AML, KYC & CTF could be indefinite. Fraud and cyber-attacks are hard to prevent in an open network.

Within the current European legislation, access to central bank reserves is restricted to credit institutions and financial infrastructure institutions.[9] Although broadening access to other payment service providers is being discussed, it is currently impossible for Sweden to deviate from European legislation. Therefore, this model should be viewed as an interesting theoretical alternative, but perhaps not as something that could practically be implemented in the near future.

Theoretically, what makes the Synthetic e-krona attractive is its limited scale compared to the other models that we have described. It would not involve major investment in infrastructure and the Riksbank could renounce all responsibility for KYC, ALM, etc. Apart from allowing more institutions access to the RTGS-system, which would involve some additional resources, the model consists mostly of new legislation that would require banks (and others) to set up segregated accounts. Thus, this system would be very similar to the current system where the role of the central bank is to be an actor in the centre of the payment system with the private market as a second layer to the customers. For the private sector, existing payment solutions could continue to operate as today with no need for additional hardware or investment.

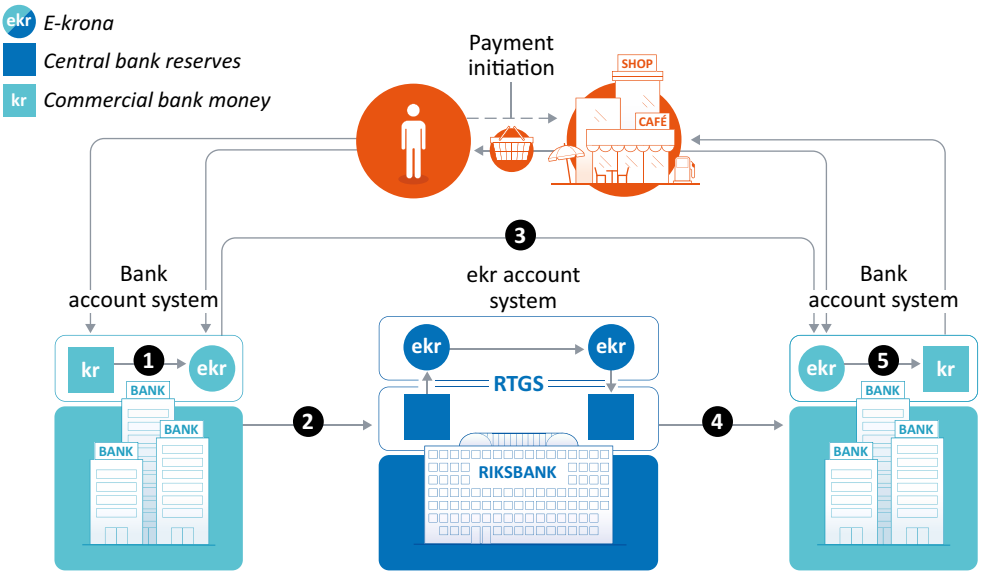
In practice however, it is not clear that this solution can be as simple as described. If all payments need to be completely backed by central bank money in real time, this would require all 'backed' accounts and all transactions to and from these accounts to be mirrored in the Riksbank's RIX system so that changes in reserves instantly accommodate these transactions. This can be done and there are similarities to how the infrastructure behind the Swedish instant payment system Swish currently works. Nevertheless, there is a need to build such an infrastructure, which might negate the simplicity described. It might, however be less of an enterprise to build a separate instant payments platform than to have the accounts for the Swedish public as in the centralized models with or without intermediaries.

Another weakness compared to the other alternatives is that the Riksbank would not be in control of important aspects of the infrastructure, like governance, back-up solutions, off-line functionality, etc. as is currently the case with the private financial infrastructure. This could pose reputational risks for the Riksbank since the money would still be considered an 'e-krona' and the Riksbank's means of payment.[10] Unless legislation is changed, or other solutions are put in place, the synthetic e-krona would also be subject to operational and liquidity risk in case of bankruptcy of the issuing institution as bankruptcy procedures can take several days. Figure 4 gives a schematic view of the model.

9 The legislation in question is the Finality Directive (Directive 98/26/EC on settlement finality in payment and securities settlement systems) that restricts access to designated payment systems.

10 The difference from the other models is that in the synthetic CBDC, the Riksbank could impose sanctions on the intermediary if they did not meet set standards since it would be the responsible party. If the system fails in the other models, it is possible that the Riksbank has the responsibility.

Figure 4. Synthetic e-krona



Source: The Riksbank

Customers and merchants can have separate accounts with commercial bank money and e-kronor at their respective banks. When they decide to increase their e-krona holdings, they instruct their banks to debit their deposit accounts and credit their e-krona accounts, a simple transfer between two accounts. The same applies in reverse if they want to decrease their e-krona holdings (steps 1 and 5 in Figure 4). The customer pays in e-kronor to the merchant from their e-krona account (step 3 in Figure 4). This transfer is mirrored in a transfer of reserves from the customer's bank to the merchant's bank in the settlement system at the Riksbank where the intermediaries hold their segregated accounts (steps 2 and 4 in Figure 4).

4 Concluding evaluation and trade-offs

In this section we will discuss the models presented above in terms of their ability to achieve the policy goals mentioned in Section 2.

Launching an e-krona would be a big step for the Riksbank. Although Riksbank banknotes have been circulating in the Swedish economy for centuries, the Riksbank itself has played a minor role in their distribution over the last decades. And although most digital payments in Sweden go through the Riksbank's settlement system at some point or another, that is a business that is quite different in nature from the handling of digital payments at the retail level. Even if the Riksbank were to use intermediaries in the provision of e-kronor, all e-krona accounts would have to be handled in the Riksbank's systems. Sweden has 10 million inhabitants and hundreds of thousands of companies and authorities that might be interested in having e-krona accounts. Commercial banks devote large amounts of resources to maintaining large numbers of accounts, and it is likely that the launch of an e-krona would have to be accompanied by a substantial expansion of the Riksbank's organization.

Implementing an e-krona could also imply a big change to the financial system, since it would introduce a new player (on special terms) at the retail level for digital payments. Ideally, the e-krona should be a complement to existing solutions that can handle the problems that might arise on the payment market without causing greater interference on the private market. However, since there are network effects (see Armelius et al. 2020 in this issue), it might not be possible to achieve the goals of an e-krona if adoption is too small. The

Riksbank should therefore collaborate with the market to ensure that the model chosen for e-krona provision will function smoothly for all involved parties.

All the models presented **ensure the general public access to the safest form of money**. For the centralized models, with and without intermediaries, and the decentralized model with intermediaries, this is obvious, since they provide money that is a claim directly on the central bank. For the models that use intermediaries however, there is still an operational risk in case of bankruptcy, or if the intermediary fails to perform its operational service to the user. Thus even if the money is safe, it might take time for the user to be able to switch to another intermediary. For the synthetic e-krona, there is also a liquidity risk as bankruptcy procedures necessary for account holders to access their e-krona holdings in case of bankruptcy of the intermediary can take several days.

All alternatives **will increase competition** since the e-krona would be competing with private bank money (it will provide a public alternative to private money). However, the more serious obstacles to competition in the payment market occur at the wholesale or infrastructure level. Barriers to entry for new entrants are currently high.[11] The largest banks together own the clearing house through which almost all retail payment flows are handled before settlement in RIX and the rulebook that regulates access to it. This is not the only barrier. The settlement system itself is strictly regulated in accordance with European legislation on settlement finality for designated payment systems.[12] The same is true of the new system RIX Inst, which will be in operation in 2022 when the Riksbank connects to the ECBs TIPS platform for instant payments. This legislation aims to secure final and irrevocable settlement of transactions but also restricts access to the system to credit institutions and clearing houses. If enhanced competition is deemed an important objective for the design of an e-krona, the Riksbank needs to provide a separate platform to RIX (RTGS and RIX Inst) that is not designated as a payment system and thus does not come under the mentioned legislation. This would increase competition for the models using intermediaries, but this would have to be investigated further.

When it comes **to increasing resilience**, e-kronor provided through intermediaries imply that the Riksbank will not be able to supply an infrastructure that functions completely independently of other systems. In case of disruptions in the intermediary's system, the e-kronor might not be available to users (unless the Riksbank could provide a fall-back solution). This could be particularly important if many intermediaries are using the same IT-supplier. The same applies to disruptions to energy provision where none of the different digital payment solutions, including e-kronor, would be available. It would also apply to the distribution of cash, which also depends critically on electricity. However, less severe but more frequent disruptions, such as internet access can be considered in the design of the e-krona. This requires that the e-krona allows for offline functionality, at least under predetermined values of transactions and periods similar to what is provided in today's card networks, something which is possible to achieve but beyond the scope of this article to discuss further.

Both the centralized and the decentralized models with intermediaries may provide some increased resilience as compared to today, since it is likely that individuals would choose to hold an e-krona wallet or account while at the same time maintaining their commercial bank account, depending on the type of failure. For example, if the international card schemes were experiencing disruptions that made card payments impossible, the e-krona account/wallet would provide an alternative payment method. In theory, decentralized models based on DLT technology may be more resilient than centralized approaches if the whole ledger is spread out over all the nodes. This is because every node has its own copy of the whole ledger of transactions. This means that if one, or some of, the nodes in the network

11 For a more elaborate discussion about competition issues, see Bergman (2020).
12 Directive 98/26/EC on settlement finality in payment and securities settlement systems.

are out of order, the rest of the system and the users with wallets in the unaffected nodes can continue to transact. Even users in the affected nodes can access their e-krona holdings through unaffected nodes. The increase in resilience is, however, at the expense of slower transaction times and - more importantly - at the expense of making all transactions publicly available. Such a solution would not be desirable from a central bank perspective. Resilience could also be increased if the Riksbank built a back-up channel that allowed users to access their e-krona holdings directly from the Riksbank even if the whole banking sector's payment system were down – a solution that could be used in case of crisis. Resilience aspects are very important and beyond the scope of this article. These are currently being analysed at the Riksbank.

All electronic payments leave traces, but **it is possible to set up rules and procedures that safeguard personal integrity and privacy**. While the Riksbank in the centralized and the decentralized model with intermediaries would have to comply with some basic checks for illegal activity, after such automatic checking it would be possible to set up principles around allowed usage or maybe even destruction of data. Privacy and private integrity can be protected through the settings of the messaging system. The models do not differ much in this dimension, however, DLT solutions are in general more prone to data being shared between participating nodes. There is a clear trade-off between resilience and privacy. It is possible to incorporate the protection of privacy and integrity to a certain extent in both the centralized and the decentralized models. In the decentralized approach, however, more privacy means less resilience since privacy requires that the nodes can only 'see' their own transactions.[13]

The different models have **different interoperability possibilities** when considering cross-border payments. To the extent that the models use conventional technology, and therefore already developed and tested messaging standardization frameworks can be applied to facilitate cross-border operations. In the case of DLT, the technology is still relatively new and it is being evaluated. Many central banks are experimenting with similar technology, which might gain interoperability in the future. It is too early to conclude that using the same approach in different jurisdictions will be the optimal approach for improving cross-border payments. This topic will not be discussed in any more depth in this article, but for a more elaborate discussion, readers are referred to FSB (2020).

From a policy perspective, we are interested not only in the costs to the Riksbank, but also in **the social costs** of the implemented e-krona model. These include all real resources that the system requires in order to work. It is not possible to evaluate the social costs of the different approaches before seeing a more detailed technical design. In general, the less the need for changes in the existing merchant payment-acceptance infrastructure, both physical and online, and new payment devices for customers, the lower the social costs of the model. A thorough cost-benefit analysis would have to be conducted for possible e-krona models at a later stage if a decision to implement an e-krona is taken.

13 This aspect is important since it may differ in comparison to other CBDC design proposals and especially if compared to crypto assets such as bitcoin or Ethereum.

5 Economic design issues

In the discussion above, we have left out some important questions regarding the 'economic design' of the e-krona:[14]

- Who should have **access** to the e-krona?
- Should there be **caps** or limits on how much e-kronor different agents can hold?
- What about **remuneration**? Should the e-krona bear interest?
- Should the e-krona be freely **convertible** to other forms of the Swedish krona – commercial bank money and physical cash?
- Can the e-krona bear its own cost or will it need a **subsidy?**

Our judgment is that none of the models and technologies discussed in the sections above limits our choices when it comes to economic design. We can restrict access, apply caps on e-krona holdings, pay interest, provide for convertibility and subsidize the e-krona under all of the design alternative designs discussed above. Thus, we can choose model and technology independently of our economic design choices.

However, it is worth keeping in mind that the economic design is important. It determines the uptake of the e-krona and its bearing on the banking system, financial stability and monetary policy effectiveness. We will now have a brief look at some relevant economic design issues, although a deeper analysis of economic design is beyond the scope of this article.

Whether or not we need **limitations on access and caps on e-krona holdings** depends on what other economic design choices we make. To give an example, suppose that the e-krona carries interest similar to the policy rate, is convertible into bank money at par and is attractive as a means of payments (for instance because it is subsidized – more on that below). In this case, the e-krona will be a very strong competitor to bank deposits. Many depositors may move their money into the e-krona and commercial banks may no longer be able to mediate funds between depositors and lenders. Limitations on access and caps can reduce or stop this kind of commercial bank 'disintermediation'. Similarly, limits on access and caps limit systemic bank runs into the e-krona.

What about **remuneration**? Should the e-krona pay interest? Here we may first notice that the demand for an e-krona is likely to depend in its interest relative to the interest for commercial bank deposits. Thus, a variable spread between the key policy rate and the e-krona could be a tool for regulating the demand for the e-krona.

Remuneration will also be important for monetary policy effectiveness. Most importantly, a non-remunerated e-krona will put an effective zero lower bound on all interest rates – short and long – and thereby add a new limitation to monetary policy (see e.g. Armelius et al. 2018). This is a serious concern and leads us to conclude that if there is no limitations on access or caps, then it must be possible to have negative interest rate on the e-krona. Some authors find that an e-krona will improve the monetary policy transmission mechanism. In Sweden, this seems not to be the case (see Armelius et al. 2018).

Free **convertibility** between e-kronor and other forms of Swedish kronor would be necessary. Otherwise the Swedish krona would no longer be 'uniform money'. The prices would have to be quoted in e-kronor, 'bank money', and so on. This makes it unclear what a Swedish krona 'is', complicates pricing and renders the Swedish krona less attractive (or unattractive) as unit of account in Sweden. It therefore seems obvious to us that there must be one-to-one convertibility between the e-krona, physical cash, reserves and bank money. However, limits to access and caps might make it harder to maintain convertibility, suggesting

14 The term was coined by the Bank of England (2020) who distinguish between *provision* (choices regarding who will do what in providing the e-krona), *functional design* (is about ensuring that the payment function of CBDC provides a clear benefit and utility for users) and *economic design*.

that limiting demand by remuneration might be preferable to limitations on access and/or caps.

What about **subsidies?** This is an important question about which there has been limited discussion and analysis so far. Below are some preliminary thoughts on the issue.

Will the e-krona have to be subsidized? Private payment alternatives charge their fees in various ways. They might charge outright fees, but might also charge implicit fees for instance by collecting information that is used for marketing, surveillance, etc. by themselves or sold on to others. Alipay and Amazon are prime examples. This means that the Riksbank might have to subsidize the e-krona in order to ensure that it will actually be used. As the e-krona, in the same way as physical cash is a public good with positive externalities, subsidizing it is in line with standard economic theory.

6 Conclusions

In this article, we have sketched out four different models for supplying the e-krona. We have discussed how well the different models would be able to fulfil the policy goals of the Riksbank. We have seen that all models would have advantages and disadvantages, but some seem better at fulfilling the current needs of the Swedish payment market than others.

If the Riksbank were to implement a fully centralized model of e-krona, it might increase resilience since it would work as a different platform handling customers directly. However, such a model would entail a completely new role for the Riksbank, much resembling a commercial bank. It would require large investments in infrastructure and personnel in order to maintain accounts for millions of users. It could possibly also be implemented in a scaled-down version for specific user groups as a complement to existing solutions provided by the private market.

A synthetic e-krona would be relatively easy to implement and would be less costly than the other alternatives. However, such a minimalistic approach might not achieve the goals of enhanced competition and resilience to the same extent, since it would be quite similar to today's system. Furthermore, it would not be a direct claim on the Riksbank, and therefore it is not clear if this should really be considered to be a CBDC.

In both the centralized model with intermediaries and the decentralized model with intermediaries, the level of involvement and costs to the Riksbank are substantial. Even if the centralized model with intermediaries seems at first glance to consume more resources, the decentralized model with intermediaries could also require a much larger involvement by the Riksbank, in particular if the Riksbank would provide a last-resort, fall-back solution. Both models are fully fledged CBDC, i.e. central bank money, and imply that the Riksbank would have to maintain an infrastructure that can handle millions of users.

In this article we have presented provisional sketches of possible models for a future e-krona. These sketches will have to be expanded in many dimensions in future work.

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