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Special issue on the e-krona **2018:3**

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Dear readers,

The Riksbank has for almost two years been conducting a review into the possibility and consequences of introducing a Swedish central bank digital currency, a so-called e-krona. This third issue of Sveriges Riksbank Economic Review in 2018 is a special theme issue discussing the e-krona from different perspectives.

Cash is becoming increasingly marginalised in Sweden and the Riksbank needs to consider the role public and private actors should play on the payments market in a digital world. The Riksbank has drawn the conclusion that a digital complement to cash, an e-krona, could be one of several ways for the bank to pro-actively meet the new digital payment market. The Riksbank has published two interim reports (The Riksbank's e-krona project, Reports 1 and 2, available at riksbank.se) which summarise the conclusions of the project.

In this issue we publish some of the background analyses and investigations made by employees of the Riksbank and which have formed part of the base for the analyses in Report 2. The articles are written in their own names, and any conclusions they may draw need not necessarily coincide with those in the report. The analyses have studied the consequences of a potential e-krona from different points of view. What is the role of the central bank in the payments market? How much demand for an e-krona might there be? What consequences will this have for the banks? How will interest-rate setting be affected, and what further effects might the e-krona have for monetary policy and economic developments in the long run?

It is important to point out that the analyses made in the articles may have slightly different starting points. This applies in particular with the assumptions regarding the characteristics of the e-krona. In certain cases, an e-krona is studied that has characteristics similar to a financial asset. In other cases, an e-krona is studied that has a more modest usage. The articles clearly describe in their respective introductions what kind of e-krona they refer to.

In more detail the articles are as follows:

• Why did the Riksbank get a monopoly on banknotes?

Gabriel Söderberg writes about what is meant by a banknote monopoly and the political process that led to the Riksbank being given the sole right to issue banknotes in 1904. At that time, the political discussion focused on the principles for the financial system and the central bank's role in society. The background was a growing banking sector and a central bank that was more clearly assuming the character of a public authority. The article points to parallels between the discussions then and now, about the role of the central bank in a payment system undergoing major changes.

• What is money and what type of money would an e-krona be?

Gabriel Söderberg begins with a brief historical retrospective of the different forms that money has taken over the years, and observes that money has over time become increasingly abstract. The author points out that the actual form of money is of minor significance –confidence in it is what matters. The central question is therefore what it is that maintains confidence in money. The article also discusses the main ways of defining what money is, and discusses what type of money an e-krona would be.

 The implications of an e-krona for the Riksbank's operational framework for implementing monetary policy

Marianne Nessén, Peter Sellin and Per Åsberg Sommar discuss the e-krona from a narrower central bank perspective. In more concrete terms, they explain how an e-krona

would change the Riksbank's balance sheet, and how the framework for implementing monetary policy might be affected. One message is that the Riksbank already issues digital money, but only to the institutions participating in the Riksbank's RIX payment system. An e-krona can then be regarded as the Riksbank broadening the circle of those who can hold digital central bank money to include the general public. Depending on how the e-krona is designed, there could at times be large flows through the Riksbank's operational framework and balance sheet, which points to there being reason to review the framework if an e-krona is introduced.

The e-krona and the macroeconomy

Hanna Armelius, Paola Boel, Carl Andreas Claussen and Marianne Nessén examine the monetary policy and economic consequences of an e-krona with characteristics that mean it can be likened to an actively traded financial asset. If such an e-krona is not interest-bearing, the consequences can be a lower bound of zero per cent for the policy rate and also for other interest rates in the economy, which could reduce the room for manoeuvre for monetary policy. Such an e-krona can lead to greater volatility in capital movements and in the exchange rate. The long-term economic developments can benefit if the e-krona improves the efficiency and resilience of the financial system. But the economy can be affected negatively if an e-krona impinges on credit supply and financial stability.

• How many e-kronas are needed for payments?

Björn Segendorf studies how great the demand for an e-krona might be, because if there is a very large demand this could significantly increase the size of the Riksbank's balance sheet and have implications for monetary policy and financial stability. The article focuses on how many e-krona may be in demand to meet the need for transactions in the Swedish economy. The overall conclusion is that it is reasonable to believe that demand will be relatively small from a transaction perspective, roughly on a par with the demand for cash in Sweden in recent years, which has amounted to the equivalent of 1–2 per cent of the gross domestic product.

When a central bank digital currency meets private money: effects of an e-krona on banks

Reimo Juks analyses how an e-krona might affect the commercial banks' balance sheets, with a focus on liquidity, financing sources and the cost of funding. The author finds that even if an e-krona leads to deposit outflows, thereby affecting the banks' financing and liquidity, the banks will normally be able to steer these outflows by means of their deposit rates. To the extent that it is not desirable or even possible for the banks to completely counteract such an outflow, the banks can to a greater degree rely on long-term market funding to continue to finance lending. The author finds that in times of financial stress, an e-krona can lead to greater disruptions compared to the current system, but that this depends on whether the e-krona has characteristics that make it more attractive than existing assets in strained financial times. To summarise, the author argues that there is no decisive argument against an e-krona from a financial stability perspective for the Swedish banks.

Read and enjoy!

Jesper Lindé and Marianne Nessén, editors of the Economic Review Eva Julin, project manager of the Riksbank's e-krona project

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Why did the Riksbank get a monopoly on banknotes?

Gabriel Söderberg*

The author works in the Financial Stability Department of the Riksbank

It is not self-evident that only central banks can issue cash. Historically, private banks in Sweden and elsewhere have issued their own banknotes. The decision that only the central bank of a country should be able to issue cash, a so-called banknote monopoly, was taken in most countries in the 19th and early 20th centuries. Today, the situation has changed, and in Sweden, cash is used to a very small extent. This raises the issue of the Riksbank's role as issuer of means of payment and its relationship to private banks in the payment system. This article examines the Riksbank's banknote monopoly, which was introduced in 1904. It concludes that the banknote monopoly should be seen as a political decision to clearly delineate the issue of means of payment from commercial operations, secure the general public's access to risk-free means of payment and make the Riksbank's position strong enough to guarantee the stability of the money and payment system.

1 The issue of the banknote monopoly is current again after over 100 years

Today, the Swedish public can use two main forms of money: cash issued by the Riksbank and digital money held in accounts in private banks. It is not self-evident that cash is only issued by central banks. Historically, private banks have issued their own banknotes in many countries, including in Sweden between 1831 and 1904. Granting the central bank the sole right to issue cash, known as the banknote monopoly, was a political decision taken in most countries in the late 19th and early 20th centuries. The question has been the subject of renewed interest and has been studied internationally in connection with the discussion concerning potential central bank issued digital currencies (Fung 2018, Weber 2014, Weber 2015a, Weber 2015b). In Sweden, the decision was taken to give the Riksbank the sole right to issue cash, the main means of payment in those days, in 1897, with the decision entering into force in 1904. But technological developments and changed payment habits have led to cash being used to a very small extent in Sweden today. The question of who issues and has responsibility for the general public's means of payment is now becoming relevant again, over a hundred years since the introduction of the banknote monopoly. In conjunction with this, the Riksbank has started to investigate steps such as the possibility of issuing central bank money in digital form, the so-called e-krona.

This article provides an overview of central banks' banknote monopolies with special focus on Sweden. The banknote monopoly is a controversial phenomenon. The debate has primarily been driven by advocates of privately issued money, who argue that the banknote monopoly is an infringement by central government of the freedom of private businesses (Hayek 1976,

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White 1984, Dowd 1992). The banknote monopoly was also introduced in many different countries in the 19th and early 20th centuries. The various countries' contexts and justifications for introducing banknote monopolies differed, which makes it difficult to treat the subject exhaustively. The aim of this article is thus not to provide a definitive interpretation but to give an overview and draw a few general conclusions on the similarities between the time of the introduction of the Riksbank's banknote monopoly and today's situation.

In the next section, I will provide a brief international overview of banknote monopolies. According to some researchers, the period of private banknote issue in Sweden, 1831–1904, was characterised by unusual stability compared with other countries. Consequently, I will then provide an overview of the system of private banknote issue in Sweden, followed by a section where I discuss why it was more stable than in other countries. I will then discuss the background to the introduction of the banknote monopoly in Sweden. Finally, I will discuss similarities and differences compared with today's situation.

2 The banknote monopoly from an international perspective

The banknote monopoly was introduced at different points in time in different countries (see Table 1). However, it may be misleading to compare starting years for the banknote monopolies in different countries. This is because, in certain countries, there were no private banks when the central bank was set up. When these later became established, no right to issue their own banknotes was granted. Even so, the table shows that Sweden's decision to wind up private banks' right to issue banknotes was taken at a relatively late stage, in 1897. They had had this right since 1824 and exercised it since 1831. All in all, the period of private banknote issue in Sweden lasted about 70 years.

Country	Central bank founded Decision on banknote monopoly		
Austria	1816	1816	
Norway	1816	1818	
Denmark	1818	1818	
United Kingdom	1694	1844	
France	1800	1848	
Belgium	1850	1850	
Netherlands	1814	1863	
Spain	1874	1874	
Germany	1876	1876	
Japan	1882	1883	
Finland	1811	1886	
Portugal	1846	1888	
Sweden	1668	1897	
United States	1913	1913 (banknotes backed by the state since 1863–1864)	
Italy	1893	1926	

Table 1. Year of foundation of central bank and year banknote monopoly was decided

Source: Capie et al. 1994 p. 6

Modern central banking developed in most industrialised countries primarily in the 19th and early 20th centuries. It is difficult to describe every country here. Consequently, the rest of this section will focus on the two of the largest economies of this period: the United Kingdom and the United States.

2.1 The banknote monopoly in the United Kingdom

Most of the oldest central banks were privately owned and profit-driven (the Riksbank was an exception, having been owned by the state since as early as 1668). The early central banks were thus competitors to other banks in the financial system (Capie et al. 1994, p. 3). The Bank of England was created in 1694 as a privately-owned bank that conducted lending operations to both the state and the general public in London. It also accepted deposits and issued paper banknotes. The Bank of England was thus not what we think of today as a central bank. Several of the principles we today take for granted that central banks will follow were first expressed theoretically. This also applies to the idea that banknotes should be issued separately from commercial banking operations. For example, David Ricardo, better known for the theory of comparative advantage, established in a posthumous publication that the Bank of England performed two functions: issuing banknotes and other banking operations (Ricardo, 1824). These two, Ricardo argued, should be separated completely to guarantee a more secure monetary system. The background to this was the general debate in the United Kingdom that started in the second half of the 1810s due to financial instability and inflation following the Napoleonic Wars. The debate continued throughout the 1840s, with recurring committees to discuss how a stable monetary and financial system could be achieved. Approximately half of the banknotes were issued by the Bank of England and the rest by smaller banks spread across the country, so-called country banks (O' Brien 1997, p. 595). One conclusion that gained ground was that inflationary pressures were due to the issue of banknotes by the smaller banks. The Bank of England quite simply controlled too little of the issuance of banknotes to be able to manage the total supply of money. Many country banks also failed during bad times and their banknotes thus became worthless, which caused major problems for the owners of these banknotes (Davies 1994, p. 298). The debate also focused on the growing opinion that it was problematic to issue banknotes with the aim of making a profit. The end came with the Bank Charter Act of 1844, which heavily restricted the smaller banks' right to issue banknotes so that the Bank of England held the sole legal right to determine the number of banknotes in circulation. The Bank of England still had far to go to become a central bank in the modern sense. For example, it was still privately owned and had no clearly stated principles for how to act in crises. But the Bank Charter Act was a milestone for starting to set boundaries between central banks and commercial banks.

2.2 The banknote monopoly in the United States

In the United States, the issue of a federal central bank and federally issued money was controversial. This was due to the question of the government's influence on issuing money, but there was also a resistance towards concentrating power in the hands of an individual institution (Erickson 2015). This helps us to understand why it took until 1913 for the United States to set up a central bank, the Federal Reserve. Before the National Bank Act of 1863–1864 (which I describe below), most banknotes were issued by private banks licensed by the states (Rolnick et al. 1998, p. 106). Between 1791 and 1836, two attempts were made at giving federal permission to a national, privately owned bank, the First and Second Banks of the United States. But political disagreements led to permission not being renewed after 1836. These two banks did not act as central banks in the modern sense but more as profit-driven banks that issued banknotes on the same principles as other banks (Wood 2005, p. 134). Neither did they have any banknote monopoly.

After 1836, and the dissolution of the Second Bank of the United States, the legislation for state banks was reviewed. A bank could now be established without the permission of the states, assuming that certain fixed capital requirements were met. The banknotes issued should be redeemable against silver and gold and, in addition, the banks should allocate collateral in the form of federal or state bonds.

By the mid-19th century, there were over 1,500 private banks issuing banknotes in the United States (Gorton 2012, pp. 13–19). These banknotes did not just circulate regionally but nationwide. Consequently, as a rule, every bank had a large proportion of other banks' banknotes on its balance sheet (Rolnick et al. 1998, p. 105). The overall problem was that banknotes issued by different banks were not worth as much. The reason was probably that the banks had different risk profiles. As mentioned above, the banknotes were supposed to be backed by state bonds and so on, but several states suspended payments of their debts, which undermined the banks' collateral. The value of the bonds held as collateral also fluctuated. The result was a highly impractical system in which traders were forced to have special handbooks to determine how much different banknotes deviated from each other in value. For example, a ten-dollar banknote issued in one state could be worth USD 9.90 in another state and USD 9.40 in a third (Gorton 2102, p. 22).

The triggering factor for introducing a system with federal, state-backed banknotes was the need to fund the American Civil War, which started in 1861. However, it is important to note that work on this legislation also had the central aim of resolving the problems that had previously existed with the private banknotes (Million 1894, p. 261). The result was the National Bank Act, which was implemented in two phases, 1863 and 1864. The state banks' right to freely issue banknotes was eliminated and many of them were forced to close. A new category of banks was created, national banks. These were privately owned but issued banknotes which were worth the same in all states and were backed by federal government bonds. The equal value of the banknotes was thus based on the legal requirement for them to be backed by risk-free government bonds. In other words, the federal government acted as guarantor for a safe payment system, even if no central bank was to exist in the United States for almost another fifty years (Gorton 2012, p. 19).

Over this period, another form of money became more important: deposits in transaction accounts that could be used to make payments by cheque. The general public now had confidence in the banknotes, as these were backed by the federal government, but, in less favourable times, there was a tendency towards distrust in the account money. In the decades after the introduction of the national banknotes, no fewer than seven crises occurred in which bank runs were a central element (Gorton 2012, pp. 21–23). A bank run here means that the general public wants to rapidly change insecure bank money for federal banknotes that were considered safe. The rationale for creating a central bank in the United States, with banknote monopoly, was therefore mainly provided by the need to create a central lender of last resort (Wood 2005, p. 158). In connection to the creation of the Federal Reserve the decision was also taken to dismantle the national bank system, and replace it with government bank notes issued by the Federal Reserve (Weyforth 1925). The last national bank notes however did not cease to circulate until the 1930s.

3 The Swedish period of private banknotes 1831–1904

The Riksbank was long the only bank in Sweden. Banknote-issuing private banks were therefore allowed by the Swedish Riksdag in 1824 as a conscious strategy to promote the growth of a banking system in Sweden. It took until 1831 for the first private bank to be started. After this, the number of private banks increased, finally totalling 26. These banks accepted deposits from

the general public, albeit on a very limited scale. Reasons for this included the limit placed on interest rates by older legislation on usury, which meant that the general public did not find depositing money particularly attractive. Consequently, from the start, issuing banknotes was the private banks' main source of funding (Lilja 2010, p. 47).

The Swedish system of 1831 to 1904 has been pointed out by researchers as a particularly successful example of the private issue of banknotes (Ögren 2006, pp. 69–70). But the system was not entirely private. On the contrary, banknotes from the private banks could be redeemed for Riksbank banknotes, namely government banknotes, which could, in turn, be redeemed for precious metals. The Riksbank thus issued banknotes which were then used as reserves by the private banks, on the basis of which they issued their own banknotes. The relationship between the Riksbank and the private banks thus had strong similarities with an early central bank system. Sweden differs here from the classic example of a free banking sector, for example the one in the United States before the National Bank Act, which issues banknotes on a profit-making basis with no link to government money. The amount of private banks collected these as reserves (Engdahl and Ögren 2009, p. 84). However, this legislation changed in 1873 when Sweden joined the gold standard in an economic union with Norway and Denmark. The private banknotes would now be directly redeemable against gold (Ögren 2006).

In addition, the system was under very strict government regulation. Permission to open a banknote-issuing bank was given by the central government and was issued very restrictively. The legislation was also clearly formulated to limit what we today call moral hazard: The banks should be organised like partnerships with unlimited economic responsibility and should not expect any government support in difficult periods (Jonung 2007 [1988], pp. 5–6).

In the second half of the 19th century, a gradual change took place, which changed the conditions for the banking sector and laid the basis for another means of payment than cash. This was the so-called deposit market revolution. In 1834, the total value of deposits constituted about 0.4 per cent of GDP. By 1913, it constituted 107 per cent of GDP (Lilja 2010, p. 42). This development is connected, above all, with industrialisation and increased incomes among households, but a contributory factor was the increasingly liberal financial legislation. Firstly, it became easier for new banks to set up. From the start, the Riksbank had a monopoly on issuing banknotes in Stockholm, but, in 1856, Stockholms Enskilda Bank was permitted to set up in Stockholm and compete directly with the Riksbank. Stockholms Enskilda Bank was also innovative in terms of attracting deposits (Lilja 2010, p. 48). In 1864, the legislation underwent further liberalisation. It became even easier to set up new banks, banks were permitted to be limited companies and the ceiling on interest rates was removed. The latter became important to make deposits more attractive for the general public (Jonung 2007 [1988], p. 12). The Riksbank's activity also declined in terms of lending, while that of private banks increased. In 1840, the Riksbank lent the equivalent of 8 per cent of GDP and the private banks lent around 2 per cent. In 1880, the corresponding figures were 2 per cent for the Riksbank and 20 per cent for private banks (Ögren 2010, p. 85). Overall, therefore, deposits started to become an increasingly important source of funding for individual banks, while issuing banknotes became less important. By the 1880s, the significance of banknotes as a source of funding for the banks had decreased heavily, compared with deposits (Brisman 1931, p. 204). At the same time, the Riksbank started to withdraw from the commercial operations it had historically been involved with.

3.1 The stability of private banknote issuance in Sweden

As was mentioned above, the period of private banknotes in Sweden has been pointed out as unusually stable. Unlike the United Kingdom and United States, for example, no banknoteissuing banks entered into bankruptcy. Different banknotes were also worth as much across the entire country and similar practical problems in trade as in the United States therefore did not exist. There were probably several reasons for this.

Local monopolies

The private banks largely had monopolies in their region. The banknotes and the issuing bank also carried the region's name, as a rule. This means that each bank had stable demand for their banknotes and stable profits (Jonung 2007 [1988], p. 26). It may also have played a part in the banks not having any greater incentive to take risks to increase their profits. The regional division of the banks also probably meant that they had reliable information on the local economy and could therefore avoid lending money to doubtful borrowers. And, conversely, local bank customers knew the regional bank well. A comparison can also be made with the United States' banking laws, where absolutely anybody could open a bank without the state's approval as long as they complied with basic capital requirements (Gorton 2012, p. 12). Consequently, around 1850, there were about 1,500 private banks issuing banknotes in the United States, in comparison with a peak of 26 banks in Sweden. The lower number of banks, with their regional specialisations, may therefore also have contributed towards the banknotes not being considered as insecure as in the United States.

Unlimited economic responsibility

The banks' owners themselves had economic responsibility for their banks' losses. This probably contributed to a more risk-conscious governance of the banks' operations. The US system instead had limited economic responsibility for the owners (Gorton 2012, p. 13).

The redeemability for Riksbank banknotes

From 1821 until the introduction of the gold standard in 1873, private banknotes were redeemable for Riksbank banknotes (Ögren 2006). As the ultimate guarantor of their value, the Riksbank's credibility contributed to and was an important factor in the credibility of the private banknotes. After that, in conjunction with the gold standard and the subsequent new banking legislation from 1874, the banks were instead required to base their issuing of banknotes on gold. However, in practice, the banks preferred to hold Riksbank banknotes instead of gold, which suggests that Riksbank banknotes were considered to be as secure as gold (Ögren 2006, p. 76). The close link between the private banknotes and the Riksbank's banknotes, even when it did not exist in a legal sense, may therefore have further strengthened the credibility of the private banknotes. In comparison, the private US banknotes were redeemable for gold or silver and federal or state bonds were required as collateral for the issue of banknotes (Gorton 2012, p. 13). The problem was that several states suspended payments on their bonds and the value of the banks' collateral was also dependent on the value of the bonds. The result was that the backing of different banknotes was of varying strength so, in practice, the banknotes were not worth the same value (Gorton 2012, p. 17).

Clear rejection of government intervention

One possibility is that the formulation of the banking legislation of 1824, which stipulated that the banks should not expect any government assistance, may have contributed towards reducing the banks' risk propensity (Jonung 2007 [1988], p. 27). Despite this, the central government intervened on two occasions to support banks in crisis: in 1857 with Skånes Enskilda Bank and in 1878 with Stockholms Enskilda Bank. It can thus be questioned, at least after 1857, how great a role this legislation played. Paradoxically, however, it is possible that these government interventions increased confidence in the private banknotes – by demonstrating its willingness to support banks in crisis, the government, in practice, backed up the private banknotes.

Cooperation between the banks

The private banks developed a system for redeeming each other's banknotes. This may have made a further contribution to stability (Jonung 2007 [1988], p. 27). The opportunity to build up such a collaboration could, again, have been facilitated by there being so few banks.

In summary, then, there were several factors that could explain why the Swedish system of private banknote issuance was unusually stable. What most of these have in common is that they can be traced back to some form of government regulation or backing. Exactly how private the private banknotes in Sweden actually were is thus a matter for discussion.

4 The political process surrounding the banknote monopoly in Sweden

In Sweden, the profits from the issuance of banknotes, known as seigniorage, played an unusually important role in the discussion of the banknote monopoly. Starting in the 1840s, a political debate was held over how the profits from the issuance of banknotes should be allocated. As described in the section above, the central government stood for a large part of the private banknotes' credibility and, using today's terminology, it could be said that the private banks received an indirect government subsidy. In any case, the banknotes were seen by many as a common social benefit. Consequently, arguments were made in Riksdag motions from the 1860s aimed at giving the Riksbank a banknote monopoly, that the profit from issuance of bank notes should fall to the government instead of the bank owners (Brisman 1931, p. 195). Over the following decades, this matter was the subject of heated debate. Several proposals were tabled in the Riksdag, and voted down, before the final decision in 1897. Resistance was mainly justified by the argument that a monopoly would threaten or even wipe out the Swedish banks (Brisman 1931, p. 196).

The issue of a banknote monopoly led to the appointment of several committees. The most comprehensive of these, whose considerations formed the practical basis of the final decision, was the committee of inquiry of 1881 (Brisman 1931, p. 204). The committee studied experiences of banknote monopolies in other countries and compared them with the Swedish situation. It also noted that more or less all countries in Europe had already introduced banknote monopolies. It is therefore highly likely that the banknote monopoly was also seen as a necessary step to modernise the country and keep up with other countries. However, the committee of inquiry cited the following main reasons for a banknote monopoly:

- Banknotes shall be risk-free. It was emphasised that, even if the private banknotes were relatively secure, their security would be even higher if they were issued by a single institution (Bankkomitén 1883, p. 235).
- The issuance of banknotes must be uniform and without short-term profit motives.
 Otherwise, claimed the committee, there will be a risk that banknote issuance will be too extensive in good times and too restricted in bad times (Bankkomitén 1883, p. 236).
- Seigniorage is necessary to fund a central bank's social function so that it does not need to act according to a profit motive. Refining the central bank's function in society and clearly differentiating it from the private banks' commercial operations would provide it with greater possibilities to increase banknote issuance in bad times to stabilise the system. The accumulation of funds to the Riksbank would also give it greater possibilities to act forcefully when necessary (Bankkomitén 1883, p. 237).

The committee summarised its justification like this: 'The advantages of such a single-bank system – greater certainty for the redemption of banknotes, greater security due to the authorised restriction of the issue of banknotes, greater solidity and strength in dangerous times – are so great (...) that the committee has found, with no disagreement, that a single

banknote-issuing bank should be established as an objective for the development of the Swedish banking system' (Bankkomitén, 1883, p. 240).

The banknote monopoly was also linked to the Riksbank ceasing to offer the general public interest-bearing accounts. This was a leftover from the time when there were no private banking operations and the Riksbank conducted commercial banking activities with both deposits and lending (Fregert 2014, p. 361). The committee seems primarily to have seen the necessity in closing this activity as a form of risk minimisation. Firstly, there was the risk of lending to 'less good' borrowers and thus incurring a credit risk (Bankkomitén 1883, p. 238). Secondly, the committee considered that deposits in the Riksbank would comprise a further vulnerability in the event that depositors would want to withdraw their deposits rapidly in bad times. However, it is likely that there was also a political motive here: ensuring that the Riksbank did not compete with the private banks in banking operations would placate their advocates in the Riksdag, making them more inclined to accept a banknote monopoly.

The committee was clear that the system of private banknotes had functioned without any major problems and had been an important factor in funding the country's growing economy. However, it reached the conclusion that this system could not guarantee sufficient stability for the future: 'But the circumstance that a house has not burned in fifty years cannot be considered by anybody to assure it is completely fireproof....and the half-century over which our banks have stayed upright is a testimony that does not stretch far (...)' (Bankkomitén 1883, p. 271). The conclusion therefore was that the government had a responsibility to ensure that the risks were minimised for society as a whole: 'The obligation to safeguard the country against such a disaster is just as great before the misfortune has affected us as it would be after we have started to suffer from it (...)' (Bankkomitén 1883, p. 271).

5 Conclusions

The political discussion of the banknote monopoly in the second half of the 19th century focused on the principles for the financial system and the central bank's role in society. The background to this was a growing banking sector and a central bank that was more clearly assuming the character of a public authority. Private issue of banknotes in Sweden was less chaotic than in other countries. This was probably due to the stringent legislation and the Riksbank's role as an early, if undeveloped, central bank. However, the discussion of the banknote monopoly focused on guaranteeing long-term stability rather than rapidly managing an acute problem. This is similar to today's situation, where the question primarily addresses the central bank's ability to guarantee an effective and secure payment system in the long term.

For the commission of 1881, whose analysis formed the basis of the decision to introduce a banknote monopoly, the revenues from the issue of banknotes formed a central part in ensuring that the Riksbank had a sufficiently large income to take long-term decisions and had enough weight in the economy. One important difference from today's situation is therefore that the discussions of the e-krona have not focused on seigniorage, but primarily on the necessity of being able to maintain an efficient and secure payment system (Sveriges Riksbank 2017). This can probably be explained by the fact that the Riksbank also has other incomes and is now firmly rooted as a non-profit central government institution. However, the Riksbank's revenues have decreased, among other reasons due to declining cash usage. Hypothetically, this could lead to decreasing possibilities for the Riksbank to fulfil its role in the economy (see for instance af Jochnick 2015). This is connected with the distribution of work that ensued from the banknote monopoly – the private banks with the sole right to conduct banking operations and the Riksbank with the sole right to issue the primary means of payment – having eroded. As regards the general public's usage of means of payment, today's situation thereby resembles the period before the banknote monopoly. To sum up, the historical banknote monopoly should be seen as a political decision establishing that the central bank is to have final responsibility for guaranteeing the stability of the financial system, together with the necessary funds. This should be seen as part of a greater political process in which the central banks gradually assumed the form they have today – clearly delimited against profit-making financial institutions and with an overall social responsibility. The banknote monopoly was therefore important for the central banks' identity and task in society as guarantor of a functioning monetary and payment system. This remains the central bank's main task, even if the tools for achieving this have changed since the introduction of the banknote monopoly. At the time of the banknote monopoly, it was not possible to predict that technological developments would result in deposits displacing cash. Today, this is a fact and the Riksbank needs to consider a digital alternative to banknotes and coins.

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What is money and what type of money would an e-krona be?

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Money fills a central function in the economy. But it is nevertheless difficult to define exactly what money is. In an age when technological developments have meant that money is increasingly in digital form, it is becoming even more abstract to many people. The Riksbank has now begun to investigate the possibility of issuing a new form of digital money, a so-called e-krona, as a result of the decline in use of physical money, cash, in Sweden. This article is about what money is and what type of money an e-krona would be. The conclusion is that the fundamental property of money is trust, regardless of what form it takes. The Riksbank's e-krona, if it becomes a reality, would be based on the same principles for trust as the existing Swedish krona. The e-krona would therefore be a continuation of the already established principles and a long historical interaction between the monetary system and technological advances.

1 Our methods of payment are changing

In recent years an increasing number of people have shown an interest in the question of what money actually is. This is due not least to technological advances and changes in payment patterns. Our money is increasingly digital and in Sweden a large percentage of the population manages entirely without using cash. Now there are also more than 1,700 cryptoassets, or even crypto-currencies as they are sometimes known, of which Bitcoin is the most well-known. These are not issued by national central banks and they are not official currency in any country. Nevertheless, advocates of crypto-assets claim that they are money and that in the long run they can replace national currencies. National central banks have also begun to discuss the possibility of issuing their own, official, digital currencies. In Sweden, this question has gained particular topicality in that the use of cash is declining so rapidly. If cash were to disappear, the general public in Sweden would no longer have access to state money, but only to money held in accounts with private banks. There are several potential problems with this (Sveriges Riksbank 2017). The Riksbank has therefore begun to investigate the possibility to issue a digital form of cash, a so-called e-krona.

Developments have raised a number of questions: What exactly is money? Are cryptoassets money? And what type of money would an e-krona be? This article aims to answer these questions. First I present a historical retrospective of the different forms that money has taken over the years, followed by a discussion of the main ways of describing what money is. After that I discuss crypto-assets and central bank issued digital currencies, with a particular focus on the Riksbank's possible future e-krona.

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2 Our money has a long history

No one knows exactly how money first arose, but there are two main theories (see, for instance, Ekenberg and Vestin 2017). According to the first theory, money was created spontaneously to bridge over the practical problems with the barter system. Barter between two people requires that both parties have something that the other wants. If, for instance, one person has pearls and wants furs, this person needs to try to find another person who both has furs and wants pearls. According to this theory, therefore, money was invented to avoid the costly search for the perfect barter partner. Money can therefore be regarded as a universally attractive commodity that everyone wants and that enables many more transactions than are possible in a barter system.

According to the second theory, money was created for the first time by early states or predecessors to states. It thus did not arise automatically, but through a political action. The theories are not entirely incompatible; early money could very well have been created spontaneously, but sooner or later needed some sort of authority to be able to function in the long run. Alternatively, early political authorities may have seen the problems with the barter system and created money to increase the trading volumes.

2.1 Money has existed in many different forms

The first money was in any case created a very long time ago. We therefore do not have access to historical documents that can give us an insight into the process. On the other hand, there are many objects preserved that have been used as money throughout history. It is therefore possible to note that money has been designed in many different ways. In its most simple form, money has been some form of commodity with an independent barter value, so-called commodity money (Davies 1994, p. 27). Historical examples of this include objects with a direct utility value, such as axes, iron collars, standardised grain volumes and cigarettes. But also ornaments or materials for ornamentation have been used as money: feathers, shells and precious metals, either in pieces or powdered. It is easy to see the idea behind this: these objects are somewhat uniform and have a direct value as a tool, material or ornament. It is therefore more likely that a person who accepts the commodity money also accepts that it has an inherent value, even if one doubts the honesty of the previous owner.

Most of this commodity money also needed some form of processing to produce, for instance, metalwork. This is of central importance: the form that money has also depends on the technological advances and the methods that are available for producing them. This is clear when it comes to coins that can be regarded as a further development of commodity money. A coin is really a standardised amount of precious metal, which has been processed into a form that makes it easier to transport, stack and count. However, there is an important difference from commodity money: coins are furnished with a symbol of political power, usually a head of state. This can be interpreted as an official guarantee - often not met in practice, however - of the value of the coin. Coins were first minted in what is now eastern Turkey around 2,500 years ago. The precursors to these coins were probably various types of pieces of metal. The development from piece of metal to coin was probably gradual, apace with metalworking becoming more advanced. Coins can be regarded both as a means of increasing the standardisation of pieces of metal and of increasing confidence in money as the coins were furnished with a sovereign's guarantee regarding authenticity and amount of precious metal (Davies 1994, p. 63). Since the advent of coins, but probably even before that, early states have been involved in issuing money and thus in the degree of trust in money.

2.2 Money can easily lose its value...

A constant challenge throughout history has been to preserve confidence in money and its worth. There are no types of money that are entirely immune to the threat of a change in

worth. Commodity money also varies in worth as its purchasing power depends on how common it is. So-called kauri shells, for instance, which were previously used as money in large parts of Africa, had declined in value considerably towards the 1920s because of increased imports of shells (Davies 1994, p. 37). Another example of this is cigarettes, which were used as the main means of payment in prison camps during the Second World War. The cigarettes were handed out regularly and their value therefore varied substantially. When a new delivery of cigarettes arrived, their value fell heavily. After that they gradually rose in value as time passed and the cigarettes were smoked, only to quickly fall in value again when the next delivery arrived and cigarettes were once again generally available (Radford 1945, p. 195). Metal coins are not safe from fluctuations in value, either. The coins can be debased (the expensive metal mixed with cheaper metals) and coins can also be cut or filed down, which reduces the metal content. Moreover, new finds of precious metals can contribute to a fall in the value of the coin. Central Europe experienced hyperinflation during the 17th century, for instance, despite its money largely consisting of metal coins (Schnabel and Shin 2018). The main reason was that the coins were debased, although the large findings of metals in the newly discovered America probably also played a role.

Inflation is primarily linked to paper money, however. These could be produced on a larger scale thanks to a further example of technological advances – the printing press. Early printing techniques, in the form of patterns carved into blocks of wood and coloured, were used in China from the 3rd century and onwards. Paper money was introduced on a larger scale during the 10th century as a complement to coins. The result was hyperinflation, which led to the world's first experiment with paper money being abandoned (von Glahn 1996).

More advanced printing presses were first manufactured in Germany in the middle of the 15th century. But the printing press was originally used not to print paper money, but to modernise the minting of coins (Davies 1994, pp. 179–180). Paper notes were a further development of the paper instruments that could be found in Europe since the Middle Ages. One example of this is the promissory note. The promissory note was a written certificate of debt and thereby entailed the right to receive a certain amount of money. The owner of the debt, and the certificate, could therefore use the certificate to pay someone else and allow them to cash in the debt at a later date. In this way, the promissory note was very much like a banknote.

2.3 ...and interacts with institutional changes

Banks existed even during the Middle Ages, but in the 17th century there was a clearer institutional development that led to the current monetary system and the form that money currently has. In London, goldsmiths began to specialise in receiving coins and issuing receipts of these holdings which could then be used to make payments with (Wetterberg 2009, pp. 19–20). The precursor to the Riksbank, Stockholms Banco, was established in 1657 and also soon began to conduct lending activities. Sweden had previously introduced the copper coin, partly to deal with the shortage of gold and silver, and also to ensure that copper prices did not fall. Stockholms Banco began to give loans in banknotes that could be redeemed against copper coins. However, there were no restrictions on how many banknotes could be issued. The result was therefore an excess of money issuing, severe inflation and a financial crisis. The bank was closed down and the Riksbank was instead started up by the state in 1668 (Persson 2018). In England, too, goldsmiths began to create banknotes that they issued as loans in the 1660s. These could be used to make payments, as the goldsmiths promised to give the bearer a certain amount of coins if they were handed in. Dissatisfaction with these early bankers, both with the state and the London merchants, and their monopoly on granting loans and issuing banknotes was one of the motives behind the establishment of the United Kingdom's central bank, the Bank of England, in 1694 (Davies 1994, p. 256).

This development continued during the 18th and 19th centuries. Private banks in a more modern sense were started in more countries, in some cases as a direct further development of the goldsmiths' activities. In Sweden, the first private bank after Stockholms Banco was started in the 1830s. Central banks were also established in several countries, sometimes as the first bank in the country, sometimes as a complement to and stabilising factor in an already established banking sector. The division of operations between banks and central banks was not always self-evident. For example, paper notes were for a long time also issued by private banks until the central banks were given a monopoly on it. This monopoly on issuing banknotes was a clear marker that the central banks were becoming the institutions that had overall responsibility for money (Söderberg 2018a).

Money was for a long time synonymous with metal, either directly in the form of coins or as a representation of metal, in the form of banknotes. Which metal was used varied between the different countries and different periods of time – silver, gold or both of them at once. However, the principle was the same: banknotes had a value because they could be redeemed for metal. At the end of the 19th century an international standard was developed, which entailed gold alone being the main source of the value of money. This was known as the gold standard, and the details differed from country to country, but on the whole it can be regarded as an attempt to establish an international system (Eichengreen and Flandreau 1997). Sweden joined the gold standard in 1873.

The gold standard was then abandoned for the first time during the First World War. Costly attempts were made to re-establish it during the interwar period, but the attempts finally came to an end during the economic depression of the 1930s. There were many factors contributing to this, but the main problem was that the gold standard made it impossible to conduct a sufficiently expansionary monetary policy (Eichengreen 1996, Federal Reserve Bank of Cleveland 2012). However, another version of it was launched by the United States after the Second World War in the form of the Bretton Woods system. Now the member countries' currencies had their worth linked to the US dollar, while the US dollar, as the anchor in the system, could be redeemed for gold. However, the system fell apart at the end of the 1960s for various reasons, including the fiscal policy effects of the Vietnam war. In 1971 the United States abandoned the system and the dollar could no longer be redeemed for gold (James 1996). The consequence of this was that money was no longer linked to any external worth.

2.4 Money has over time become increasingly abstract

Money as a phenomenon has thus developed from being a utility and precious metal to a paper representation of precious metal and finally to paper that does not represent precious metal. The digitalisation of money can be regarded as a natural continuation of this process.

Two factors lie behind the digitalisation process. The first is that the size of the financial sector started to increase substantially, and so did the number of financial transactions. This means that increasingly large volumes of information needed to be processed. The second factor was technological advances, and in particular the emergence of modern computers. However, technological advances did not have any clear-cut effect on the use of physical money. When the ATM arrived in the mid-1960s, it became easier to quickly withdraw cash to use in payment. But at the same time, further innovations in the payment field meant in practice that cheques became outdated. The smart card first appeared at the end of the 1960s and was improved during the 1970s. Payment terminals began to spread in the retail trade in the 1980s (Bátiz-Lazo and Wood 2002). These innovations revolutionised the possibility to use deposits in banks for payments.

In purely concrete terms, there are currently two main forms of money for the general public: money in accounts, which is in a digital form, and cash, which is in a physical form. That deposits began to be used as money was because different instruments, such as cheques and

direct debits, were developed further and made payments from one account to another much easier. The possibility to make payments directly from one's account means that deposited funds can in all practical aspects be regarded as money. However, it has not always been selfevident that funds in accounts could be regarded as money. During the early 19th century, for instance, the question was discussed of whether deposits in accounts with banks could be regarded as money (O'Brien 1997, p. 599). The technological advances, most recently with Internet and smart phones, have further increased the possibilities to quickly make payments from one's account and instantly see the balance there. There are thus few people today who would doubt that the funds in their account can be regarded as money.

To summarise, one can draw three conclusions from this retrospective. Firstly, that money's exact form changes over time. Secondly, that it has not been self-evident how to draw up a monetary system that functions smoothly. Thirdly, money has always had an institutional framework that consists of states and various types of institutions. The current discussion on digital currencies and how they should be defined is thus part of a long historical interaction, where technological advances and institutions' influences affect the design of money.

3 Different views on what money is

A simple definition, which is independent of the technologies and institutions involved, is that money is something that is generally accepted as a means of payment. The actual design is thus of secondary importance. Confidence is instead of central importance for money: by trusting the value of money we dare to accept it as a means of payment. A paper banknote or a series of binary digits in a computer may thus have a value as long as we believe that they do. This means that money to actually be money has to be based on some form of confidence principle. The next question is then how money must be constructed to be able to be generally accepted. The nature of money therefore becomes as much a normative as a descriptive question: *how* money should be is difficult to distinguish from *what* it is. There are three main views with regard to what money is and they all ultimately concern this: guaranteeing a functioning monetary system.

3.1 Metallism

According to the first view, money should either consist of or be attached to something that has an independent value. The link to historical systems of commodity money or coins is clear. As it has in recent centuries primarily been precious metals that has been a guarantee for the value of money, this view is often called *metallism* (Goodhart 1998). Paper money can in this view still be regarded as money, but receives its value primarily from banknotes being redeemable for precious metals. A banknote is in this case a claim for a certain amount of precious metal that can be redeemed if the bearer so desires. As long as the bearers trust that the banknote can be redeemed, the note can function as a means of payment. Historically, both silver and gold were used, often together with a reciprocal value relationship, for this purpose (Eichengreen and Flandreau 1997). The peak of metallism came with the gold standard, which was mentioned in the historical overview. The idea behind metallism is that the availability of precious metals, and the cost of quarrying more metal, should set an automatic limit on how much money can be created. This creates confidence and price stability. The trust in the system is ultimately based on the natural rarity of the precious metals.

3.2 Chartalism

According to another view, *chartalism*, money is instead something that is created in legal terms by a state. What money exactly consists of – precious metal, paper or ones and zeros in a computer – is therefore irrelevant. To be money, it must quite simply be defined as

money by a state. This may appear very categoric. But one way of interpreting this view is that only national states have the power to legislate that something shall be money and the resources to be able to preserve confidence in this money.

Chartalism was first advocated by a German economist called Georg Friedrich von Knapp in 1905, but later also by John Maynard Keynes. According to this view, money does not need to be issued directly by the state, but the state defines what is counted as money by accepting it as payment (Wray 2014, p. 6). For example, a person can pay their taxes to the state with money deposited in an account with a commercial bank. Money in accounts can therefore also be classified as money according to chartalism.

3.3 Functionalism

The third view, which is currently the most accepted, can be called *functionalism*. The reason for this term is that money, to be counted as money, must fulfil a number of functions. These were first proposed in 1875 by the British economist Stanley Jevons (Söderberg 2018b). Money must first of all function as a means of payment between buyer and seller. Secondly, money must function as a common standard of value so that various goods and services can be evaluated according to the same measure. Thirdly, money must have a sufficiently stable value so that decisions on buying and selling are not affected by changes in value. If money rapidly declines in value, the holder will want to get rid of it quickly. If money increases in value, the holder will instead want to hold on to it and therefore postpone purchases while waiting for the money to increase in value even more. In other words, money may neither rise nor fall too far in value to be classified as money. One usually summarises these three functions as money having to function as a means of payment, a unit of account and a store of value.

3.4 What type of money are the established currencies?

The three main ways of looking at money discussed above are summarised in Table 1.

View	Conditions	
Metallism	Consists of or is tied to an article with a market value	
Chartalism	Legal creation issued by national state	
Functionalism	Must function as: 1) Means of payment 2) Unit of account 3) Store of value	

Table 1. Different views on what money is

Source: Söderberg (2018b)

How shall we then classify the established currencies, for instance, the Swedish krona and the US dollar, in relation to this? Since the 1970s there has been no link at all, as mentioned in the previous section, between the national currencies and precious metals. Established currencies, such as the Swedish krona and the US dollar, can be regarded as a mixture of chartalism and functionalism. As their value is not linked to any external item, such as gold, they are sometimes called 'fiat money' from the Latin word *fiat* which means an order from above – in this case that money shall be created and have a value. The currencies are issued by national states, through a state central bank, and are then managed by the central banks in accordance with legislation, in Sweden the Sveriges Riksbank Act.

Cash is issued directly by the central banks, but the largest volume of money is not created by the central banks, but by private banks when they grant loans (Ekenberg and Vestin 2017, McLeay et al. 2014). One can therefore say that state and private money complement one another in the current monetary system (Committee on Payment and

Settlement System 2003). However, the state and the central banks have the ultimate responsibility for the total volume of money and the long-term value of money. States therefore affect the banks' creation of money with the aid of regulations and monetary policy. Funds in accounts are also now backed up by state deposit guarantees, which further increase confidence in them. The private funds in accounts therefore also have a large state component. Even a purely chartalist interpretation of money would therefore accept that funds in accounts are also money despite not being issued directly by the state (Wray 2014, p. 6).

What then are the principles that maintain confidence in the national currencies if there is no absolute limit on how much money can be created? The answer is the confidence in the national states and the competence in the bureaucracy at the disposal of the states. One could here talk about modern currencies resting on a 'Weberian' foundation, after the German sociologist Max Weber. Weber analysed the emerging modern national states in the late 19th and early 20th centuries. He said that they based their legitimacy primarily on an emerging bureaucracy that endeavoured to carry out critical societal functions in a rational manner.

With regard to money, the central banks have the decisive responsibility for maintaining the basic functions of money. If the politicians in charge had responsibility, they could be tempted to allow exaggerated money production to fund public expenditure, which would mean that the value of money was undermined. There are also several examples in modern times of states that have not managed to administer the money system, which has resulted in hyperinflation, for instance Zimbabwe and Venezuela. To further increase confidence in money, many countries including Sweden in 1999, have legislated that the central bank shall be politically independent. Within the EU, for instance, it is essential that governments have no mandate to influence monetary policy and that the central bank is not used to fund the government's budget. Legally independent central banks can be regarded as the latest state in the long institutional development that was outlined earlier.

According to metallism, the established currencies could not be classified as money, as they are not formally linked to precious metals. On the other hand, it is important to remember that central banks usually own, or have the possibility to rapidly acquire, large volumes of precious metal. One could therefore say that even modern fiat money is indirectly backed up by gold. Although gold, when regarded from a yield point of view would no longer be regarded as an optimal investment for central banks, its history and psychological effect probably play an important, albeit indirect role.

4 Crypto-assets

Many also wonder how crypto-assets, which have recently gained considerable attention, relate to established currencies. There is no established definition of crypto-assets. But one could say that they are digital units that are created and transferred between users with the aid of cryptographic calculations. Most crypto-assets are decentralised, which means that they are not issued by any formal institution.¹ Instead, they are created through an interaction between the users themselves according to a set of rules, what is known as a protocol. The oldest and most well-known crypto-asset, Bitcoin, was created in 2009 by an unknown person or group under the pseudonym Satoshi Nakamoto. Since then, many other crypto-assets have been created and in the second half of 2018 they numbered more than 1,700 (Coinmarketcap 2018). Taking into account total market value, Bitcoin is still the largest, but other crypto-assets, such as Ethereum, have increased their market shares.

¹ Some crypto-assets are issued in more closed systems and therefore often have a company as official issuer. One example is Ripple.

4.1 Crypto-assets were created as a result of lack of confidence

Section 3 describes how the established currencies mainly rest on the confidence in national states and the competence of the authorities managing the currencies – the central banks. The emergence of crypto-assets is linked to a drop in confidence in the financial system during the financial crisis 2007–2008. Several of the technological innovations on which crypto-assets are based were already familiar to computer scientists and cryptographers (Lansky 2018). But the will to combine these into a hypothetically new payment system arose when the financial crisis, the banks' major losses and the state support to the financial sector undermined confidence in the monetary system. Nakamoto wrote:

The root problem with conventional currency is all the trust that's required to make it work. The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust. Banks must be trusted to hold our money and transfer it electronically, but they lend it out in waves of credit bubbles with barely a fraction in reserve (cited in Davis 2011).

Nakamoto's fundamental idea was therefore to create an alternative means of payment that could function without confidence in a third party, for instance a bank or central bank (for a detailed description of how Bitcoin functions, see Segendorf 2014, Söderberg 2018b).

4.2 Are Bitcoin and other crypto-assets money?

So are Bitcoin and other crypto-assets money? The best way to discuss this question is to start from the three different views described above. According to metallism, the value of money shall be backed up by a commodity with an independent market value. Crypto-assets are not linked to anything like this. Many crypto-assets, especially Bitcoin, use large amounts of energy to create an artificial cost to create new crypto-units. But the electricity used to create Bitcoins cannot be re-used and sold and therefore cannot serve as a guarantee of their value.

According to the chartalist view, the answer is simple: as crypto-assets are not issued by a national state and not accepted by national states as payment for tax, they cannot be money. But what about functionalism? Here the question is whether crypto-assets, at least thus far, fulfil the three main functions (means of payment, unit of account and store of value). Crypto-assets are constructed to function as a means of payment, but in practice they are used to a very small extent as such. Probably the main reason for this is that one regards the holdings as an investment that one expects will increase in value. Most people thus do not regard crypto-assets as a means of payment, but rather as an investment. If one expects money to increase in value, one will of course make a loss every time one buys something with it – the increase in value one believes one would have had if one still had the money. Crypto-assets also vary quite substantially in value, which means that they cannot be said to fulfil the function of a store of value (for a more in-depth discussion on this, see Söderberg 2018b).

Crypto-assets thus cannot be classified as money according to any of the main views of what money is. However, there are many experiments under way in which the aim is to try to bridge over the problems described here.² Hypothetically, an already existing crypto-asset or a future crypto-asset could after technological improvements fulfil the conditions for functionalism. But it is still too early to determine whether or not this is possible.

² For example, Bitcoin has been split up into other rival crypto-assets. Other examples of experimental crypto-assets are Saga, Ethereum and Dash.

5 Central bank issued digital currencies and the e-krona

The development of digital technology has raised questions regarding the future of the established currencies. At present, a private individual cannot own digital state money. An important question is therefore whether central banks shall issue digital money that is accessible to the general public and how it should then be designed. The idea is not a completely new one. The American economist James Tobin argued in 1987 that central banks should have transaction accounts for the general public (Tobin 1987). He said that this would enable cashless payments outside of the commercial banking sector. With today's technology, it would entail digital state money. Interest in state issued digital money has also increased as interest in crypto-assets has increased in the media (see, for instance, Konig 2014). Several central banks have ongoing projects regarding digital currencies issued by central banks, either in the form of analysis or testing of relevant technology (see, for instance, Bank of Canada 2017, Monetary Authority of Singapore 2017).

5.1 What type of money would an e-krona be?

In Sweden, the question of central bank issued digital currencies has become important because the use of cash has declined and the Riksbank has therefore begun to investigate the possibility of introducing a digital form of the krona, an e-krona (Sveriges Riksbank 2017). So what type of money would an e-krona be?

Firstly, regardless of how it is designed, it would be issued by the Riksbank, which is a state authority. It could therefore be classified as money according to chartalism. The state issuance would also, as at present, be managed by the Riksbank, which is politically independent. A large part of the confidence would thus, as today, rest on confidence in the Riksbank's ability to maintain price stability. The difference from crypto-assets is that confidence there is replaced with mechanical principles for creating money and confidence in the underlying protocol.

The e-krona would not be any form of independent currency. This means, quite simply, that the e-krona would be a Swedish krona in another form, in addition to the already existing cash and money in bank accounts. This would mean that its value would develop alongside that of other forms of Swedish krona in accordance with the Riksbank's task to maintain a stable development of the krona's purchasing power. Its value would therefore not vary in the same way as that of crypto-currencies. If it did so, the Riksbank's undertaking to maintain an efficient payment system would not be fulfilled. The Riksbank would in other words be obliged to guarantee that the e-krona fulfils the three basic functions of money. From both a chartalist and a functionalist point of view, the e-krona would therefore be classified as money. One could also, as mentioned above, argue that the Riksbank's holdings of precious metals constitute an indirect and psychological back-up of money in accordance with metallism.

Table 2 below summarises the main characteristics of the potential means of payment that the general payment in Sweden could have access to if the e-krona becomes a reality.

	Cash	Funds in account	Crypto-assets	E-krona
Claim on?	Sveriges Riksbank	Bank	-	Sveriges Riksbank
Form?	Physical	Digital	Digital	Digital
Confidence in?	Sveriges Riksbank	Bank, deposit guarantee, regulations, the Riksbank's monetary policy	Underlying protocol	Sveriges Riksbank
Money?	Yes	Yes	No	Yes

Table 2. Overview of potential future means of payment available to the general public in Sweden

6 The e-krona – a krona that meets the requirements we have of money

This article has discussed what money is and what type of money a potential e-krona could be. As the historical section showed, money can be many different things and take many different forms. Similarly, several different techniques can be used to produce and distribute it. Another conclusion is that money can never be separated from an institutional context that also changes over time. The underlying requirement for money to function, on the other hand, is timeless – confidence. The central issue is therefore what it is that maintains confidence in money. During the course of history, a physical reminder has often been needed that money has a direct value – in its most basic form money has consisted of something with a direct utility value such as axes or grains. In modern times, the national state with a well-developed bureaucracy is the main source of confidence in the established currencies. By making the central banks politically independent and ensuring that they are not used to fund government budgets, one has further increased confidence in money.

An e-krona, if it becomes a reality, would be issued and managed by the Riksbank, which is a public authority, in a way that guarantees that it fulfils the fundamental functions that are required of money. It would therefore be based on the chartalist and functionalist principles that are now the basis for our monetary system. Crypto-assets enthusiasts in many cases lack confidence in the ability of states and central banks to manage money. It is therefore very important to make a clear distinction between crypto-assets and central bank issued digital currencies – the former are usually issued in a decentralised process with no formal issuer, while the latter are issued by national states and managed by central banks. The principles for maintaining confidence in a potential e-krona and a crypto-asset are thus diametrically different.

It is easy to see historical parallels to the current situation. Historically, we have seen that technological advances create new forms of money and can force institutional changes. The primary example is perhaps when paper money was first established. This started up a long process of institutional development that resulted in the emergence of the modern central bank system. The current developments in Sweden, where information technology and reliance on digital technology have fundamentally changed payment patterns, are a further example of this. If the Riksbank was to decide to issue an e-krona, it would not be a departure from earlier established principles for the central bank's actions. It would rather comprise a continuation of the interaction between technological advances and institutional changes that we have seen earlier in history.

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The implications of an e-krona for the Riksbank's operational framework for implementing monetary policy

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If the Riksbank introduces an e-krona, it will mean, to put it simply, that the Riksbank extends its counterparty circle to include households and companies that are not credit institutions. These groups will have the opportunity to have a direct claim on the Riksbank. The e-krona will be a further item on the Riksbank's balance sheet that can be both extensive and volatile. The volatility means that the current framework for implementing monetary policy may need to be adapted to reduce the risk of volatility in short market rates. The e-krona is an example of how the framework for implementing monetary policy needs to be reformed apace with the changes in the surrounding world to continue to function smoothly. If the e-krona is not an interest-bearing instrument, it is probably no longer possible to have negative policy rate. However, if the e-krona is an interest-bearing instrument, it can be regarded as a monetary policy instrument and the interest rate on it set in a way that is compatible with the monetary policy conducted.

1 Introduction

This article analyses the possible consequences of the introduction of a digital e-krona for the Riksbank's framework for implementing monetary policy. By the latter we mean the regulations and the measures taken to put the Executive Board's decisions on the policy rate into practice on the financial markets. Will the practical implementation of monetary policy be the same as now or will it be necessary to make changes?

The Riksbank's ongoing project regarding a potential e-krona contains many questions – technical, legal, policy-related – and these questions are often very complex. As we will see, the effects of an e-krona on the Riksbank's framework for implementing monetary policy may not be so complicated to understand, at least in terms of principles. The reason for this is that the Riksbank already 'issues' digital money, although this is only accessible to the institutions participating in the Riksbank's RIX payment system. That the Riksbank is considering introducing an e-krona can therefore briefly be expressed as the Riksbank considering expanding the circle of those who can receive digital central bank money to include the general public.

But there are questions that are more complicated, and it is difficult to try to answer them in advance. One question is how great the demand for an e-krona will be. One decisive factor will probably be what counterparty circle is given access to an e-krona, as this will

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determine both the level and volatility in demand for the e-krona. In this article, we assume that the general public is allowed to own the e-krona with no limitations. This is an important assumption for our reasoning. Another question is whether or not the e-krona will be interestbearing. We discuss both cases in the analysis below. Further, we assume that cash will continue to be supplied by the Riksbank as long as there is a demand from the general public.

We begin the article with a brief description of the RIX payment system and how the Riksbank's framework for implementing monetary policy looks now.¹ After that, we analyse the consequences for this framework of introducing an e-krona. The analysis is done in two stages. First, we look at an e-krona that is not interest-bearing and thereby comprises a close substitute for banknotes and coins. In stage two we analyse the consequences of introducing an e-krona that is interest-bearing, which also includes the possibility to have a negative interest rate. After that we discuss the special circumstances that can arise in a period of financial unease. We conclude with some main conclusions. In an appendix we use simplified balance sheets to illustrate what is meant by, for example, central bank money and commercial bank money.

2 The Riksbank's operational framework for the implementation of monetary policy

The Riksbank has chosen under normal circumstances to steer the shortest interest rate on loans from today to the next banking day, what is known as the *overnight rate*, and to rely on this indirectly affecting interest rates for longer maturities.² To steer the overnight rate, the Riksbank uses monetary policy instruments in the form of standing facilities and market operations. The standing facilities are linked to the banks' accounts in the RIX payment system.

RIX is the Riksbank's system for the transfer of funds in accounts and is one of the major hubs of the Swedish financial system.³ The Riksbank gives banks and several other market participants with the right to hold accounts in RIX the opportunity to make transfers to each other in a manner that does not entail credit or liquidity risks. Almost all of the payments in Swedish kronor that are not made internally within an individual bank are handled in the RIX system in some form. To increase the efficiency of the payment system, the Riksbank adds liquidity by granting credit during the day – *intraday credit* – against collateral.

The RIX payment system and the framework for implementing monetary policy interact in several ways. When intraday credit is repaid at the end of the day, the banks may have a surplus or a deficit on their accounts in RIX. To even out the balance, they may need to borrow money from the Riksbank or to deposit money there overnight. The Riksbank's possibilities to influence the overnight interest rate ultimately depends on the Riksbank being in a position to set the terms and the extent of overnight deposits and lending. Moreover, the requirements concerning collateral in RIX for intraday credit are partly the same as those for monetary policy instruments.

The rest of this section discusses the monetary policy instruments in greater detail, and how they have an impact on the Riksbank's balance sheet.

2.1 Standing facilities

The Riksbank offers banks that are monetary policy counterparties to the Riksbank the opportunity to borrow from or deposit money with the Riksbank from one day to the next, that is 'overnight' on predetermined conditions, what is known as *standing facilities*. Using these standing facilities the Riksbank can set limits – an *interest rate corridor* – for the

¹ See Sveriges Riksbank (2012) for a description of the RIX payment system and Sellin and Åsberg Sommar (2012) for a detailed description of the framework for the implementation of monetary policy. See also Sellin (2018) for a description of the Riksbank's various operational frameworks since the end of the 19th century.

² The market for balancing liquidity overnight – also known as *the overnight market* – is the market in which banks manage temporary surpluses or deficits in their liquidity in Swedish kronor.

³ The average daily turnover in the RIX system exceeded SEK 600 billion during the first four months of 2018.

overnight rate. The Riksbank's deposit rate comprises the floor and the lending rate comprises the ceiling in this corridor. The overnight interest rate will invariably lie inside the interest rate corridor because a bank in need of liquidity can always borrow from the Riksbank (against collateral) at the lending rate and a bank with surplus liquidity can always deposit the surplus in the Riksbank at the deposit rate. As there is a difference between the deposit and lending rates, the banks have an incentive with regard to overnight loans to agree on an interest rate that lies between the rates they would pay to or receive from the Riksbank. The Riksbank can thus ensure that the overnight rate falls within the interest rate corridor.

The interest rate on the deposit facility (the deposit rate) is currently equal to the Riksbank's policy rate (also known as the repo rate) minus 0.75 percentage points and the interest rate on the lending facility (the lending rate) is equal to the policy rate plus 0.75 percentage points, see Figure 1. If the balance of a bank's account with RIX shows a deficit when the payment system closes for the day, the bank has to pay the lending rate on the balance overnight (that is until the next bank day). If the balance of a bank's account shows a surplus when the payment system closes, the bank earns the deposit rate on the sum overnight. The sum that can be borrowed from the lending facility is limited by the adjusted value of the collateral provided by the bank.⁴ On the other hand, there is no limit on how much a bank may deposit in the deposit facility.

Figure 1. The monetary policy interest rates – the policy rate, the interest rate corridor and the fine-tuning rate



Source: Sveriges Riksbank

2.2 Market operations

However, the standing facilities are not sufficient in themselves to stabilise the overnight rate close to the policy rate. This is because the banking system as a whole may have a deficit or a surplus with regard to RIX and because the interest rate corridor is relatively wide. If the Riksbank did not have further measures to implement, the overnight rate would end up close to the lending rate if the banks in total had a deficit. And vice versa, it would fall close to the deposit rate if the banks in total had a surplus. The Riksbank therefore also carries out market operations to either provide liquidity (which was most often the case up to the year 2008), or to reduce a liquidity surplus.

The market operations can be divided into two categories. In the first, the Riksbank every week issues *Riksbank Certificates*, if the banking system has a liquidity surplus in relation to the Riksbank, or offers *monetary policy repos*, if the banking system has a liquidity deficit in relation to the Riksbank, in both cases with a one-week maturity to the policy rate.

⁴ A so-called haircut is made on all of the collateral the banks need to provide to be able to borrow from the Riksbank. This haircut varies between 0 and 40 per cent for price risk and between 4 and 9 per cent for exchange rate risk.

The Riksbank's monetary policy counterparties are thus given the opportunity to invest in securities with a short maturity (one week) issued by the Riksbank or alternatively to borrow money for one week. The volumes offered correspond to the banking system's liquidity surplus or liquidity deficit.⁵

The second category is the *fine-tuning transactions* the Riksbank implements at the end of every banking day to stabilise the overnight rate close to the policy rate. In the fine-tuning transactions, the Riksbank offers credit against collateral or overnight deposits at an interest rate equal to the policy rate plus/minus 0.10 percentage points. If the banking system as a whole has a liquidity deficit at the end of the day, the Riksbank lends funds, although not to an amount that exceeds the banking system's total deficit. A similar procedure applies if the banking system as a whole has a liquidity surplus at the end of the day. In this case, the Riksbank receives funds, but not to an amount that exceeds the banking system's total surplus. Allocation takes place on a 'first come, first served' basis, as long as there are funds left to lend or deposit. Figure 1 summarises the interest rates in the standing facilities and fine tuning and how they relate to the policy rate.

2.3 The banks' liquidity position, the framework for implementing monetary policy and the Riksbank's balance sheet

To conclude the description of the operational framework for implementing monetary policy we also need an explanation of how it manages the banking system's liquidity in concrete terms and how the Riksbank's balance sheet is affected. We illustrate here the case where the banking system as a whole has a liquidity surplus against the Riksbank, which is the situation that has prevailed since 2008.

Figure 2 is a schematic description of the liability side of the Riksbank's balance sheet. According to this description, the liability side of the Riksbank's balance sheet can be divided into two parts: the monetary policy instruments and the so-called *autonomous factors*, that is, claims on the Riksbank governed by the creditors' demand and which the Riksbank cannot control. The monetary policy instruments all have the property that they withdraw liquidity – Figure 2 illustrates the situation with a surplus in the banking system – partly in the form of the standing deposit facility and partly in the form of market operations (fine tuning and issuing of certificates). The autonomous factors currently comprise the general public's demand for banknotes and coins, allocations made to the Bankgirot client funds account in RIX to back up real-time payments overnight (BiR account) and deposits and withdrawals from the correspondent accounts with the Riksbank.⁶

⁵ The banking system has had a liquidity surplus since 2008, which has thus meant that the Riksbank has issued Riksbank Certificates every week since then. Prior to 2008, the banking system had a liquidity deficit, which meant that the Riksbank supplied liquidity through repos. See further Nessén et al. (2011).

⁶ Those who have correspondent accounts with the Riksbank are foreign central banks and international financial institutions that need to implement transactions in Swedish krona. Banks that are RIX participants and participants in Bankgirot's BiR system can make provisions in a special account in RIX (the BiR account). These provisions back up the payments made between the banks on Bankgirot's BiR platform overnight when RIX is closed. At present, the BiR platform is only used by the Swish payment service. The banks' total provisions in the BiR account may amount to a maximum of SEK 10 billion with effect from October 2018.

Figure 2. The liability side of the Riksbank's balance sheet and the Riksbank's creditors, in a situation with a liquidity surplus in the banking system



Source: Sveriges Riksbank

In connection with the weekly issues of Riksbank Certificates, the Riksbank forecasts how large the liquidity surpluses will be in the coming week. Firstly, the Riksbank Certificates that mature need to be replaced with new ones. But then claims in the autonomous factors also need to be taken into account. For example, an increased demand for banknotes, new provisions to the BiR account or new deposits in a correspondent account in the Riksbank will lead to the Riksbank's debt to the monetary policy counterparties declining to a corresponding degree, and the amount of new Riksbank Certificates that needs to be issued will be lower.⁷ And the reverse, if the demand for banknotes is expected to decline, the volume of Riksbank Certificates issued needs to be greater. The part of the surplus that is not withdrawn by issuing Riksbank Certificates – either because the banks do not buy all of the certificates issued or because there are unexpected changes in autonomous factors – is then managed by means of the daily fine-tuning transactions.

3 The implications of an e-krona

As we wrote in the introduction, the implications of the e-krona for the operational framework for implementing monetary policy are relatively easy to understand, at least in terms of principle. In this section we begin by first looking at how the balance sheet is affected on an overall level, and then we discuss the effects on the lower bound for the repo rate.

3.1 Effects on the balance sheet

We begin by looking at how the balance sheet is affected. As previously mentioned, the e-krona means that the circle of those who can hold digital central bank money will be extended to include the general public. This entails a new liability item on the Riksbank's balance sheet, with the general public as a counterparty, see Figure 3.⁸ How large this item can become depends on a number of factors and is discussed in two separate articles, see Segendorf (2018) and Juks (2018). In brief, this is a question of how demand for the e-krona would affect, for instance, the demand for banknotes or for normal bank deposits and how the banks would react to it.

⁷ One can also express this as a decline in the banking system's liquidity surplus towards the Riksbank. The Riksbank's total debt

is unchanged, but there has been a reallocation from monetary policy liability to autonomous factors

⁸ This representation applies regardless of the technical design of the e-krona.

Figure 3. The e-krona and the liability side of the Riksbank's balance sheet and the Riksbank's creditors, in a situation with a liquidity surplus in the banking system



Source: Sveriges Riksbank

Whether the e-krona is to be regarded as an autonomous factor or counted as one of the monetary policy instruments depends on whether or not it is interest-bearing.

3.2 An e-krona without interest

If the e-krona is not an interest-bearing instrument, it can be regarded as a further autonomous factor, that is, a claim on the Riksbank that is governed by demand from the general public and which the Riksbank cannot control. As in the case with an increased demand for banknotes and coins, an unexpected increase in the amount of e-krona will lead to the banking system's liquidity surplus declining (or the deficit increasing). An unexpected decline in the amount of e-krona will correspondingly lead to the liquidity surplus increasing. If the banking system has a liquidity deficit to start with, this will of course instead decline. What this means for the practical implementation of monetary policy is that the Riksbank needs to be able to forecast how many e-krona will be demanded in the following week in order to supply or withdraw an appropriate volume of liquidity via market operations. Described in this way, the e-krona would not entail anything significantly new and the current operational framework should be able to deal with it adequately.

However, it appears likely that it will be more difficult to forecast the volume of e-krona than the volume of cash, as it will be easier to move money between a bank account and an account for e-krona than it is to move money between a bank account and cash. Handling cash is more complicated. This means that the demand for e-krona will probably vary more over time than the demand for cash. And in a low interest-rate environment like the one we have now the e-krona can become even more attractive, even if it is not interest-bearing. Particularly for participants in the RIX payment system, who do not have access to the standing facilities, the e-krona will comprise an attractive investment alternative if the deposit rate is negative. We will return to this in later sections.

The increased volatility in the liquidity surplus and the potentially large amounts that may be involved risk leading, if no other changes are made to the operational framework, to increased volatility in interest-rate setting on the overnight market, with potential consequences for other interest rates at longer maturities.⁹ This would indicate that the operational framework needs to be reviewed.

⁹ The increased variation also risks leading to the system 'tipping over', that is, going from a surplus to a deficit, in an unplanned manner. If the banks have invested all the liquidity surplus in Riksbank Certificates and the demand for e-krona suddenly increases, the banking system will 'tip over' to a deficit in relation to the Riksbank. The banks will then need to borrow money overnight in the Riksbank's fine-tuning operations. Another alternative for the banks would be to sell back some of their certificates to cover the liquidity deficits, but then the payment would not be available until the following day. The probability that the Riksbank will from day to day alternately lend and borrow in the fine-tuning transactions will likely increase if the e-krona is introduced.

3.3 An interest-bearing e-krona

With the current legislation, it may not be possible for the Riksbank to pay interest on an e-krona. However, the legislation might be amended in the future and it is therefore also worth analysing the consequences for the operational framework if an interest-bearing e-krona is introduced.

If it is possible to have an interest-bearing e-krona, the interest rate on it would need to be set so that the monetary policy counterparties cannot use the e-krona to circumvent the Riksbank's monetary policy interest rates. For instance, the Riksbank would in the case of a liquidity surplus not be able to set the interest rate on the e-krona higher than the Riksbank's policy rate, as the monetary policy counterparties would then probably prefer the e-krona to bidding in the weekly issues of Riksbank Certificates (at the policy rate) or to investing in the daily fine-tuning transactions (at the policy rate minus 0.10 percentage points). Correspondingly, it would in the case of a liquidity deficit in the banking system be a problem for the Riksbank to supply liquidity to the banking system via monetary policy repos at the policy rate if this money could be immediately invested at an interest rate on e-krona that was higher than the policy rate. Such interest-rate setting could risk undermining the Riksbank's possibility to steer the overnight rate to keep it close to the policy rate. The interest rate on the e-krona would thus have to be set so that it harmonised with pricing of the monetary policy instruments, which means that the e-krona itself needs to be fitted in with the monetary policy instruments.

If it becomes easy to move funds between deposit accounts in the banks and e-krona, the Riksbank could use the interest rate on the e-krona to influence the banks' deposit rates in a more direct way than is currently possible. If the interest rate on the e-krona was raised (at the same time as the policy rate is raised) the banks could be forced to raise their deposit rates by the same amount if they wished to avoid depositors moving their money from the banks' deposit accounts to e-krona. Correspondingly, cutting the interest rate on the e-krona could make it possible for the banks to reduce the interest rates on their deposits without risk of depositors moving their money over to the e-krona. The operational target for monetary policy would then need to shift focus from solely ensuring that the overnight rate is close to the Riksbank's policy rate. It would then be interesting to also evaluate how changes in the interest rate on the e-krona have an impact on the banks' deposit rates.

We note that in the system we have outlined here, it would be fully possible for the Riksbank to cut the interest rate on the e-krona without at the same time cutting the policy rate. The only restriction is that the interest rate on the e-krona cannot be higher than the Riksbank's policy rate. ¹⁰ But is there any situation in which the Riksbank would consider cutting the interest rate on the e-krona without this being justified by a cut in the policy rate? Yes, possibly if the banking system were affected by a bank run against deposits in accounts. If such a confidence crisis were to occur, the Riksbank would want to make the e-krona less attractive. See Armelius et al. (2018) for further discussions on how the e-krona can be used as a monetary policy tool.

Finally, the conclusion is that an e-krona that is interest-bearing should be included as a further monetary policy tool in the Riksbank's toolbox. Moreover, the operational target for monetary policy – for the overnight rate to be close to the Riksbank's policy rate – needs to be supplemented if one wants to make use of the new opportunities offered by an interest-bearing e-krona when implementing monetary policy.

¹⁰ It is more correct to say that the interest on the e-krona cannot be higher than on any of the monetary policy interest rates, even for example the deposit rate. In this context, it is interesting to note that as of 1 November 2018, the Riksbank is offering central counterparties that are RIX participants and clear in Swedish krona the opportunity to apply for access to a new deposit facility, intended to counteract disruptions in central counterparties' managing of liquidity in Swedish krona spreading throughout the financial system. The deposit facility means that central counterparties have the opportunity to deposit money with the Riksbank's deposit rate, that is, the interest rate on the Riksbank's standing deposit facility to which the Riksbank's monetary policy counterparties have access.

3.4 On the e-krona and the effects on the lower bound for monetary policy interest rates (including the policy rate)

So far, the main focus has been on how the interest rate on the e-krona, if it were to be interest-bearing, should be set. Another way of looking at this is whether the e-krona can determine how low the monetary policy rates can become. As in the case with cash, the e-krona will determine a floor for the interest rates on the monetary policy instruments. This follows from the e-krona, like cash, being perceived as a risk-free investment, available to all and determined by demand. If the monetary policy interest rates are set too low, banks, companies and households will prefer cash or e-krona.

Previously, one considered that the existence of cash, which does not give any return, set a floor for nominal interest rates at zero per cent, what was known as the zero lower bound. But several central banks have had negative policy rates in recent years. In the case of the Riksbank, the policy rate has been negative since February 2015.¹¹ This has been possible because of the costs of storage, insurance, transport and so on that are linked to holding cash as an alternative to the monetary policy instruments. The concept 'zero lower bound' has thus been replaced by the 'effective lower bound' (ELB), which is below zero per cent. See Table 1 below. However, it is difficult to know this lower bound in advance in that it is difficult to quantify the different costs exactly. Moreover, they can change over time.¹²

Holding an e-krona is not linked to corresponding costs. How the lower bound is affected in more detail will depend, however, on whether or not the e-krona is interest-bearing.

Let us begin with the case of an e-krona that is not interest-bearing. If the Riksbank's deposit rate, policy rate and/or fine-tuning interest rate on deposits were negative in this situation, interest in investing in the corresponding interest-bearing monetary policy instrument would be minimal, as it would be more beneficial to invest money in e-krona at zero per cent interest. This means that the lower bound in the case of a non-interest-bearing e-krona would probably be much closer to zero than the bound that applies without an e-krona. It may be the case that negative monetary policy interest rates are on the whole no longer possible. See Table 1 below.

This in turn has implications for the width of the interest rate corridor, in that it will determine the lower bound for all interest rates on monetary policy instruments. The indications are that the interest rate corridor would need to become much narrower if one wants to continue with an interest rate corridor that is symmetrical around the policy rate. The broader the corridor, the higher the lower bound for the policy rate will be. One alternative in such a situation would be to change over to a floor system where the policy rate comprises the lower bound in the corridor instead of lying in the middle of the corridor. This is attained by the central bank ensuring that the banking system has so much liquidity that all banks have to deposit with the central bank, which would lead to the overnight rate being pushed down to the floor of the corridor. Such a system is currently applied by the central banks in the United Kingdom, Norway and New Zealand.

If, on the other hand, the e-krona is interest-bearing, the interest rate can be set at both positive and negative levels. The lower bound for the policy rate is then determined by the level that is highest of either the lower bound in the case of cash (that is, the level where it is more profitable to hold cash than to have money in an account) or the interest rate on the e-krona.¹³ If the interest rate on the e-krona is positive, for instance, the policy rate cannot be set lower than this. See Table 1 below.

¹¹ During 2009, when the policy rate was 0.25 per cent, the deposit rate was negative for a period of time. However, this had no effect on interest-rate setting in general, in that the amounts deposited at a negative interest rate were very small. 12 See Alsterlind et al. (2015) for a discussion of the lower bound for the repo rate.

¹³ If the interest rate on the e-krona is lower than ELB, however, the demand for e-krona will probably be low as long as cash exists.
Without an e-krona	Non-interest-bearing e-krona	Interest-bearing e-krona
ELB < 0	ELB ~ 0	ELB = the highest of ELB without an e-krona and interest on an e-krona

Table 1. Lower bound for monetary policy interest rates

Note. ELB stands for Effective Lower Bound. See the text for further explanations.

Finally we can draw the conclusion that an e-krona that is not interest-bearing comprises a further autonomous factor in the Riksbank's balance sheet that the operational framework for the implementation of monetary policy needs to manage. This new autonomous factor may be strongly volatile, which could lead to increased interest rate volatility if no changes are made to the operational system. A further consequence is that it will probably not be possible for the Riksbank to use negative interest rates on its monetary policy instruments. If the e-krona is instead interest-bearing, the interest rate on it would have to be set in a way that was compatible with interest-rate setting on monetary policy instruments.

4 Variations in the demand for e-krona, under normal circumstances and times of financial unease

In times of unrest on the financial markets, an e-krona could be an attractive, risk-free investment regardless of whether or not it is interest-bearing. At such times the general public could therefore prefer to invest its money in e-krona accounts with the Riksbank where it is immediately accessible and almost risk-free, instead of having deposits with a commercial bank that might suffer problems. Although the general public's deposits in accounts in commercial banks are covered by the deposit guarantee, funds from the deposit guarantee are not immediately accessible for the bank's depositors when a bank has been declared bankrupt.¹⁴

The general public's demand for e-krona can therefore vary substantially, depending on the financial situation. In normal times, when the risks are low, the general public may prefer to have deposits in commercial banks as this gives a higher return. In times of financial unease with increased risks, the general public may instead prefer safer investment alternatives. This could mean that in times of financial unease the commercial banks may be subjected to substantial withdrawals and the general public could prefer to deposit money in the Riksbank, where e-krona would be immediately accessible. Appendix A explains these sequences of events with the aid of some very simplified balance sheets.

With the assumptions we have made in this article – that an e-krona is accessible to all and to an unlimited extent – such a scenario with large withdrawals could lead to the commercial banks losing a large share of their funding in a short time. If this were to happen, the banking system could have a significant liquidity deficit in relation to the Riksbank instead of the liquidity surplus it has now (see Appendix A). In this situation, the Riksbank would need to supply liquidity to the banking system through credit against collateral. One question which would then arise is whether the banks have sufficient collateral to cover the acute funding need with credit from the Riksbank. In such a situation the Riksbank may be forced to consider quantitative limits to alleviate undesired effects of an increased demand in e-krona from the general public, particularly in times of financial unease. See Juks (2018) for more detailed analyses of these issues.

¹⁴ The deposit guarantee replaces capital and accrued interest up to SEK 950,000 per person and institution. The compensation amount in SEK applies to depositors in Sweden, see information on the deposit guarantee on the Swedish National Debt Office's website. 'General public' also covers companies whose cash reserves prior to supplier and wage payments are often above what is covered by the deposit guarantee.

5 E-krona affects the operational framework for implementing monetary policy

To summarise, the introduction of an e-krona means, put simply, that the Riksbank extends its circle of counterparties from the current relatively narrow circle to a very broad one that also includes companies and households.

An e-krona that is not interest-bearing would be a further autonomous factor that the operational framework for implementing monetary policy needs to manage. Moreover, the demand for e-krona could vary substantially over time and be difficult to forecast, which could make it more difficult to determine the volumes in the Riksbank's weekly market operations. If no changes are made to the current operational framework, this may in turn lead to increased volatility in short market rates. However, there needs to be closer study of what changes need to be made.

An e-krona that is interest-bearing must be priced in a way that is compatible with the monetary policy instruments and will thereby itself become a further monetary policy instrument for the Riksbank.

The existence of an e-krona that is accessible to all and to an unlimited extent could increase the risk of major withdrawals from the banks in times of financial unease, as it would be simple to transfer means from an account in a commercial bank to an e-krona account with the Riksbank. The Riksbank would then be acting in an environment where the banking system once again had a liquidity deficit in relation to the Riksbank and would therefore need to supply the system with liquidity. These fluctuations in demand for the e-krona, especially in times of financial unease, would likely raise the question of whether it might be justifiable to consider quantitative limits to the supply of e-krona. However, this would entail a new element in the operational framework for implementing monetary policy, with the Riksbank offering a volume of liquidity that is demanded given the level of the policy rate determined by the Executive Board of the Riksbank. Such measures would require further investigation.

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Appendix A – What is money? An illustration using simple balance sheets

What is money, and how is it created? In this section we use a very simple approach to describe in a purely schematic way how money is created, what is meant by central bank money and commercial bank money, and how an e-krona could cause financial flows between the general public, the commercial banks, the central bank and abroad.

To illustrate these concepts in the simplest manner possible, we begin with an economy with only three sectors – the general public (households and companies), commercial banks (which receive deposits from the general public and lend to households and companies) and a central bank that lends money to and receives deposits from the commercial banks.¹⁵ See Figure A1.

	Centra	l bank		Co	ommer	cial bar	nks	Households and firms				
Ass	Assets		Liabilities		Assets		Liabilities		Assets		Liabilities	
R⁻		S		R⁺		R⁻		S		L		
	R+		L		D		D					

Figure A1. Balance sheets, closed economy with only three sectors

In more concrete terms, we imagine that the general public has banknotes S and deposits D on the assets side of their balance sheet, and bank loans L on the liabilities side. The commercial banks have bank loans L and potential loans to the central bank R⁺ ('reserves') as assets, and bank deposits D and loans from the central bank R⁻ as liabilities. Finally, we have the central bank that has the banks' deposits with the central bank R⁺ ('reserves') and banknotes S on the liabilities side, and potential lending to the banks R⁻ on the assets side of the balance sheet. Note that all items have a counterpart item on another balance sheet, which follows on from our assumption that only these three sectors exist.

Section 2 of this article contains a description of the operational framework for the implementation of monetary policy and how this relates to the Riksbank's balance sheet. It describes banknotes as a so-called autonomous factor, which means that the Riksbank is not able to directly affect its size. The size of S is governed entirely by the general public's demand for cash. R⁺ and R⁻ represent the central bank's operational framework for the implementation of monetary policy, in real terms the Riksbank's monetary policy instruments. The Riksbank determines which quantities shall be offered and at what price, that is, interest rate.

With the aid of these balance sheets we can now briefly discuss some concepts.

Money. The sum of R⁺, S and D. That S is money is easy to understand. But also deposits D are counted as money, or a means of payment, since they in modern financial systems are usually very liquid. The fact that D is counted as money illustrates the fact that banks 'create' money when they grant credit, which gives rise to new deposits. R⁺ also counts as money. When central banks buy assets they pay using reserves.

Central bank money. The sum of S and R⁺. In the older macroeconomic literature this is also called 'outside money', see the definitions in Lagos (2006). This money is created outside of the private sector and thus comprises a net asset for the private sector.

¹⁵ This is a very simplified view of, for instance, how banks fund their lending. Here we disregard wholesale funding, as the banks are assumed to fund their operations solely through deposits.

Commercial bank money. D on the commercial banks' liabilities side. Also known as 'inside money', see Lagos (2006). This money is created inside the private sector and does not constitute a net asset as one private agent's liability is another agent's asset.

What happens if the demand for cash increases?

If the general public demand more cash, this is in practice via the commercial banks (that is to say, the general public does not turn directly to the central bank). The commercial banks buy cash from the central bank, and pay by reducing their loans R⁺ to the central bank (alternatively by increasing their borrowing R⁻). See Figure A2. The banks sell this cash to the general public, who pay by reducing their bank deposits D (or by borrowing). The central bank's balance sheet total is unchanged as S increases as much as R⁺ declines (or R⁻ increases). It is not generally possible to say what else happens to the banks' balance sheets, this depends on a number of circumstances and on what has caused the increased demand for cash.

Figure A2. An increased demand for cash



What happens if the central bank introduces an e-krona?

Now we imagine that the central bank begins to issue a digital central bank currency. As we explained in the main text, the e-krona entails a new item, E, on the liabilities side of the central bank's balance sheet. In Figure A3 we assume, for the sake of simplicity, that all e-kronas are held by the general public, and none by the commercial banks. The assets side of their balance sheet thus gains a new item.

	Central bank				ommer	cial bar	nks	Households and firms			
Ass	ssets Liabilities		Assets		Liabilities		Assets		Liabilities		
R⁻		S		R⁺		R⁻		S		L	
		R⁺		L		D		D			
		E						E			

Figure A3. An e-krona is introduced

What happens to bank deposits if an e-krona is introduced?

One question that often arises when the e-krona is discussed is to what extent it can replace traditional bank deposits. There is no general answer to this question, as a number of circumstances are involved.¹⁶ An extreme scenario is shown in Figure A4, where the general public replace bank deposits with the e-krona. Bank deposits D decline and E rises to a corresponding degree. But when bank deposits D fall, the banks lose some of their funding, and lending L must fall unless other measures are taken. One such measure would be for the central bank to lend more to the commercial banks (R⁻ rises as much as D has fallen). In Figure A4 we assume that L is ultimately not affected. It may be worth noting that the central bank needs collateral when lending to the commercial banks. In this example we have implicitly assumed that L can be used as collateral for the loans from the central bank.

	ci ciai s	anno											
	Central bank				ommer	cial bar	nks	Ηοι	Households and firms				
As	Assets Liabilities		Ass	Assets		ilities	As	sets	Liabilities				
R⁻	\uparrow	S		R*		R⁻	\uparrow	S		L			
		R⁺		L		D	\checkmark	D	\checkmark				
		Е						E					

Figure A4. The central bank counteracts the fall in bank deposits by lending to the commercial banks

In reality, the commercial banks have other funding sources, as they can issue securities on the financial markets. See Juks (2018) for a detailed analysis.

We now add a further balance sheet in Figure A5 for 'abroad' to the above system to be able to illustrate international capital flows, for instance. Once again, we make strongly simplified assumptions and study a situation where only the central bank has foreign claims (B^F), as the focus is on what is happening to the central bank's balance sheet and not on the private capital flows. Further we assume that agents abroad can hold e-krona. Therefore we have the items E^F , and $E=E^P + E^F$.

	Central bank				Commercial banks				Households and firms				Abroad		
As	Assets		Liabilities		Assets Liabilities		Ass	Assets		lities	Assets L		Liabili	ties	
R⁻		s		R⁺		R⁻		S		L		E₽		BF	
BF		R⁺		L		D		D							
		Е						EP							

Figure A5. Small open economy

What happens if the demand for e-krona abroad rises?

Figure A2 above showed in purely schematic terms what happens if the demand for cash rises. This description reminds us of what happens if the demand for the e-krona rises, but with certain changes. One difference is that the general public will not need to go via the commercial banks in the same way, but can more directly exchange banknotes for the e-krona. Alternatively, they can reduce their bank deposits and in this way increase their holdings of the e-krona.

Now, however, the question is what happens if the increased demand for e-krona comes from abroad. We can imagine, for instance, a situation where the e-krona has come to be regarded as an attractive form of saving, even among foreign investors. The foreign investor has an account for e-krona with the central bank and wants to increase their holding of e-krona. The investor pays for these e-krona with assets in foreign currency, which means that the assets side of the central bank's balance sheet increases. Figure A6 illustrates in this overall manner that the central bank's balance sheet is affected by international demand for e-krona. The exchange rate will be affected, probably appreciating, because the demand for Swedish krona has increased.

	Central bank				Commercial banks					Households and firms				Abroad			
As	sets	Liabi	ilities	As	sets	Liabi	ilities		Ass	ets	Liab	lities	As	sets	Liabi	lities	
R⁻		S		R+		R⁻			s		L		EF	↑	BĔ	↑	
BF	\uparrow	R⁺		L		D		[D								
		E	\uparrow					E	E٩								

Figure A6. Increased international demand for the e-krona

The e-krona and the macroeconomy

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In this article, we discuss potential implications of an e-krona for the conduct of monetary policy and for macroeconomic developments in general. We argue that a universally accessible, non-interest-bearing e-krona supplied according to demand would establish a zero interest-rate floor for the policy rate and possibly all other interest rates in the economy. The effect of quantitative easing can thereby also be reduced. Furthermore, it is unlikely that the monetary policy transmission mechanism would be strengthened by an e-krona. We also note that international financial flows may increase and induce more exchange rate volatility. Finally, an e-krona could have long-run level effects on economic activity. The effects would be positive if an e-krona improves the efficiency and the resilience of the payment system and negative if an e-krona impinges on the supply of credit and financial stability.

1 Introduction

The Riksbank is currently conducting a review into whether to issue a digital complement to physical cash, the so-called e-krona.¹ In this article, we analyse possible consequences of an e-krona for the conduct of monetary policy and for macroeconomic developments in general.

The discussion regarding a digital central bank currency (CBDC) is new and a result of the ongoing digitalization of modern society. But from a theoretical point of view, the questions that arise when thinking about the possible consequences of CBDCs often turn out to be classic topics that have been investigated in macroeconomics in the past century or more. For example, issues such as the liquidity trap, the lower bound to monetary policy, inside versus outside money, and even monetary policy autonomy and the classic trilemma arise. This article sheds light on some of these matters. In some cases we arrive at firm results (conditional on our assumptions), in other cases we present only an overview of the issues involved. Many of our colleagues at other central banks have written about CBDCs and their possible consequences. The focus in this article is on monetary policy and macroeconomic issues that are important in a Swedish context.

The article is organized as follows. The next subsection describes the key properties of the type of e-krona analysed in this article. Section 2 studies the implications of such an e-krona for the effective lower bound of the monetary policy rate and other interest rates. Section 3 analyses how the transmission of monetary policy to the rest of the economy may be affected. Section 4 discusses other effects of an e-krona on the economy. Section 5 concludes. Appendix A contains the theoretical model that underlies the analysis in section 3.

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¹ See the two reports on the e-krona review published so far, Sveriges Riksbank (2017) and (2018).

Key characteristics of the e-krona analysed in this article

There are several design choices for an e-krona, including whether it should be meant only for small payments, bear interest, be universally accessible and in unlimited quantities, and so on. However, the technical design, for instance whether or not it should use a distributed ledger technology, matters only to the degree that it affects an e-krona's functional features. We therefore abstract from technical issues.

The e-krona analysed in this article has the properties outlined in the Riksbank's first e-krona report (Sveriges Riksbank 2017):²

- 1. It is a direct claim on the Riksbank and specified in Swedish kronor.
- It is universally accessible: by this we mean that it can be held by financial institutions, firms and members of the general public, both foreign and domestic residents, and without restrictions.
- 3. It is supplied according to demand: the Riksbank will supply as much e-krona as is demanded.

With these properties an e-krona will be similar to cash in the sense that it is universally accessible (without restrictions) and supplied according to demand. The properties may also be necessary conditions for parity between an e-krona and other forms of the Swedish krona. Furthermore, and importantly, they also imply that an e-krona would constitute a safe and liquid asset with essentially zero transaction costs that could be held by all (including professional investors) and in unlimited quantities. This is, as we shall see in later sections, important since some of our key conclusions apply only to such an e-krona. If, instead, an e-krona were not universally accessible or provided only in limited quantities its effects would be much smaller.

In our analysis, we distinguish between two cases, which in turn have very different consequences for the conduct of monetary policy:

- a) The e-krona does not carry interest. In this case the policy rate continues to be the monetary policy instrument and the implementation of monetary policy can be conducted largely as it is today (see Nessén et al. 2018). However, negative policy rates will, as we explain below, most likely not be implementable.
- b) The e-krona carries interest. In this case, the interest rate on an e-krona positive or negative – could become a monetary policy tool, and it would have to be set in line with the overall stance of monetary policy.

2 Impact on the lower bound of the policy rate

We begin by examining the consequences of an e-krona – with the characteristics outlined above – on key instruments of monetary policy. Normally, we think of monetary policy as aiming to affect inflation and the real economy by influencing market interest rates, the exchange rate and expectations about future policy and the economy. Traditionally, the principal tool for influencing short-term market rates is the policy rate at which monetary policy counterparties (typically banks) can borrow or deposit their reserves at the central bank.³

Since the onset of the global financial crisis ten years ago, central banks in several advanced economies, including Sweden, have also used other policies to spur economic activity. One example is quantitative easing (QE) which consists of purchasing large quantities of long-term securities with the objective of reducing long-term interest rates.

An e-krona that fulfils 1–3 and is interest bearing will be quite reminiscent of what is sometimes called 'reserves for all' (see Niepelt 2018). A possible difference could be that we allow for a spread between the policy rate and the e-krona rate.
 In a corridor system, other interest rates than the policy rate may matter too. For example, in Sweden banks currently deposit reserves at the Riksbank partly at the policy rate, partly at the repo rate minus a fixed spread, see Nessén et al. (2018) for details.

In this section, we analyse the implications of an e-krona for the lower bound of the policy rate and other interest rates in the economy. Specifically, we demonstrate why a universally accessible zero-interest e-krona that is supplied according to demand most likely will raise the lower bound not only for the policy rate but also for market interest rates. This, in turn, may also have implications for the efficacy of QE.

2.1 The current lower bound to interest rates comes from cash

The policy rate of the central bank was traditionally thought to be subject to a zero lower bound (ZLB), meaning that any cuts in the policy rate below zero would have no effect. The reasoning was that with the option to hold cash, yielding a zero rate of interest, banks would exchange their reserves for cash if the policy rate was set below zero. Likewise, firms and households, it was thought, would quickly substitute into cash if interest rates became negative. However, holding and handling cash is risky and costly for firms and households and for banks (see e.g. Alsterlind et al. 2015). It is costly to acquire safe and secure transportation, storage and insurance, for instance. For banks, it is certainly less expensive to keep reserves at the central bank than to hold large amounts of cash. As a consequence, the Riksbank and some other central banks have in recent years been able to successfully implement negative policy rates. However, there is still a limit to how low the policy rate can go and still have an effect on market rates. This limit is determined by the risks and associated costs of holding cash. This point is somewhere below zero, may vary over time and is often called 'the effective lower bound' (ELB) for the policy rate (see Nessén 2016).

While negative nominal policy rates are a relatively new phenomenon, the lower bound constraint and its implications have long been analysed. The concept was first introduced by Keynes (1936) who discussed it in terms of a 'liquidity trap'. In modern macroeconomics, a liquidity trap has come to identify situations in which the lower bound for the policy rate is strictly binding, in that it prevents the central bank from setting the real interest rate at its desired level. Therefore, the problem with a liquidity trap is that even though the policy rate is zero (or somewhere slightly below), the real (short-term) interest rate is too high and economic activity and/or inflation is too low. The central bank would therefore prefer a more expansionary monetary policy in the form of a lower real interest rate, if that were at all possible.

It has been suggested by a number of researchers (see for example Bordo and Levin 2017 and Goodfriend 2016) that an interest-rate bearing CBDC could relax current lower bound constraints on nominal interest rates. In their view, the ability of paying interest on CBDCs would constitute a clear advantage compared to physical cash. However, as noted by Camera (2017), the current cash-related lower bound will not disappear as long as cash is a viable mean of payment.⁴

2.2 A non-interest-bearing e-krona raises the lower bound

We turn now to the effects of a non-interest-bearing e-krona on the lower bound for the interest rates in the economy. The effects of such an e-krona will depend on how attractive an asset it is relative to other ones. In order to analyse this, we set up a simple relationship that builds on the basic principle that an asset will be preferred if it provides net benefits that are at least as high as those that can be obtained from an alternative one.

We can start by noting that the yield of an asset A may be divided into two components: the average of expected short (risk free) rates (*i*) over the maturity of the asset (*n*) and a premium $(P_t^{A,n})$,

⁴ If the introduction of an e-krona were to be accompanied by the phasing out of cash, this way of escaping negative rates would disappear. This, however, has been neither a goal of the Riksbank, nor a part of the e-krona project. It is also worth noting that in a country like Sweden, where the use of cash is declining rapidly, cash may cease as a medium of payments anyway. For example, Bigoni et al. (2018) show that if money is accepted infrequently, its value decreases, which in turn has a feedback effect on its use. Simply put, the value of cash declines if it is accepted less frequently.

(1) $i_t^{A,n} = \frac{1}{n} \sum_{j=1}^{n} E[i_{t+j}] + P_t^{A,n}.$

The premium represents the net of compensation for illiquidity, risk etc. and 'discounts' for services that the asset may provide (for instance if it can be used as collateral, for payments, etc.).

Inspired by (1) we define a similar expression where the premium represents the difference between the interest on an e-krona and the alternative asset. Let i^{ekr} and i^A be the nominal interest rate on an e-krona and an alternative asset *A* respectively, over an arbitrary time horizon. An agent *j* will be indifferent between holding an e-krona and an alternative asset if

$$i^A = i^{ekr} + P_i$$

where P_i is a premium over the same arbitrary time horizon.⁵

Let φ_j^{ekr} and φ_j^A represent the benefits that an e-krona and an alternative asset A provide respectively for agent *j*.⁶ Moreover, let σ_j^{ekr} and σ_j^A represent the cost of holding an e-krona and an asset A, respectively, including the cost of the perceived risk for agent *j*. We can then define the premium as

$$P_{j} = (\varphi_{j}^{ekr} - \varphi_{j}^{A}) + (\sigma_{j}^{A} - \sigma_{j}^{ekr}).$$

By combining the expression for i^A and the one for P_j , we derive the following relationship, where we abstract from the agent subscript *j* since the argument is the same for all agents:

(2)
$$i^{ekr} + \varphi^{ekr} - \sigma^{ekr} = i^A + \varphi^A - \sigma^A$$
.

Relationship (2) describes a condition that has to hold in order for an agent to be indifferent between holding an e-krona and an alternative asset. If $i^{ekr} + \varphi^{ekr} - \sigma^{ekr} > i^A + \varphi^A - \sigma^A$, then the agent will prefer to hold an e-krona, and vice versa if $i^{ekr} + \varphi^{ekr} - \sigma^{ekr} < i^A + \varphi^A - \sigma^A$.

In the remainder of this section, we will use variations of equation (2) to analyse the effect of a non-interest-bearing e-krona on the lower bound of returns of different types of assets.⁷

Central bank reserves

To study how an e-krona will affect the effective lower bound for the policy rate we can think of the alternative asset in equation (2) as central bank reserves. Then, i^A denotes the policy rate, which is the interest rate on bank reserves.

Given our assumptions, an e-krona and bank reserves can be seen as investments with very short maturities and very close substitutes. In fact, they are both claims on the central bank and the risk should be the same for both. Thus, $(\sigma^{ekr} - \sigma^{reserves}) = 0$. A difference between the two is that an e-krona could be used as a broader means of payment and thus might provide some more services and is more liquid than reserves. We therefore have that $(\varphi^{ekr} - \varphi^{reserves}) \ge 0$. Using this together with equation (2) we get

 $i^{ekr} + (\varphi^{ekr} - \varphi^{reserves}) = i^{reserves},$

⁵ In general equilibrium, the (endogenous) market rate *i*^A may change with the introduction of an e-krona. However, for the argument in this section we can take the market rate *i*^A as given. Meaning et al. (2018) provide a framework for analysing how the endogenous (market) premiums will depend on the introduction of a CBDC.

⁶ The value of the service φ^{ekr} is likely to depend on how much e-krona the individual has. However, even if the marginal utility of holding an e-krona is decreasing it does not affect our results.

⁷ A similar asset-by-asset comparison is found in Meaning et al. (2018) although there the focus is not on the lower bound.

that is, the interest rate on reserves cannot be lower than the one on an e-krona. Thus, if an e-krona is universally accessible without limitations, does not carry interest and is supplied according to demand, then the rate on reserves cannot fall below zero. Compared to the situation today, this means that the effective lower bound for the policy rate would rise to zero, or even slightly above it if ($\varphi^{ekr} - \varphi^{reserves}$) > 0 with a non-interest bearing e-krona.

Interbank rates

Let now the alternative asset be interbank debt, which provides fewer services compared to an e-krona. For instance, it cannot be used as a broad means of payment. Thus $(\varphi^{ekr} - \varphi^{interbank}) > 0$. Furthermore, lending to a private bank is typically more risky than to the central bank, so that $(\sigma^{interbank} - \sigma^{ekr}) \ge 0$. Thus, in the presence of a non-interest-bearing e-krona available without limitations, we get

 $i^{ekr} + (\varphi^{ekr} - \varphi^{interbank}) + (\sigma^{interbank} - \sigma^{ekr}) = i^{interbank}$

that is, interbank rates are unlikely to fall below zero (the two terms in parentheses are (weakly) non-negative). Looking at Figure 1, which shows the policy rate and interbank market rates of different maturities from 2008 until 2018, we can see that this would constitute a change from the current situation in Sweden, where interbank interest rates have been negative for the past three years.





Commercial bank deposit rates

In comparing commercial bank deposit rates with an e-krona, we can first notice that deposits covered by deposit insurance can be viewed as being as risk free as an e-krona. Deposits that are not covered by deposit insurance are more risky. Thus, $(\sigma^{bankdep} - \sigma^{ekr}) \ge 0$. At the same time, bank-deposit accounts are often bundled together with other services, e.g credit lines, so that we may have $(\varphi^{bankdep} - \varphi^{ekr}) > 0$. In that case, bank deposit rates may be below the return on an e-krona:

 $i^{ekr} - (\varphi^{bankdep} - \varphi^{ekr}) + (\sigma^{bankdep} - \sigma^{ekr}) = i^{bankdep}$

Thus, if $\varphi^{bankdep}$ is sufficiently high, then the interest rate payed on deposits could possibly be lower than the one on an e-krona, that is, it could be negative in case of a non-interest bearing e-krona, at least for some customers.

It should be noted here that there may be other factors influencing how commercial banks set deposit rates, in effect preventing them from dropping below zero. This has been the case in the recent period with a negative policy rate in Sweden, where banks have not passed this on to household's deposit accounts. Indeed, as seen in Figure 2, such rates have remained at zero during the last three years.⁸



Note. MFIs' (monetary and financial institutes) average deposit rate is a weighted average of all interest rates on deposits with different maturities. Sources: Statistics Sweden and the Riksbank

Government bonds

Next, comparing government bonds with an e-krona we use (2) and let government debt be the alternative asset. We then get

 $i^{ekr} + (\varphi^{ekr} - \varphi^{gov}) + (\sigma^{gov} - \sigma^{ekr}) = i^{gov}.$

We see that government bond yields can be below the interest rate on an e-krona if government bonds provide more services (($\varphi^{ekr} - \varphi^{gov}$) < 0) and/or are associated with less risk (($\sigma^{gov} - \sigma^{ekr}$) < 0). However, an e-krona is just another form of government debt and its credit risk should therefore not be higher than for government bonds. Furthermore, an e-krona is more liquid than a government bond. Thus, ($\varphi^{ekr} - \varphi^{gov}$) ≥ 0 and ($\sigma^{gov} - \sigma^{ekr}$) ≥ 0 . Consequently, government bond yields would not fall below the interest rate on an e-krona. Looking at Figure 3, which shows the policy rate and government bond rates of different maturities, we can see that this would constitute a change from the situation in Sweden, where medium term government bond rates have been negative for the past three years or parts of these three years. However, and importantly, if various forms of regulation were to favour government bonds over an e-krona, it is possible that ($\varphi^{ekr} - \varphi^{gov}$) < 0 and government bond rates could go below zero even in the case of a zero-yielding e-krona. We return briefly to this important issue in Section 2.3.

⁸ Customer relations and competition between banks have been mentioned as possible causes. See Alsterlind et al. (2015).





Note. Implied zero-coupon yields from government bonds. Source: The Riksbank

Risky assets

To conclude our comparison across various types of assets, we now turn to more risky assets. These are assets with more credit risk than government bonds such as e.g. corporate bonds, so that $(\sigma^{risky} - \sigma^{ekr}) > 0$. Furthermore, risky assets provide fewer services compared to an e-krona, so that $(\varphi^{ekr} - \varphi^{risky}) \ge 0$. Thus, it follows from (2)

 $i^{ekr} + (\varphi^{ekr} - \varphi^{risky}) + (\sigma^{risky} - \sigma^{ekr}) = i^{risky},$

that is, the rate of return on risky assets will be higher than the one on an e-krona, and as such higher than zero.

To summarize, an e-krona that is universally accessible without limitations, does not carry interest and is supplied according to demand is likely to impose a zero lower bound constraint on all market rates. However, and importantly, if various forms of regulation favour government bonds, returns on other assets could still be below the return on an e-krona. If there is a zero lower bound on government bond yields, this may in turn also reduce the effectiveness of QE. In the next section we explain why.

2.3 Quantitative easing with a non-interest bearing e-krona

As mentioned above, QE has been used as an expansionary monetary policy tool whereby the central bank buys assets, typically government bonds, in the secondary markets. One of the aims of QE is to lower longer-term market rates.9

⁹ Indeed, there is substantial empirical evidence showing that quantitative easing can alter long-term interest rates, as shown for example by Krishnamurthy and Vissing-Jorgensen (2011), Hamilton and Wu (2012), Gagnon et al. (2010) and Williams (2014) among others. This is why QE is considered as having had beneficial effects on the economy, in particular at the ELB. Theoretically, Woodford (2012) and Bhattarai et al. (2013) have argued that QE may have real effects by reinforcing forward guidance. By increasing the size of the central bank balance sheet and exposing it to capital losses if interest rates rise, the central bank commits to keeping interest rates lower than is optimal. Auerbach and Obstfeld (2005), instead, show that open market operations at the ZLB can be welfare-improving provided that long-term interest rates are positive and short-term interest rates are expected to be positive at some point in the future. Williamson (2016) is a model where QE is beneficial because purchases of long-maturity government debt by the central bank will always increase the value of the stock of collateralizable wealth. However, Wallace (1981) showed that Modigliani-Miller applies to a central bank's balance sheet, and thus QE-type policies should be ineffective. Eggertsson and Woodford (2003) and Cúrdia and Woodford (2011) show a similar result in a New-Keynesian model once the ZLB is reached. There remains a tension in the theoretical literature about whether QE is beneficial or not.

From (1) we have that government bond yields (i^{gov}) may be divided into two components, the average of expected short (risk free) rates (*i*) over the maturity of the bond (*n*) and a so-called term premium (*TP*)

(3) $i_t^{gov,n} = \frac{1}{n} \Sigma_1^n E[i_{t+i}] + TP_t^n.$

There are different accounts of how QE affects government bonds yields. Some emphasize the effect on expected short rates, while others focus on the effects that QE may have on term premiums. A pragmatic interpretation of the empirical literature would suggest that the QE programs put in place by several central banks in recent years have affected both components.

From equation (3) we see that there are two channels through which the introduction of an e-krona could dampen the efficacy of QE. First, a floor for the policy rate affects expected future short rates as they can no longer be negative. Since the longer-term market rate is the average of expected future short rates, higher (expected) short-term rates make the longer-term rates higher. Another way of stating this is that the lower bound truncates the yield curve so that yields of longer maturities are also affected (see for instance Swanson and Williams 2014 and De Rezende 2017).

Second, QE is thought to work by lowering the term premium (TP_t^n) . As mentioned in the previous section, government bonds provide certain 'services' that make them attractive. For example, there are leverage constraints, needs for collateral, and other features and frictions in financial markets that make some investors willing to pay more for government-emitted debt instruments than other types of assets. As long as an e-krona is not considered a perfect substitute in this regard, QE could still work by lowering term premiums. However, if an e-krona came to be perceived as providing the same services as government bonds and there were no regulations that made investors prefer government bonds over an e-krona, the efficacy of QE could be diminished.

2.4 Implications for the conduct of monetary policy

In the decade since the onset of the Great Financial Crisis, several advanced-economy central banks have engaged in various forms of unconventional monetary policy. Specifically, some central banks have conducted large scale asset purchases (or QE), others have lowered policy rates below zero, and some others have employed forward guidance. A few central banks have implemented all of the above.

Beginning in 2015 the Riksbank lowered the policy rate in steps into negative territory. At the same time the Riksbank began purchasing government bonds, and current holdings amount to about 40 per cent of the outstanding stock of government debt. As briefly mentioned above (and shown in Figure 3), through these various measures the Riksbank has been able to lower government bond rates down below zero, at times even been below the policy rate. Even though deposit rates and many other rates have stayed above zero, changes in the policy rate into negative territory have led to reductions in other (positive) rates. For instance, and as can be seen in Figure 4, lending rates to households have decreased after negative policy rates were implemented, although by less than the decrease in the policy rate. It is also worth noting that corporate lending rates have decreased by at least as much as the policy rate. These figures and more formal analyses by e.g. De Rezende and Ristiniemi (2018) and Laséen and De Rezende (2018) indicate that the unconventional policies pursued by the Riksbank in recent years have indeed led to more expansionary financial conditions.



Figure 4. Change of repo rate and lending rates to households and companies since 2015

Note. The cumulative changes in each rate since the start of January 2015. Outcomes are monthly data and lending rates are value-weighted averages of the actual lending rates reported by the banks Sources: Statistics Sweden and the Riksbank

The discussion in sections 2.3 and 2.4 however suggests that the impact of these types of unconventional policies on financial conditions would be smaller if a non-interest bearing e-krona were to be introduced.

A relevant guestion then is whether it is likely that such unconventional policies will be needed in the future. The root cause of the low levels of nominal interest rates and the fact that the lower bound has become a constraint on traditional interest rate policy is the secular decline in global interest rates in the past decades. Indeed, there are many studies documenting how global real rates have fallen in the past decades, and also indicating that real rates will remain low in the future (see e.g. Armelius et al. 2014, and Holston et al. 2016). This development, together with low inflation rates, means that nominal interest rates will most likely remain low in the foreseeable future, thus implying that central banks could in the future again hit the zero lower bound. This implies that with an e-krona that is universally accessible without limitations, does not carry interest and is supplied in unlimited quantities, the room for manoeuvre for monetary policy by means of the key policy rate and QE could be curtailed in the future.

Other options

QE and negative interest rates are not the only tools available to a central bank if there is a need for more monetary stimulus. There are further measures that work through other channels, such as for instance procedures that improve the transmission mechanism or that work through the exchange rate channel. These measures will generally not be affected by an e-krona. It is also worth mentioning that lower-bound constraints for the policy rate can be alleviated if the inflation target is raised. That is because if inflation is higher on average, the nominal interest rate will also be higher on average, thus reducing the risk of the policy rate becoming too low and hitting the lower bound. See Apel et al. (2017) for a discussion.

Furthermore, some argue that a CBDC opens up the possibility of a new form of unconventional monetary policy, as money transfers to households would be easier to implement, much like a digital helicopter drop. The idea behind such measures is not new and dates back to Friedman (1969). It involves the central bank supplying large amounts of money to the public, as if the money was being distributed or scattered from a helicopter. Colourful images aside, helicopter money is meant to be made directly available to consumers to increase spending in times of weak demand. Former Federal Reserve Chairman Ben Bernanke popularized this idea in 2002 as a money-financed (as opposed to debtfinanced) tax cut policy that theoretically generates demand and should therefore ideally be used in a low-interest-rate environment when an economy's growth remains weak.¹⁰ However, in Sweden it is not obvious that helicopter drops would be easier to implement with an e-krona since almost all adult Swedes already have accounts at commercial banks (see Sveriges Riksbank 2017).

In sum, we can conclude that raising the effective lower bound for the policy rate means that there is a risk that the primary tool for monetary policy cannot be used optimally. In the absence of other policies, this could impact negatively on economic activity. We discuss long run effects of an e-krona in Section 4.

3 Effects on the monetary transmission mechanism

We have shown that a non-interest bearing e-krona could reduce the effectiveness of monetary policy if it raises the effective lower bound. BIS (2018) and Meaning et al. (2018) amongst others have suggested that an interest-bearing CBDC may make monetary policy more effective through improved pass-through of policy rate changes. In this section we analyse if this is the case for an e-krona.

The monetary policy transmission mechanism normally describes the process by which changes in the policy rate influence the real economy and inflation. The mechanism can be divided into two parts. The first describes how changes in the policy rate pass through to changes in deposit rates, lending rates and other market interest rates that matter for economic decisions. The second part describes how changes in these interest rates influence the real economy and inflation. As explained above, the pass-through may be hampered when the effective lower bound is increased to zero. In our analysis below we focus on scenarios with an interest-bearing e-krona and thus no binding effective lower bound induced by it.

3.1 Transmission from the policy-rate to market rates

In order to keep the analysis in this subsection tractable, we add a few assumptions. First, we focus solely on the pass-through to banks' deposit and lending rates, which are considered key in the transmission mechanism. Second, we only consider an attractive e-krona, i.e. an e-krona that pays a high enough interest rate to create competition with bank deposits, since an unattractive one would not influence the banks' behaviour. Third, we assume a fixed spread (which could be zero) between an e-krona and the policy rate. If the spread could vary it would not make sense to talk about the pass-through from the policy rate to market rates. Furthermore, if the spread were allowed to vary, the spread itself would be a separate policy instrument.

The left-hand panel of Figure 5 contains a scatter plot of average bank deposit rates and the policy rate in Sweden over the past 25 years. It illustrates that the pass-through from the policy rate to deposit rates has been less than one to one in this period. Specifically, a regression based on the data in the figure suggests that an increase in the policy rate by one percentage point leads to an increase in deposit rates by on average 0.6 percentage points during the same quarter.¹¹ Thus, historically when the policy rate has increased in Sweden, deposit rates have also increased but by a smaller amount.

¹⁰ See Bernanke (2002). Helicopter money is enjoying a new revival as a last-resource option with influential advocates including Caballero (2010) and Galí (2014) among others. Such an unconventional idea has its critics too. For example, since central banks pay interest on reserves, Kocherlakota (2016) observes that new money created would eventually have the same cost as if the fiscal authority borrowed it. Along those same lines, Borio et al. (2016) find that helicopter money becomes more expansionary than a debt-financed programme only if the central banks credibly commits to setting policy at zero once and for all, thus implying giving up monetary policy for ever.

¹¹ An OLS estimation of the following equation $\Delta t_i^p = \beta \Delta i_i^R + \epsilon$, where i_i^p and i_i^R denote the deposit and the policy rate respectively, gives (p-values in brackets) $\beta = 0.64$ (0.00), $R^{2\alpha i j} = 0.86$. We exclude the most recent years when the policy rate has been negative.



Figure 5. Pass-through from the policy-rate to banks deposit rates and lending rates for households

Note. Quarterly data for the period 1993:Q1 to 2018:Q2. Deposit rates for new agreements. Lending rates for floating rate contracts. Sources: The Riksbank and Statistics Sweden

We assess that with an e-krona **the pass-through to banks' deposit rates** is likely to increase and become close to one to one. To see why, consider as an example a representative bank. If such a bank wants to retain deposits, it has to make them at least as attractive as an e-krona. In formal terms, this implies:

(4) $i^{ekr} + \varphi^{ekr} - \sigma^{ekr} \leq i^D + \varphi^D - \sigma^D$,

where 'D' refers to 'bank deposits'. It follows directly that for any given φ^{ekr} , σ^{ekr} , φ^{D} and σ^{D} , an increase in the e-krona rate (i^{ekr}) will have to be followed by a similar increase in the interest rate on deposit accounts (i^{D}). Similarly, the bank can follow a reduction in the e-krona rate with a corresponding reduction in the interest rate on deposit accounts without fear of losing deposits. Thus, unless the bank compensates e-krona rate changes by altering φ^{D} and σ^{D} , the pass-through from the policy rate changes to the bank's deposit rates will become one to one with an e-krona under the assumptions made at the beginning of the current section.¹²

The bank, however, might not find it profitable to compete with an e-krona. In that case, that bank's deposits will flow into deposit accounts at other banks that compete with an e-krona instead and where the pass-through is again close to one to one. Alternatively, deposits might flow into e-krona accounts. We can therefore conjecture that with an attractive e-krona, pass-through to deposit rates will be close to one to one. Indeed, in Appendix A we prove that this conjecture holds in a formal banking model.

One might also argue that an e-krona will speed up the pass-through as it will be a very explicit competitive alternative to bank deposits. Meaning et al. (2018), however, suggest that a potential offsetting effect could be for banks to respond to the increased competition from a CBDC by making it more costly to move funds out of the bank. Such effects may also slow down the pass-through and we cannot exclude a priori that this would happen in Sweden.

In sum, our analysis suggests that an interest bearing e-krona with a fixed spread vis-à-vis the policy rate may improve pass-through from the policy rate to deposit rates in Sweden.¹³

Results for **the pass-through to banks' lending rates** are less clear cut. There are two reasons for why this is the case.

¹² An important caveat is that these mechanisms may not come into play when the interest rate on the e-krona is close to zero, see Appendix A.

¹³ However, if – differently from the assumptions of this subsection – the spread between the policy rate and an e-krona were allowed to vary this conclusion would not necessarily hold. For example, if the e-krona rate were kept constant while the policy rate increased, the mechanisms described above would not come into play.

First, the pass-through to banks' lending rates is already high, close to one to one, without an e-krona. This can be seen in Figure 5, Panel b., which contains a scatterplot of the average of Swedish banks' lending rates and the policy rate. As can be seen in the figure, the dots lie on a 45 degree-line. Furthermore, a regression based on the data in Figure 5 suggests that an increase in the policy rate by one percentage point leads to an increase in the lending rate of one percentage point.¹⁴

Second, theoretically it is not obvious that an e-krona would influence the pass-through from the policy rate to lending rates. Think for example of banks as pursuing business in two separate markets: a deposit market and a lending market (see Appendix A for a formal model).¹⁵ Under this scenario, banks in the deposit market borrow from depositors and invest in the money market. The profit from this activity arises from the *deposit* intermediation margin, i.e. the spread between the money market rate and the deposit rate. In the lending market, banks borrow in the money market to invest in loans. The profit from this activity arises from the lending intermediation margin, i.e. the difference between the lending rate and the money market rate.¹⁶ An e-krona would have no direct effect on the lending market in this environment. If it had any, such effects would have to come from changes in the way the policy rate affects money market rates, changes in loan demand relations, altered competition in the lending market, or changes in banks' costs for providing loans. It is not obvious that any of these would be affected by an e-krona. A formal and more thorough discussion of these theoretical arguments can be found in Appendix A. Notice that such a conclusion might differ depending on the interconnectedness of the deposit and lending markets. However, the assumption of separate deposit and lending markets makes sense in Sweden where the banks rely heavily on market funding.

In sum, our analysis suggests that the pass-through from the policy rate to bank interest rates is already high in Sweden and any marginal improvement would most likely occur on the deposit side. Two things are important to notice in connection with this. First, the improved pass-through might not be of much help as the improvement in the pass-through might only take place for high levels of the policy rate (see Appendix A). However, it is primarily when the policy rate is low and close to the lower bound that a stronger pass-through is useful. At higher levels, weak pass-through can be fully compensated for by larger changes in the policy rate. Second, an improved pass-through to deposit rates coupled with an unchanged pass-through to lending rates might be problematic, since the aggregate demand effects of a change in the deposit rate are ambiguous.¹⁷

3.2 Transmission from market rates to the real economy and inflation

We now turn to how an e-krona may impact the second part of the transmission mechanism. That is, we analyse whether an e-krona would change the transmission from deposit-, lending- and other market rates to the wider economy. We find it useful to formulate the discussion along the following channels of the transmission mechanism: the interest rate channel, the exchange rate channel, the credit channel and the risk-taking channel.

The **interest rate channel** refers to the effect of interest rate changes on households' savings and consumption, as well as firms' investment. If prices and inflation expectations are sticky, a reduction in nominal market rates will also reduce the real interest rate in the

¹⁴ OLS estimation of $\Delta i_t^i = \beta \Delta i_t^{\beta} + \epsilon$ gives (p-values in brackets) $\beta = 1.00(0.00)$, $R^{2\alpha i_j} = 0.795$. We shorten the sample to exclude the recent years with a policy rate below zero.

¹⁵ Result 1 in Appendix A shows that this separation derives from disjoint variable costs of managing loans and deposits.
16 This (theoretical) separation does not mean that all bank deposits are literary invested in the money market and all lending is literary funded by the money market. The banks use deposits to finance lending. Only the gap between deposits and lending is actually financed or invested in the money market.

¹⁷ The income effect of a lower deposit rate reduces the 'income' from deposits and leads to a reduction in demand. The price effect (substitution effect) of a lower deposit rate reduces the price of consumption today relative to tomorrow and leads to an increase in demand today.

economy. Lower real interest rates make it more beneficial for households to consume and borrow and less beneficial to save. Similarly, firms will prefer to borrow and invest. The increased demand in the economy gradually results in prices and wages starting to increase more quickly. The effects will be the same but of opposite sign when the interest rate increases.

We, as other authors, assess that an e-krona is unlikely to affect how changes in real market rates affect agents' consumption, savings and investments decisions. These relations are determined by underlying preferences which are not expected to be influenced by the introduction of an e-krona.

The **exchange rate channel** refers to the mechanism through which monetary policy influences inflation and the real economy by affecting the exchange rate. A reduction in the policy rate normally leads to an exchange rate depreciation. If prices are sticky, the exchange rate also weakens in real terms, which in turn makes domestically-produced goods cheaper compared to foreign ones. This leads to an increase in the demand for exports and for products that compete with imported goods, which gradually result in inflation rising as well. The exchange rate channel also has a more direct effect on inflation. That is because the domestic price of imported goods, which are included in the consumer price index, rises when the exchange rate weakens.

The parity conditions determining the exchange rate are unchanged by the introduction of an e-krona. However, a universally available e-krona would constitute a new, liquid and safe deposit where to hold money balances in Swedish Krona. To the extent that this leads to more active currency management by different actors, an e-krona might induce the exchange rate to become more sensitive to changes in market rates. This, in turn, would imply stronger and/or faster exchange rate movements for a given change in the market rates in Sweden and abroad.¹⁸ However, we are not aware of any formal theory of this effect.

The **credit channel** refers to the mechanism through which interest rate changes affect the credit market and thereby the macroeconomy. A lower interest rate generally leads to an increase in the price of various kinds of assets. For example, it leads to an increase in the net present value of the future cash flows that a financial asset can be expected to generate. This means that the price of the financial asset increases. When the interest rate is low, the demand for and prices of real assets such as houses also increase. As these assets are used as collateral for loans and the collateral increases in value, banks become more willing to lend money. In addition, future wages of households and future profits of companies tend to rise when demand increases as a result of the lower interest rate levels. On the whole, the credit channel is a mechanism by which the effect of changes to the policy rate is enhanced through lending from the banks.

The main reason for why the introduction of an e-krona would matter for the credit channel is the reduced supply of credit if banks were to cut down on their lending due to lower revenues on the deposit side. In this case, the credit channel could become weaker. Theoretically, whether this will occur depends –among other things – on the interconnectedness of the lending and deposit markets. If the two are independent of each other, then it may be less likely that banks will decrease lending as a response to lower profits from the deposit market (see Appendix A). It is also worth pointing out that a CBDC may enable greater competition in the provision of credit for instance through improved possibilities for peer-to-peer lending (Meaning et al. 2018).¹⁹

Another, and much discussed, channel in the transmission mechanism is the socalled **risk-taking channel**. It suggests that low policy rates lead banks and other financial

¹⁸ This change is different from the one described in Meaning et al. (2018). They suggest that the exchange-rate channel might become stronger because market rates become more sensitive to changes in the policy rates.

^{19 &#}x27;For instance, peer-to-peer lenders would no longer have to clear settlements through their competitors in the banking sector, as is currently necessary in the existing system of tiered access to central bank money. This process incurs a cost which CBDC could potentially eliminate, putting non-bank credit providers on a more equal footing with their banking sector counterparts and would limit the extent to which banks could vary margins in light of changes in funding costs.' Meaning et al. (2018), p. 21.

institutions to take greater risks. This is not a specific, well-defined monetary policy channel, but a collective term used to denote different kinds of mechanisms, whereby monetary policy can affect the risk-taking of banks, financial institutions and the economy as a whole. One mechanism is due to low interest rates resulting in a so called search for yield, whereby banks start to search for riskier investments with a higher expected return (Rajan, 2005). One reason for doing this could be that banks have a specific nominal rate of return that they have to achieve. Another mechanism might be due to the economy experiencing low risk and low interest rates over a long period of time, thus leading economic actors to become too complacent and placing a disproportionally low weight on risk factors.²⁰ Again, we consider it to be unlikely that the relationship between market interest rates and risk-taking in the economy would change with the introduction of an e-krona.

In sum, we assess that the exchange-rate channel and possibly also the credit channel are the only channels that may be altered in a significant way by the introduction of an e-krona.

4 Other effects on the economy

4.1 Small open economy aspects of an e-krona

As discussed in the introduction, the e-krona we study is universally available and supplied according to demand. This opens up new questions, since investment in an e-krona by international investors could give rise to large capital flows, thus amplifying the potential volatility of the balance sheet of the central bank and possibly creating greater exchange rate volatility.²¹

But it is very hard to anticipate more precisely what effects an e-krona might have on the exchange rate. As long as an e-krona is primarily used for domestic payments it will most likely not influence the exchange rate at all. However, there is an important difference between an e-krona and cash, and that is that an e-krona can be a good substitute to other forms of saving vehicles such as government bonds or savings accounts. There is also the added factor that an e-krona can be purchased and sold much faster than cash, thus increasing the risk of volatility. If an e-krona became an attractive asset among foreign institutional investors then it could influence the exchange rate, both its level and its volatility.

Here we can return to the simple framework introduced in Section 2, expressing it in terms of foreign currency:

(5)
$$i^{ekr^*} + \varphi^{ekr^*} - \sigma^{ekr^*} = i^A + \varphi^A - \sigma^A$$
,

where all terms now are denominated in foreign currency, e.g. i^{ekr^*} is the return on an e-krona in foreign currency. The term σ^{ekr^*} includes exchange rate risk from the point of view of the international investor. The interpretation of equation (5) is that there will be inflows to the domestic economy if the left-hand side exceeds the right-hand side, e.g. if the interest rate on an e-krona is high, if it provides useful services, etc. It is possible that financial stress abroad (here represented by an increase in σ^A) could trigger large inflows to an e-krona, for instance. Conversely, there could be large flows out of e-krona holdings if financial conditions change.

In sum, for a small open economy, a CBDC that is universally accessible without restrictions and limitations could facilitate large capital flows that might in turn lead to volatility in the exchange rate and in the size of the central bank's balance sheet.²²

²⁰ See Apel and Claussen (2012) for a detailed discussion of the risk-taking channel.

²¹ See also Nessén et al. (2018), Danmarks Nationalbank (2017) and BIS (2018).

²² See the appendix of Nessén et al. (2018) for a very simple illustration using highly simplified balance sheets.

4.2 Financial stability

Juks (2018) analyzes the effects an e-krona might have on Swedish banks. In what follows, instead, we summarize the current literature on the consequences CBDCs might have on financial stability. Engert and Fung (2017), for example, suggest that if a CBDC is non-interest bearing, then it is unlikely that it would lead to a significant shift away from traditional instruments such as deposit accounts. That is because financial institutions can effectively compete with CBDC as a store of value since they can offer enhanced financial services such as wealth management or engage in cost-cutting measures. Nonetheless, in times of economic stress, there may be an increase in demand for CBDC, which would be viewed as risk free. The shift away from traditional deposits would be likely to disrupt the financial system and increase volatility, as discussed by Camera (2017).

In this regard, the analysis in Kumhof and Noone (2018) distinguishes between runs on individual banks and systemic runs. In the first case, they claim that the presence of CBDCs could potentially make it easier and faster to resolve an individual troubled institution, by giving the authorities the option of repaying its depositors in safe CBDC at an early stage and thus reducing the potential for contagion. Since bank depositors would know this ex-ante, this may in fact reduce the probability of a bank run compared to a world without CBDCs. They do find that systemic bank runs would be more difficult to solve instead, even in a world with CBDCs. Indeed, in such a case the run to CBDCs could potentially be so large at the current CBDC interest rate, that CDBC holders would not be willing to sell sufficient quantities of CBDC to satisfy the demand for it. The high demand could be addressed by the central bank with a decrease in the interest rate on CBDC, if any were paid. However, there would be potential limits to such a policy if it required a highly negative interest rate, which could become politically untenable.

4.3 Economic activity

In the standard models used in policy analysis, monetary policy effects on the real economy are usually due to nominal frictions that limit the speed of the adjustment of the general level of prices. Such frictions are short-term phenomena and their empirical significance is a matter of ongoing research. There is a general consensus among economists that long-term economic growth, instead, is driven by factors such as technological change, population growth, and human capital accumulation, thus implying monetary policy's effects on real economic activity are small in the long term. We should thus expect an e-krona to have no significant effect on long-term growth via monetary policy.

However, an e-krona could potentially lead to significant level effects on economic activity because of its interaction with the payment system and the banking sector. Indeed, it has been shown that a well-functioning payment infrastructure enhances the efficiency of financial markets and the financial system as a whole, boosts consumer confidence and facilitates economic interaction and trade both in goods and services (see ECB 2010). At the same time, unsafe and inefficient payment systems may hamper the efficient transfer of funds among individuals and economic actors (Humphrey et al. 2006). Hasan et al. (2013) even confirm that more efficient electronic retail payments stimulate the overall economy, consumption and trade. Indeed, they find that developments in the use of electronic payment systems are related to notable improvements in banking performance, due to both a decrease in costs and an increase in revenues. Moreover, as shown by Berger (2003), switching to electronic payment instruments has significant effects in terms of banks' gains in productivity and economies of scale. So, to the extent that an e-krona would enhance the resilience and the efficiency of the Swedish payment system, we could expect it to have meaningful positive effects on the real economy (see Sveriges Riksbank 2017 and 2018).

Moreover, an e-krona may raise the seigniorage revenue of central banks (see e.g. BIS, 2018). If such increases were large and transferred to the government, they would allow for

less distortionary taxation and might therefore even have GDP effects. Barrdear and Kumhof (2016) argue that there could be such positive consequences for the level of GDP.

However, as we already discussed, an e-krona could also have negative implications for financial stability. This could in turn have detrimental effects on economic activity even in the long run. For example, Ennis and Keister (2003) use an endogenous growth model to show that bank runs can have permanent effects on the levels of the capital stock and of output. That is because as the probability of a run increases, it becomes more likely that a bank will have to liquidate investments early. Since the liquidation value of illiquid investments is relatively low, the bank prefers to hold more liquid assets to deal with a run if it occurs, thus leading to substantially less investment in new capital. Moreover, if banks' funding costs were to increase in a meaningful way and if such costs were passed onto consumers, we would expect the real economy to be negatively affected.

5 Concluding remarks

We have analysed possible implications of introducing an e-krona for monetary policy and overall macroeconomic activity. Since an e-krona that is universally accessible and supplied according to demand would be a perfect substitute for bank reserves, a non-interest bearing e-krona would introduce a zero interest rate floor for the policy rate and plausibly all other interest rates in the economy. This result arises as an e-krona is less risky and offers a level of other benefits or payment services that are of equal magnitude (or higher) than other assets. The inability to implement negative interest rates in economic downturns could possibly be compensated for by the use of other monetary policy tools. However, the zero interest rate floor would also most likely apply to government bonds, which would reduce the effectiveness of QE during times of a binding lower bound constraint. We also argue that the effects on the transmission mechanism are likely to be small in normal times.

It is possible that an e-krona could have consequences for both the level and the volatility of the exchange rate of the Swedish krona and the balance sheet of the Riksbank if it were to become attractive for foreign investors. It is also plausible that an e-krona could affect the financial system and increase its volatility in times of economic stress. Moreover, while an e-krona could be helpful in dealing with runs on individual institutions, systemic runs would be more difficult to solve as that might require highly negative interest rates.

Finally, we argued that an e-krona could potentially have long-run level effects on economic activity because of its interaction with the payment system and the banking sector. On the one hand, it could improve the efficiency and resilience of the payment system thus stimulating economic activity. On the other hand, we would expect detrimental long-run effects if an e-krona impinges on financial stability.

In sum, there seems to be an 'impossible quaternity' or 'quadrilemma' for the type of CBDC envisioned in the Riksbank's first e-krona report.²³ If an e-krona is designed with similar characteristics to cash – i. e. *non-interest bearing*, in *perfectly elastic supply* and *attractive* to use – then it will most likely not be compatible with *unchanged macroeconomic risks*. Consequently, a CBDC cannot have these four features at the same time.

It is worth noting that the negative effects we have identified could be mitigated by giving up one or more of the four features in the quaternity which would give the Riksbank a mechanism to influence the demand for an e-krona. One obvious example is to let the e-krona be interest bearing, but there are other alternatives such as fees or other frictions that would limit the attractiveness of an e-krona in relation to other assets. However, adding limits to the amount of e-krona that can be held risks breaking the parity against other forms

²³ Bjerg (2017) discusses a CBDC 'trilemma'. He argues that in the presence of a CBDC a central bank that tries to uphold free convertibility between private money and CBDC, and parity between all forms of money, would have to give up monetary sovereignty.

of krona, such as money held in private bank accounts or bank reserves at the Riksbank. Other types of frictions, such as fees on withdrawals might therefore be preferable, but would have to be carefully calibrated so that an e-krona would still function as a viable payment instrument.

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Appendix A. The effects of an e-krona on pass-through: A banking model

In this appendix, we use an industrial organization model of banking to analyse the effects of an e-krona on the pass-through from policy rate changes to banks' deposit and lending rates.²⁴ The model helps structure the analysis and provides some key insights. In particular, it demonstrates that the conclusions conjectured in Section 3 hold in a standard banking model.

A representative bank

To keep the analysis as simple as possible, we consider a monopolistic bank and our discussion follows what is known as the Monti-Klein model from Monti (1972) and Klein (1971). Qualitatively, the results will be analogous with an oligopolistic banking sector.²⁵

Consider a representative bank accepting deposits *D* and giving out loans *L*.²⁶ Let $i^{L} = i^{L}(L)$ denote the (inverse) loan demand where i^{L} is the lending rate, and assume $\frac{di^{L}(L)}{dL} < 0$. Similarly, let $i^{D} = i^{D}(D)$ denote the (inverse) deposit supply where i^{D} is the deposit rate, and assume $\frac{di^{D}(D)}{dD} > 0$.

The bank has also access to a money market, from which it can borrow and lend in unlimited quantities at the policy rate i^{R} . Note that this assumption is reasonable in Sweden where monetary policy is implemented in a corridor system, and where the (short-term) money-market rate is typically close to the policy rate.

Finally, the bank is subject to managing costs C(D, L) satisfying $C_L(D, L) > 0$, $C_D(D, L) > 0$, $C_{LL}(D, L) \ge 0$ and $C_{DD}(D, L) \ge 0$. Note that the sign of the mixed partial derivative $C_{DL}(D, L)$ is related to the notion of economies of scope. If $C_{DL}(D, L) < 0$, a universal bank jointly offering loans and deposits is more efficient than two separate entities specializing in loans and deposits. If $C_{DL}(D, L) > 0$, there are diseconomies of scope. If $C_{DL}(D, L) = 0$ there are neither.

As a monopolist, the bank takes into account that lending demand and deposit supply depend on the respective interest rates, which are under the control of the monopolist. The bank's profit therefore is: $\pi = L[i^{L}(L) - i^{R}] + D[i^{R} - i^{D}(D)] - C(L, D)$.

Thus, the bank's profit is the sum of the intermediation margins on loans and deposits, net of managing costs. The first order conditions for profit maximization then are:

(6) $\frac{\delta\pi}{\delta L} = 0 \rightarrow \left(\frac{di^{L}}{dL}L + i^{L}\right) = i^{R} + C_{L}(L, D)$

(7)
$$\frac{\delta\pi}{\delta D} = 0 \Rightarrow i^{R} = \left(\frac{di^{D}}{dD}D + i^{D}\right) + C_{D}(L,D)$$

Note that marginal revenues and marginal costs are on the left- and right-hand-side of the equations, respectively. This implies the monopolistic bank sets the lending and the deposit rates so that marginal revenues in the two markets equal marginal costs.

See, for example, Freixas and Rochet (2008) and Matthews and Thompson (2014) for a textbook presentation of the model.
 See Freixas and Rochet (2008), pp. 79–80 for details.

²⁶ This simplifies the analysis, but qualitatively the results are the same in more elaborate versions of the model featuring several identical banks.

The following observation is a key result in the model, and we refer to it extensively in Section 3:

Result 1: If there are no joint variable costs in the managing of loans and deposits, then the bank sets deposit and loan volumes separately.

<u>Proof:</u> Set $C_{LD}(L, D) = C_{DL}(L, D) = 0$. Then, Result 1 follows from (6) and (7).

Case 1: Pass-through without an e-krona

The following result holds in this case.

Result 2: The pass-through from the repo rate to deposit and lending rates can be different from one to one.²⁷

<u>Proof</u>: If the pass-through is one to one, then the deposit intermediation margin $i^{R} - i^{D}$ must be constant. From (7) it follows that this can only be the case if

(8)
$$\frac{di^{D}(D)}{dD}D + C_{D}(L,D) = k$$

where k is a constant. Thus, equation (8) will only hold under some very specific assumptions regarding the deposit supply and the managerial cost relations.²⁸ The proof for the pass-through to lending rates is similar.

Result 2 implies that we can expect the pass-through to be typically different from one to one without an e-krona.

Case 2: Pass-through with an e-krona

We hereby examine the effects of the introduction of an e-krona on the pass-through from the policy rate to lending and deposit rates in the case of a monopolistic bank. Let i_{MON}^{D} be the deposit rate that such a bank would set if there were no e-krona. If $i^{Ekr} < i_{MON}^{D}$, an e-krona would be unattractive and therefore not used in equilibrium.²⁹ In that case, the introduction of an e-krona would not impact the pass-through.

Before looking at the pass-through with an attractive e-krona, it is useful to notice that if the e-krona margin $i^R - i^{Ekr}$ is fixed, the attractiveness of an e-krona and therefore also the pass-through may depend on the level of the policy rate. To see why that is the case, notice that it follows from (7) that the optimal deposit intermediation margin $i^R - i^D$ can be increasing in D. That is true, for instance, if the marginal managerial cost is constant or increasing in D and the deposit supply function is linear in D. Thus, if the e-krona margin $i^R - i^{Ekr}$ is sufficiently large, the optimal intermediation margin $i^R - i^D$ can be smaller than the margin $i^R - i^{Ekr}$ for D smaller than a threshold value \underline{D} . Thus, if $D < \underline{D}$, the profit-maximizing monopolist may anyhow set a deposit rate that is higher than the e-krona rate thus rendering an e-krona unattractive. If instead $D > \underline{D}$, this will no longer be the case and an e-krona will be attractive.

The following result holds for the case when an e-krona is attractive.

Result 3: If the e-krona margin $i^R - i^{Ekr}$ is constant and an e-krona is attractive, then the pass-through from policy-rate changes to deposit rates will be one to one.

²⁷ Pass-through will be one to one under perfect competition if C_{oo} is constant as in that case the term $\frac{di^{o}}{dD}D$ disappears from expression (8). Similarly, the pass-through to lending rates will be one to one under perfect competition and constant marginal managerial costs.

²⁸ For example, this will be true if $i^{D}(D) = \ln(D)$ and $C(D,L) = Y^{D}D + Y^{L}L$

²⁹ Note that here we disregard the gains from additional services and from differences in risk and set $\varphi_t^{ev} - \sigma_t^{ev} = \varphi_t^D - \sigma_t^D$ (see equation (4) in Section 2.2).

<u>Proof</u>: If $i^{Ekr} \le i_{MON}^{D}$, we need to identify two separate cases:

- (i) If $i^{Ekr} > i^{D}_{BRE}$, where i^{D}_{BRE} is the bank's break-even deposit interest rate (i.e. $i^{D}_{BRE}D - C(D,L) = 0$), the bank will cease its deposit-taking activities as they are loss-making. Then, all deposits will be e-krona. Moreover, the pass-through will be one to one as long as the margin between the policy-rate and the e-krona rate is constant.
- (ii) If instead $i^{Ekr} \le i^{D}_{BRE}$ the monopolist bank will set $i^{D} = i^{Ekr}$, and the pass-through to deposit rates becomes one to one as long as the margin between the policy rate and the e-krona rate is constant.

The following result also holds.

Result 4: If there are no joint variable costs in the managing of loans and deposits, the passthrough from policy-rate changes to lending rates will not be affected by the introduction of an e-krona.

Proof: This follows directly from Result 1. ■

How many e-krona are needed for payments?

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Many central banks are studying the opportunities for and consequences of issuing digital currencies. The Riksbank's e-krona project is part of this work. However, the consequences for the Riksbank's work on monetary policy and financial stability depend on how great the demand for the e-krona will be. This article comprises a preliminary attempt to quantify how great this demand could be with regard to meeting the domestic transactional needs in the Swedish economy. A reasonable assumption is that demand will be relatively low and correspond to 1–2 per cent of the gross domestic product.

1 Introduction

If the Riksbank chooses to issue central bank ditigal currency, a so-called e-krona, as a complement to physical cash, the Riksbank will also need to obtain an idea of how large the demand for this money may be. This is because a large demand could significantly increase the size of the Riksbank's balance sheet and have implications for monetary policy and financial stability, especially in an environment with low interest rates.¹ Juks (2018) discusses the demand for e-krona from a savings and investment perspective. This article supplements his analysis by studying how much e-krona may be in demand to meet the need for transactions in the Swedish economy. We start by looking at the existing literature on demand for cash.

The e-krona studied by the Riksbank comprises central bank digital currency that is available to the general public (see Sveriges Riksbank, 2018b). There are currently very few examples of central bank digital currency, but many central banks are looking into this question.^{2 3}

There is no empirical or theoretical research into the demand for central bank digital currency and therefore no generally-accepted method to rely on. Below we will use the so-called *transaction approach*, and the analysis is based on reasonable assumptions. It is therefore important to take the analysis for what it is: a preliminary attempt to discuss some of the demand for a hypothetical means of payment. The overall conclusion is that it is reasonable to believe that demand will be relatively small from a transaction perspective, roughly on a par with the demand for cash in Sweden in recent years, which has amounted to the equivalent of 1–2 per cent of GDP.

In section 2 we survey the value of payments in the Swedish economy in 2016 and the sectors they are made between. Based on this, we then calculate in section 3 a possible demand for the e-krona in those sectors under a couple of assumptions of how various participants would act. In section 4 we sum up the various parts and discuss the whole. A short summary of the conclusions is given in section 5.

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¹ See Sveriges Riksbank (2017, 2018b) as well as the Committee on Payments and Market Infrastructure and Markets Committee (2018) and Armelius et al. (2018).

² Uruguay carried out a sex-month long test on consumers and companies from November 2017.

³ Central Bank Digital Currency (CBDC) can be made accessible to a limited group of users (wholesale CBDC), for instance the financial sector, or to everyone (retail CBDC). CBDC is studied in international collaboration forums for central banks, see the Committee on Payments and Market Infrastructure and the Markets Committee (2018), and by individual central banks such as Sveriges Riksbank (2017) and Norges Bank (2018) and also by individual researchers at different central banks, see for instance Engert and Fung (2017).

1.1 We know little about the demand for cash

Money is traditionally defined on the basis of the three roles it fulfils.⁴ The first is as a *means of payment* when we buy something. The buyer uses money to transfer a value to the seller as compensation for a product or service. The second role is as a *unit of account*, that is, a standardised means of expressing prices in the economy. This allows us to simply compare prices of different products. The third role is that of *store of value* when we save money to use later.

It is in the roles as means of payment and store of value that the demand for money arises. A person wanting to buy a cup of coffee or put money in a piggy-bank needs banknotes and coins. But despite this simple truth, it is remarkable how little we actually know about what governs demand for cash in the economy. On an overall level there is consensus among central banks, academia and market participants that driving forces such as technological advances, changes in consumption patterns and demographics have contributed to reducing demand, but no one knows how much of this reduction in Sweden is due to the percentage of cash payments declining.⁵ In many countries, the demand for cash is growing, despite electronic payments becoming increasingly common around the world, see Bech et al. (2018). How consumers choose to pay is also a question of culture, and cash has traditionally held a stronger position in some countries than others.⁶ There is thus no simple qualitative correlation between the transaction need in the economy and the demand for cash.

1.2 The transaction approach

One method of calculating the demand for cash is the so-called *transaction approach*. This is based on the value of cash payments in the economy and links this to the demand for cash via an estimated velocity of cash, i.e. rate of turnover in cash. The correlation is described in equation (1) below:

(1) $M^*V = p^*T$

where *M* is the value of cash in the economy, *V* is the velocity of cash and p^{*T} is the value of cash payments (*p* is prices and *T* is the number of transactions). If one knows the value of the cash payments in the economy and the velocity during a certain period of time, it is easy to calculate the demand for cash. The larger the value of cash payments is, the greater the demand will be. If the velocity increases, less cash will be needed to implement a certain amount of payments and demand will decline. This method has been used by, for instance, Humphrey, Kaloudis and Öwre (2000, 2004) and Guibourg and Segendorf (2007). The advantage with this method is that it is based on a clear causal and simple correlation. The disadvantage is that there is rarely good quality data on cash payments. In particular, there are no time series, although surveys and so-called diary studies of consumers' payment patterns can provide snapshots, see for instance Esselink and Hernández (2016), Jonker and Kosse (2013) or Henry, Huynh and Shen (2015).⁷

⁴ See Söderberg (2018) and Camera (2017) for an outline.

⁵ See for instance Segendorf and Vretman (2015) or Committee for Payments and Market Infrastructure (2012, 2014).

⁶ For instance, there is a considerable difference between neighbouring countries such as Germany, Austria and Switzerland on the one side and Sweden, Norway and Denmark on the other. There are also major differences within the eurozone, see Esselink and Hernández (2017).

⁷ In the academic literature, two main approaches have emerged for calculating the demand for cash. One is the transaction approach, and the other is the currency demand approach, which aims to measure the size of the black economy, see for instance Buehn and Schneider (2016). The basic idea is that the black economy is largely driven by tax pressure and that transactions in the black economy are preferably made in cash. This approach calculates the demand for cash as a statistical function of macroeconomic variables and tax pressure. The advantage of this method is that good quality data is available for most countries. The disadvantage is that there is no direct causal relationship between the macroeconomic variables and cash and that consumption patterns, technology, social norms and so on, change over time.

2 Payments in the Swedish economy

The first stage in the analysis is to chart the transaction need in the Swedish economy, that is, p^{*T} in equation (1).

Every year, the Riksbank gathers and publishes statistics on the Swedish payments market. These statistics cover card payments, cheques, credit transfers, account transfers and direct debits. But there are unfortunately no reliable statistics on cash payments. A survey carried out by the Riksbank in spring 2018 showed that the percentage of cash payments at points of sale was 13 per cent.⁸ In terms of size, this is around the same percentage as for cash withdrawals from ATMs and in shops in relation to the total value of card payments.9 We will therefore use the value of cash withdrawals to estimate the value of the cash payments. In Table 1 you can see that the value of payments in the Swedish economy in 2016 amounted to just over SEK 16,000 billion. On top of this come the payments mediated within the Plusgirot system, but there is also a lack of data here. Regardless of this uncertainty, it is very probable that the total value of payments in 2016 in terms of size amounted to around four times the value of the gross national product (GDP).¹⁰ In this article, we relate the value of payments and demand for a potential e-krona to the value of GDP.

Payment method	SEK billion				
Cards	1,008				
Debit cards	773				
Delayed debit cards and credit cards	230				
Credit transfers	14,561				
Electronic	14,381				
Form	180				
Direct debit	508				
Cheques	4				
Cash withdrawals	128				
ATMs	108				
In a shop*	20				
Total	16,204				

Table 1. The value of payments in the Swedish economy 2016

Source: Sveriges Riksbank

Estimate based on interview responses in Sveriges Riksbank (2018a).

Table 2 gives an overview of the size of payment flows between different sectors of the economy in relation to GDP. It is produced on the basis of information from individual or groups of participants, such as the government budget or household incomes, which have been put together to form an overall picture. But as it is not possible to verify the overall picture, we regard them as uncertain and we have rounded off to the nearest 5 per cent to avoid giving an incorrect impression of the accuracy. The primary sources of information have been the budgets for the central government, the county councils and municipalities, data from the Swedish National Debt Office and statistics on households' disposable incomes.¹¹ Payments in the specified sectors have been estimated using other

⁸ Sveriges Riksbank (2018a).

⁹ In addition, Arvidsson, Hedman and Segendorf (2017) found that the percentages of cash payments in shops were equally large with regard to number and value.

¹⁰ In 2016, Swedish GDP amounted to around SEK 4,400 billion. Source: Statistics Sweden

¹¹ See, for instance, the Swedish National Debt Office (2016) and Statistics Sweden's databases.

data sources or as residuals. For instance, households' disposable incomes are known, as is their consumption. The latter gives rise to payments to the private sector, municipalities and county council. Households generally do not pay their taxes to the state themselves, this is done by their employers. This is visible in the upper row of Table 2, where one can see that households pay a value corresponding to around 40 per cent of GDP to the private sector, around 10 per cent to municipalities and very little directly to the state. The total value of these payments should correspond to the value of the payments households receive from the same sectors, that is, a value of around 50 per cent of GDP. The 5 per cent that households pay to themselves is an estimate based on the value of Swish payments that are largely person-to-person payments, that a large share of cash withdrawals are used for person-to-person payments and so on.

				Payees		
		Households	Private sector	Municipalities and County councils	Government	Total
	Households	5	40	10	0	55
	Private sector	30	200	10	25	265
Payers	Municipalities and County councils	10	20	0	0	30
	Government	10	10	10	30	60
	Total	55	270	30	55	410

Table 2. Size of payment flows between different sectors in Sweden expressed as a percentage of GDP

We now have an estimate of the value of the payments that are made by various types of economic agents to one another. The next stage is to investigate how many e-krona the various agents need to make these payments.

3 Transaction demand for e-krona

The demand for e-krona for transactions can be regarded as the solution to an economic optimisation problem. A payment from one party to another assumes that the first has the money, for instance, banknotes and coins or money on account, which shall be paid to the counterpart. At the same time, holding this money is linked to an opportunity cost which in this case is the return that the money could give if invested somewhere else. Cash does not carry any interest and if held to make payments, that is, not as savings, the opportunity cost is the interest that money would generate, for instance, in a transaction account. Similarly, an e-krona would be linked to an opportunity cost in the form of loss of yield. There is thus a financial incentive to hold as few e-krona as possible. On the other hand, there is a risk that the paying party will not be able to pay if they have too little money available, something that is generally also linked to a cost. All economic agents therefore need to weigh up the costs and benefits regarding how many e-krona they need to hold to refrain as little as possible from a return but at the same time be certain they can meet their payment obligations. This is usually called liquidity management, and is a central function in large corporations, for instance. In terms of the transaction approach in Equation (1), liquidity management will determine the velocity of the e-krona V. The faster someone chooses to convert e-krona into something else, the higher the velocity.

Based on economic theory, there is no reason to believe, for instance, that companies and households would have different ways of weighing up the pros and cons. But they may have different time preferences, different costs for liquidity management and different revenues. Large corporations have employees and administrative systems to deal with this, while the individual consumer or sole proprietorship firm does it in their spare time. The gain from active liquidity management is generally less for an individual consumer than for a large corporation, as the underlying amounts are much lower. We cannot explicitly resolve the liquidity optimisation problem for all parties in the economy, as this requires masses of information that we do not have. Instead, we will use rules of thumb for how the participants act and which seem reasonable on the basis of the pros and cons we have described above.

3.1 Assumptions of how economic agents act

The first assumption is the rule of thumb that we differentiate between households and other agents as companies, municipalities, county councils and the central government manage liquidity within the scope of their day-to-day operations, while households do not. On the other hand, it is not possible for us to distinguish between large and small companies, we will instead assume that companies, municipalities, county councils and the central government all act in the same way.

The second assumption is that the professional agents will hold liquidity to meet the payment obligations in the coming two days. We will also report the results if this period is extended to five days. By days, we mean here banking days, that is, the days when banks and payment systems are open and payments are mediated and settled.¹² We will use as a standard calculation of 250 banking days a year.

The third assumption is that households do not actively manage their liquidity. Households normally receive their income on one or two fixed dates each month and they spend the money gradually up to the next time they receive income. There is some periodicity in the other sectors too, for instance, tax payments are made on certain dates, but they have a more continuous flow of incoming and outgoing payments. To the extent that households do actively manage their liquidity, this will result in a lower demand for e-krona. These assumptions are of course gross simplifications, but they are nevertheless sufficiently realistic to comprise a base for a preliminary discussion of the transaction demand for e-krona. In brief, the assumptions state that the velocity, *V*, is significantly lower in the household sector than in other parts of the economy.

It is assumed that an e-krona can be used for all types of domestic payments: when paying in shops, e-commerce, household bills, invoices, wage payments and so on. In the calculations below, we assume that the e-krona has a market share of 10 per cent. This corresponds e-krona payments to a value of around 40 per cent of GDP, that is, a little more than SEK 1,700 billion based on GDP in 2017. However, this figure should not be regarded as a forecast or objective. It is a market share that can easily be used in calculations and can simply be scaled up or down, depending on what each individual reader considers to be a reasonable assessment.¹³

3.2 The household sector

The household sector has a disposable income corresponding to around half of GDP.¹⁴ Let us for the sake of simplicity assume that income and consumption are evenly divided over all of the months of the year. Households will then have incoming payments in the form of salaries, pensions, benefits and so on corresponding to just over 4 per cent of GDP per month. This inflow is balanced by an equally large outflow. Salaries are usually paid out

¹² Banks, including the Riksbank, are closed on Saturdays and Sundays and some other public holidays.

¹³ The market share that a potential e-krona might gain will depend on how it is designed and what properties the competing payment services have. There are currently no clear proposals for its design and we therefore shall not pursue an in-depth reasoning regarding market shares.

¹⁴ In 2017, households' disposable income was SEK 2,250 billion (including households non-profit organisations) and GDP amounted to around SEK 4,600 billion. Source: Statistics Sweden, income and expenditure and capital transactions (ENS2010), current prices, SEK million according to sector, transaction item and year.

on the 25th of each month and pensions are paid out one week earlier. Benefits are paid out around the same dates as salaries and pensions. Households spend around half of their incomes through card payments and cash. These payments normally concern regular consumption that we for the sake of simplicity assume is divided evenly over time. This means that the remaining half of the disposable income is used for credit transfers and direct debits, which are often used for periodic expenditure, such as accommodation. This expenditure is usually paid late in the month.

Let us illustrate the above using figures from 2016. Households' disposable incomes were then almost SEK 2,200 billion and according to Table 1, the value of bank card payments amounted to SEK 773 billion and credit card payments to SEK 230 billion. Cash withdrawals amounted to around SEK 128 billion.¹⁵ Cash and debit cards are used almost exclusively by consumers, while credit cards are used by both consumers and companies, but households account for almost all credit card debt.¹⁶ We therefore make the simplified assumption that credit cards are also largely used by households. The total value of household payments with cards and cash should therefore be just under 773 + 230 + 128 = SEK 1,131 billion. This corresponds to around half of the disposable income. In an average month, therefore, households have income of SEK 183 billion, of which half (SEK 90 billion) is consumed regularly at a value of SEK 3 billion per day. In the final week of the month, households pay bills to a value of around SEK 90 billion.

The rate of turnover becomes 1 per month if we assume that households do not actively manage their liquidity. If the e-krona has a market share of 10 per cent of the payments market, households would then at most demand 18 billion e-krona around the 25th. Towards the end of the month the demand would decline by half (9 billion) and then gradually decline to a billion or so before increasing again at the next salary and pension pay out. In the more general case were we state demand as a percentage of GDP, demand is at its highest 0.4 per cent of GDP and then declines rapidly to 0.2 per cent at the end of the month, to gradually approach zero before turning upwards again.

3.3 Central government

The central government sector consists of parliament, the cabinet offices and the public authorities, including the county administrative boards. Their income and expenditure correspond in size to around 30 per cent each of GDP.¹⁷ This corresponds to an average payment need of SEK 5.6 billion per banking day, which gives SEK 11.2 billion for the two days we have assumed they need with regard to their liquidity management. However, the payment need will vary and be greater on certain dates and lower on others, for instance, depending on payment of salaries, sickness insurance, pensions and subsidies to the household sector (see section 3.2).¹⁸ Similarly, the value of the incoming payments will also vary. The two largest inflows are VAT, which is paid in around the 12th, corporate taxes and preliminary taxes, which are paid in around the 25th.

The state's inward and outward payments are made through the state's internal bank at the Swedish National Debt Office. How they choose to manage these payments will therefore be of central significance for the demand for e-krona. If we assume that the state makes 10 per cent of its payments (SEK 11.2 billion for two days) in e-krona, the demand will amount to just over a billion, which corresponds to 0.024 per cent of GDP.

¹⁵ Cheques are extremely rare. In Table 1, 0.02 percent of total payments are made by cheques. The households' share of that is unknown. Therefore we will not include cheques in the calculation.

¹⁶ See Statistics Sweden, financial market statistics, section 7.7, lending in form of convenience credit card and extended credit card credit.

¹⁷ In 2017, incomes amounted to SEK 1,414 billion and expenditure to SEK 1,347 billion. GDP amounted to SEK 4,604 billion. Source: Statistics Sweden's databases.

¹⁸ The need to pay out is also greater around the 12th of each month when payments to pension funds are made, similarly around the 23rd when tax payments are made to municipalities and county councils. Source: Swedish National Debt Office (2016).

3.4 Municipalities and county councils

Municipalities and county councils do not use the state's internal bank to make payments, they use commercial banks. There is no coordination between municipalities and county councils with regard to using a particular bank, for instance. They instead act as independent units and are in this way more like companies than the state in the way they make payments. Municipalities and county councils, including regions, have incoming and outgoing payments corresponding to around one quarter of GDP each.¹⁹ This is equivalent to an average payment need of SEK 4.4 billion per banking day. The liquidity need for two days will then be SEK 8.8 billion. If we, as in the case of households, assume that the e-krona has a market share of 10 per cent, this means that municipalities and county councils would demand on average 0.9 billion e-krona (0.02 per cent of GDP). But there can be considerable variation in the demand from municipalities and county councils for e-krona because of the concentration of outgoing and incoming payments around certain dates.

3.5 Private sector

It is difficult to chart the payment flows to, from and within the private sector. But as we know the approximate total value of payments in the economy and the value of payments to and from the state, municipalities, county councils and households, we can regard the private sector as a residual; the payments not made by the other sectors must be made by the private sector. The other sectors have outgoing payments to a total value of 140 per cent of GDP (see Table 2). The total value of payments in the economy is around four times GDP and the private sector must therefore make payments to a total value corresponding to slightly more than two and a half times GDP. The private sector makes payments equivalent to two thirds of GDP to the other sectors in the form of salaries, taxes and so on. This means that the value of the payments between agents in the private sector ought to be in the magnitude of twice the size of GDP. On average this is around SEK 55 billion per banking day. If we assume that the e-krona has a market share of 10 per cent, the liquidity need for two days will be 11 billion e-krona. This corresponds to 0.24 per cent of GDP.

4 The total transaction demand

When, for instance, the private sector pays salaries to households, e-krona are transferred from one account to another. The sum of e-krona is not affected, they just change owner. When we add together the different sectors' need for e-krona, we only study the expenditure side. Otherwise there is a risk of double counting the transaction need as each payment is an expenditure for the paying party and an income for the receiving party. In section 3 we have consistently looked at the different sectors' expenditure sides. Table 3 contains a compilation of the demand for e-krona that we have assessed agents will need to meet the transaction need in the various sectors. We have based this assessment on their expenditure at liquidity management planning horizons of two and five days with a market share for the e-krona of 10 per cent. The table also takes into consideration whether households have just received their salaries (high demand) or if we are in the middle of the month just before pension payments (low demand).

19 For the financial year 2017, total income for municipalities and county councils amounted to SEK 1,083 billion and expenditure to SEK 1,099 billion. Source: Statistics Sweden, National Accounts, public sector incomes and expenditure broken down into sub-sectors.
Table 3. Transaction demand for the e-krona under the assumption of a 10 per cent market share

The transaction demand for e-krona in different sectors of the economy, expressed as a per cent of GDP and in the final column as number of billion SEK based on GDP for 2017

	High d	emand	Low de	emand
	2 days liquidity 5 days liquidity		2 days liquidity	5 days liquidity
Households	0.4	0.4	0.05	0.05
Central government	0.024	0.048	0.024	0.048
Municipalities and county councils	0.02	0.04	0.02	0.04
Private sector	0.24	0.48	0.24	0.48
Demand (% of GDP)	0.68	0.97	0.33	0.62
SEK billion (GDP 2017)	31	45	15	28

We can see in the table that if the e-krona has a market share of 10 per cent of the payments market the transaction demand should vary between SEK 15 and 31 billion, depending on what part of the month, with a two day planning horizon. This is below the current demand for cash, which is just over SEK 50 billion including cash held for saving (see Section 4.2). If we relinquish the assumption of a two-day liquidity management and instead assume a working week (five days), demand is SEK 28-45 billion, depending on the part of the month. At five days, demand thus increases by SEK 13-14 billion. If we instead relinquish the assumption of a 10-per cent market share and assume a higher market share, say 30 per cent, then Table 3 implies that demand will be 1-2 per cent of GDP for a two-day liquidity management. This means that even if the e-krona has a significant share of the payments market, the effect of transaction demand on the banks' deposits and the Riksbank's balance sheet will be manageable. However, the table does not take into account variations in demand from the central government, municipalities, county councils and the private sector. There are many indications that payments are concentrated around certain dates, which can make demand volatile. Figure 1 shows how the central government's inward and outward payments vary during an average month in 2014.



Source: Swedish National Debt Office (2016)

The calculated demand is probably an overestimation as the table does not give consideration to agents matching ingoing and outgoing payments. If e-krona are paid in

at the same time as other e-krona must be paid out, the incoming e-krona can be used to finance the outgoing payments (V increases). This effect should be fairly small in the case of a small market share, but if the e-krona were to have a large share of the payment market the effect could be significant. Section 4.1 about Postgirot discusses this further.

4.1 A comparison with Postgirot

A possible benchmark to test the reasonability of the demand calculation above is Postgirot. Postgirot was a separate payment system that was offered by a state-owned bank – Postgirot Bank.^{20, 21} The customers could move money in and out from Postgirot, i.e. to and from bank accounts outside Postgirot, and make payments between accounts in the Postgirot system. On an overall level it describes exactly what an e-krona is: a state account structure for payments to which a number of payment services have been linked. Deposits in Postgirot Bank can be regarded as demand for 'Postgirot money' and comprise a point of reference for calculations of the demand for e-krona.

In 1998, when Postgirot's market share had already begun to decline, 430,000 companies and one million households had accounts there. The number of payments was 400 million and the total turnover was SEK 5,000 billion. The Swedish population was then 8.85 million, GDP was SEK 1,873 billion and the total value of payments in the economy was SEK 7,899 billion.²² Postgirot thus had in turnover terms a market share of around two thirds of the payments market and a large share of private and corporate customers. Postgirot itself claimed a market share of just over 46 per cent of the payments market. Postgirot Bank also provided corporate credit on a small scale. Figure 2 shows the average deposits in Postgirot Bank between 1994 and 1998.





During 1998 the average deposits increased to SEK 31.1 billion from 29.6 billion in 1997. However, the increase could be attributed to deposits in accounts with favourable interest rates. Deposits had a high level of volatility, which indicates that the customers primarily maintained liquidity in Postgirot to be able to make payments, that is, Postgirot's customers held on average SEK 31.1 billion in Postgirot to be able to make payments of SEK 5,000

²⁰ Postgirot Bank was a part of the Post group, see Posten (1998).

²¹ Postgirot was established in the mid-1920s after an investigation of the need for a postal cheque system (Swedish Government Official Reports, 1922). The investigation identified the advantages of account-based payments and the purpose of a postgiro system was to simplify payments, make the state's payments more efficient and reduce the use of cash. At that time, not all households had access to bank accounts and nor were there bank branches in all parts of Sweden. Postgirot expanded gradually and over time became the dominant payment system for credit transfers and direct debit payments. Towards the end of the 1990s, Postgirot's dominant position was gradually weakened. In 2001, Postgirot was sold to Nordea, a private commercial bank, and changed its name to Plusgirot in 2005.

²² See Committee on Payments and Market Infrastructure (2001).

billion. The average deposit thus corresponded to 0.6 per cent of the transferred value. Postgirot was probably a very efficient system, as a large share of households and companies had accounts there, which made it easier for professional agents to manage their liquidity by using incoming liquidity for outgoing payments.

The e-krona, with an assumed market share of 10 per cent, is at between 15 and 45 billion, which corresponds to around 0.9–2.6 per cent of the payment turnover. The average deposits in Postgirot in 1998 (the demand for 'Postgirot money') amounted to 0.6 per cent of the turnover. The comparison indicates that our calculations above are reasonable and not under dimensioned.

4.2 Household saving in cash

Households demand for e-krona will not be solely determined by their transaction needs. Some households may want to have savings in e-krona in the same way that some households today have an amount of savings in cash. In normal times, banks and other financial institutions would probably be able to offer savings products that in terms of yield are more beneficial than an e-krona, just as they currently offer savings products that give a higher return than cash. Below is a brief description of households' savings in cash.

The Riksbank carries out an interview survey of households' payment habits every other year.²³ In spring 2018, 12 per cent of respondents over the age of 18 said they had savings in cash. Of these, 60 per cent had less than SEK 10,000, 11 per cent had between SEK 10,000 and 100,000 and 2 per cent had more than SEK 100,000 saved in cash. A further 18 per cent did not know and 10 per cent did not want to tell the amount.

Let us assume that those who did not know or did not wish to respond on average behave in the same way as those who stated an amount. We can further assume that those who stated an interval on average were in the middle of the interval, that is, have SEK 5,000 or SEK 50,000 saved. We assume that those who have stated SEK 100,000 or more have SEK 200,000. The number of people in Sweden aged 18 or over is around 8 million.²⁴ Under the assumptions we have made above and if the sample is representative, household savings in cash would amount to around SEK 17 billion.²⁵ If households save in e-krona in the same way as they now save in cash, it will then correspond to slightly more than 0.35 per cent of GDP.

5 Closing comments

The value of the e-krona needed by economic agents to meet their domestic transaction needs is relatively small under reasonable assumptions regarding the e-krona's market share and the agents' liquidity management. The effects of this transaction demand on the banks' and the Riksbank's balance sheets are thus also relatively small, as are the effects on monetary policy and financial stability.

If an e-krona proves to have significant effects on the balance sheets, monetary policy and financial stability this will instead be due to demand arising for two other reasons. To begin with, we have so far focused exclusively on the domestic transaction need. One cannot rule out the possibility that agents from other countries might demand e-krona to make payments in situations of financial stress in their home countries. This is not something that could happen overnight, however. All agents who wish to hold e-krona will need to undergo an investigation based on the regulations for the e-krona. Although there are no regulations as yet, we can assume that they will include the customary money laundering and know-

²³ See Sveriges Riksbank (2018a).

²⁴ At the end of 2017 the number of people aged 18 years and older was 7,998,644. Source: Statistics Sweden database, population according to age and gender 1860–2017.

²⁵ This agrees with a survey made by Forex Bank in 2013 where they found that Swedish households had SEK 18 billion at home, see Forex (2013).

your-customer checks. It is also likely that foreign agents would need to use Swedish banks as agents or to become participants in the Riksbank's settlement system. There are thus certain rigidities and costs if a foreign agent wishes to have e-krona.

The second reason is a significant need for savings and investment. That there is a substantial investment need is confirmed if we compare demand deposits in monetary financial institutions with the liquidity needed to make payments. In August 2018, demand deposits amounted to SEK 2,580 billion.²⁶ The liquidity to make all payments in the economy should be around SEK 200 billion if we assume that the liquidity need amounts to around 1 per cent of the turnover value (around SEK 18,000 billion or four times GDP), which is a lower liquidity utilisation than in the old Postgirot system. Even if this figure can be discussed it is clear that around 90 per cent of demand deposits are held for other reasons than payments.

26 Source: Statistics Sweden, Financial market statistics, Table 5.1. Monetary financial institutions cover more institutions than the banking sector alone, for instance, the Swedish National Debt Office.

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When a central bank digital currency meets private money: effects of an e-krona on banks

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The introduction of a central bank digital currency (CBDC) is often perceived to have far-reaching implications for banks with adverse effects on financial and macroeconomic stability. We study the effects of CBDC on banks using the Swedish banking sector as an illustration. We find that, while a given outflow of retail deposits into e-krona reduces banks' liquidity portfolios and worsens their funding profiles, banks can normally control this outflow via deposit rates. Banks can also issue more market funding to restore their liquidity and funding profiles. An indicative calculation of the demand for e-krona in normal times shows that it would be below three per cent of nominal GDP and that the impact of an e-krona on bank funding costs would be up to 25 basis points under plausible assumptions. In times of distress, an e-krona may increase the number of banks experiencing a run. This will be the case if an e-krona has features that make it more attractive than existing run assets, such as deposits at the safest banks, tax accounts or cash. The exact features of an e-krona can, however, be controlled by the policy maker. In sum, we do not find any decisive argument against the issuance of an e-krona when studying financial stability effects on banks.

1 Introduction

The introduction of a central bank digital currency (CBDC) is being actively discussed both in academic and central bank circles. One of the most frequently raised issues is the impact of CBDC on banks.¹ How would banks fund their lending if deposits were converted into CBDC? What would CBDC mean for bank lending rates? And would not CBDC open up for large-scale bank runs? These are frequently asked questions in the context of CBDC. This article considers a specific CBDC in the form of an e-krona and studies the effects of an e-krona on the Swedish banking sector.

The article starts with a description of the assets and liabilities of the Swedish banking sector and the Riksbank. Next, the article considers a scenario where banks experience a given outflow of retail deposits into e-krona. The scenario is used to understand the effects of a given outflow of retail deposits into e-krona on banks and the Riksbank. The scenario is also used to illustrate what measures banks could take to compensate for a loss in liquidity and funding stability due to an outflow.

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¹ See, for instance, Bank for International Settlements (BIS) (2018).

The article then moves on to discuss the potential demand for e-krona in normal nonstressed times. Using data on deposits and estimates on payment volumes via e-krona from Segendorf (2018), the article gives an indication of how large the demand for e-krona could be in normal times. The analysis of this demand is used to understand the implications of an e-krona for banks' funding costs and lending rates taking into account banks' own counterbalancing measures.

The article then discusses the demand for e-krona in stressed times when confidence in the banking sector is low. In particular, bank runs with and without an e-krona are discussed together with the measures that can be taken to mitigate the adverse effects of an e-krona on banks in times of distress.

The article concludes with a discussion of broader aspects of an e-krona. In particular, an e-krona as a medium of exchange as well as acting as a payment system is discussed together with costs and benefits stemming from the reduced role of deposits in banking and the increased role of central banks in financial markets.

2 The balance sheet of the Swedish banking sector and the Riksbank

To understand the effects of an e-krona on Swedish banks, it is useful to start with the description of their assets and liabilities. Swedish banks have a large portfolio of liquid assets, worth around 3 550 billion (see Table 1). Out of this liquidity portfolio, 450 billion is held at the Riksbank as reserves² and 3 100 billion is held in liquid securities and as reserves at foreign central banks. Banks fund their liquidity portfolio by issuing short-term securities, such as certificates, and other short-term liabilities, such as deposits from asset managers.

Assets		Liabilities		
Reserves at the Riksbank	450	Short-term issuance	1 300	
Other liquid assets	3 100	Other short-term liabilities	2 250	
Lending to the real sector	6 100	Retail deposits	2 800	
		Long-term issuance	3 300	
Total	9 650	Total	9 650	

Table 1. Swedish banks' liquid assets, lending in Sweden and their sources of funding
SEK billion

Note. Data is as of April 2018. Reserves at the Riksbank refer to monetary policy deposits as well as certificates issued by the Riksbank. The real sector refers to Swedish households and non-financials. Retail deposits are taken to be equal with deposits from the real sector. Short and long-term issuance refers to market funding, such as certificates and bonds, issued in the domestic and foreign currencies. Some assets and liabilities, such as lending outside Sweden and derivatives, are excluded. Sources: The Riksbank and the author's calculations

Swedish banks also have a lending portfolio to Swedish households and non-financial firms that is equal to approximately 6 100 billion. This is funded with a mix of retail³ deposits from households and non-financial firms (approximately 2 800 billion) and long-term market funding (approximately 3 300 billion). Almost all retail deposits are on demand and can be used immediately for payments.

² Banks' claims against the Riksbank come in the form of overnight deposits and certificates. For simplicity, the article refers to these claims as reserves.

³ Retail refers to small and medium-sized non-financial customers. The distinction between retail and non-retail is important since it is retail deposits that can be used to fund illiquid lending.

The Riksbank's balance sheet is currently around 900 billion. The Riksbank has no outstanding monetary policy lending to banks, but it has a security portfolio in domestic currency and a foreign currency reserve. The largest item on the liabilities side is the reserves held by banks.

SEK Dillion					
Assets		Liabilities			
Lending to the banks	0	Reserves to the banks	450		
Securities	370				
Foreign reserve, gold, other	530	Cash, other liabilities	450		
Total	900	Total	900		

Table 2. The Riksbank's balance sheet

Note. Data is as of April 2018. Sources: The Riksbank and the author's calculations

3 An outflow of retail deposits into e-krona

In this section, we consider a scenario where banks experience a deposit outflow into e-krona. The goal of the scenario is to understand how a given deposit outflow into e-krona affects the asset composition and funding sources of banks and the Riksbank. The total outflow in the scenario is given and assumed to be 900 billion. The outflow itself takes place in two days in equal magnitudes, that is, 450 billion in deposits leaves the banking sector and moves to e-krona each day.⁴

The scenario focuses on retail deposits since it is these deposits that banks use to fund illiquid lending. The specific features of an e-krona are irrelevant for the scenario since the outflow is given and cannot be affected by banks. We do, however, assume that e-krona are supplied in exactly the same way as cash is supplied today: banks can buy e-krona from the Riksbank using reserves and the Riksbank takes measures to satisfy banks' aggregate need for reserves.⁵

3.1 Effects of an outflow on banks' balance sheets and the Riksbank

To begin with, banks have reserves at the Riksbank equal to 450 billion. Therefore, banks can use their existing reserves to manage the first outflow. Banks simply buy e-krona from the Riksbank using their reserves. These e-krona are then sold further to depositors who pay for them with their existing bank deposits.

After the first day, there are two changes in banks' balance sheets: on the asset side, reserves held at the Riksbank have been exhausted fully, since banks used these to buy e-krona, and on the liability side, retail deposits have gone down since depositors used these to pay for e-krona (see Panel A, Table 3). The Riksbank's asset side is the same, but the Riksbank now has a new liability of 450 billion in the form of e-krona towards the real sector while there is no liability towards banks (see Panel B, Table 3).

⁴ The reason why we consider 450 + 450 billion is because banks can meet the first outflow with existing reserves, while there

are not enough existing reserves for the second outflow

⁵ There are also other ways to issue an e-krona. See also Section 5.2.3.

Panel A. Swedish banks					
Assets		Liabilities			
Reserves at the Riksbank	0	Short-term issuance	1 300		
Other liquid assets	3 100	Other short-term liabilities	2 250		
Lending to the real sector	6 100	Retail deposits	2 350		
		Long-term issuance	3 300		
Total	9 200	Total	9 200		

Table 3. Changes in the balance sheets of Swedish banks and the Riksbank after the first outflow of 450 billion in retail deposits into e-krona

SEK billion

Panel B. The Riksbank					
Assets		Liabilities			
Lending to the banks	0	Reserves to the banks	0		
Securities	370	E-krona to the real sector	450		
Foreign reserve, gold, other	530	Cash, other liabilities	450		
Total	900	Total	900		

Note. The changes have been marked in red.

At the beginning of the second day, banks have no reserves left. Banks must therefore first borrow reserves from the Riksbank to buy e-krona.⁶ The Riksbank offers intraday credit to facilitate payments, so banks can use this facility to obtain reserves and buy e-krona to manage the outflow. However, the intraday credit must be paid back before the day ends. Therefore, banks also need an overnight loan from the Riksbank to be able to pay back their intraday credit. The Riksbank can use its regular monetary policy lending or any other facility to make the loan to banks. Irrespective of the facility, the Riksbank's lending will always be conducted against eligible collateral meaning that banks must encumber approximately 450 billion⁷ of their liquidity portfolio to manage the second outflow (see Table 4).

Unlike the first day, the second day leaves the size of banks' balance sheets constant, while the Riksbank's balance sheet increases. Despite the constant size of banks' balance sheets, the outflow leads to changes in banks' asset and funding structure. On the asset side, some liquid securities become encumbered. On the liability side, retail deposits go down while borrowing from the central bank goes up.

The hypothetical scenario considered above leads to the following three general conclusions (see Figure 1 for a schematic view).

First, the outflow of retail deposits into e-krona reduces banks' liquidity portfolio. Banks' unencumbered liquidity portfolio goes down since they must either use their existing reserves or borrow new reserves by encumbering their securities to buy e-krona from the Riksbank. While the reduced amount of retail deposits also diminishes the need for banks' liquidity portfolio going forward, banks' liquidity situation can be said to have worsened after the outflow.⁸

⁶ Interbank borrowing or any other transaction between banks such as the sale of assets does not help here since there is an aggregate shortage of reserves in the banking sector.

⁷ Since the Riksbank also applies haircuts to different securities taken as collateral, banks need to pledge a bit more than 450 billion.

⁸ This effect is quantified in the next section.

Table 4. Changes in the balance sheets of Swedish banks and the Riksbank after the second outflow of	
450 billion in retail deposits into e-krona	

SEK billion	
-------------	--

Panel A. Swedish banks					
Assets		Liabilities			
Reserves at the Riksbank	0	Short-term issuance	1 300		
Other liquid assets	3 100	Other short-term liabilities	2 250		
of which pledged to the Riksbank	450	Borrowing from the central bank	450		
Lending to the real sector	6 100	Retail deposits	1 900		
		Long-term issuance	3 300		
Total	9 200	Total	9 200		

Panel B. The Riksbank					
Assets		Liabilities			
Lending to the banks	450	Reserves to the banks	0		
Securities	370	E-krona to the real sector	900		
Foreign reserve, gold, other	530	Cash, other liabilities	450		
Total	1 350	Total	1 350		

Note. Securities that are pledged stay on banks' balance sheets.

Secondly, if the demand for e-krona is larger than banks' initial holdings of central bank reserves, the outflow also means that the central bank has to create new reserves, for instance, by granting new loans to banks. For central banks, creating new reserves means increased balance sheets and for banks, it may mean increased usage of central bank funding.⁹

And finally, the outflow of retail deposits into e-krona has a negative impact on banks' funding stability, since a loss of retail deposits reduces the volume of stable funding available for banks. This means that there will be an imbalance between illiquid lending and stable funding.





Source: Author's own illustration

9 If reserves are created via buying assets, banks' use of central bank funding does not increase.

3.2 Potential measures to restore banks' liquidity and funding positions

Banks can take measures to restore their liquidity and funding positions after a deposit outflow into e-krona. These measures are needed to restore banks' resilience against future unexpected outflows.

Consider again banks' balance sheets before and after an outflow of retail deposits into e-krona (see Table 5). We define *liquidity* as a difference between unencumbered liquidity portfolio and the sum of short-term issuance and other short-term liabilities.¹⁰ The idea here is that short-term liabilities can generate an outflow that needs to be covered by the liquidity portfolio. According to this definition, banks' liquidity initially equals zero. Similarly, we define funding stability as the difference between real sector lending and the sum of retail deposits and long-term issuance. The idea here is that real sector lending is illiquid and needs to be funded with stable funding sources. According to this definition, banks' funding stability initially equals zero.

Due to the outflow, liquidity and funding stability both fall by 900 billion, the magnitude of the total outflow. Liquidity worsens since banks use their liquidity portfolio to satisfy depositors' demand for e-krona. Funding stability goes down since retail deposits, which are a stable source of funding, fall. The new levels of both measures are equal to -900 billion, respectively.

Banks can restore their funding and liquidity situation by issuing new long-term funding. The issuance of new long-term funding means that banks roll-over their maturing short-term liabilities, such as deposits from asset managers, into new long-term market funding (see Panel C in Table 5 for balance sheet and Figure 2 for an illustration). By rolling over 900 billion in short-term liabilities into long-term market funding, banks restore both their liquidity and funding stability. Liquidity is restored since a reduction in liquidity portfolio due to an outflow of deposits into e-krona is compensated by a fall in short-term liabilities. Funding stability is restored since a loss of stable funding from an outflow of retail deposits is compensated by an increase in long-term market funding.



Figure 2. A schematic illustration of the outflow of retail deposits into e-krona with banks' measures to balance their funding

Source: Author's own illustration

¹⁰ We use a simplified version of Liquidity Coverage Ratio (LCR). We exclude retail deposits despite their short maturity as well as central bank borrowing. In practice, even these liabilities generate some outflow that may need to be covered by the liquidity portfolio. We also assume that the entire short-term issuance needs to be covered by the liquidity portfolio. In practice, only issuances that have remaining maturities below 30 days need to be covered by the liquidity portfolio. These simplifications make the analysis easier to follow, but do not affect the general conclusions of the analysis.

It is worthwhile to note that adjusting the liability side of banks is the only feasible strategy to restore *funding stability*. Banks could, of course, also cut their lending to the real sector. However, if they were to do this, the amount of retail deposits would also be affected.¹¹ Therefore, cutting lending would not lead to a better funding situation for the banking sector as a whole.

Table 5. The balance sheets of Swedish banks before and after the outflow of 900 billion in retail deposits into
e-krona when banks restore their liquidity and funding profiles
SEK billion

Panel A. Swedish banks' balance sheet before the outflow of 900 billion in retail deposits					
Assets		Liabilities			
Reserves at the Riksbank	450	Short-term issuance	1 300		
Other liquid assets	3 100	Other short-term liabilities	2 250		
Lending to the real sector	6 100	Retail deposits	2 800		
		Long-term issuance	3 300		
Total	9 650	Total	9 650		

Panel B. Swedish banks' balance sheet immediately after the outflow of 900 billion in retail deposits				
Assets		Liabilities		
Reserves at the Riksbank	0	Short-term issuance	1 300	
Other liquid assets	3 100	Other short-term liabilities	2 250	
of which pledged to the Riksbank	450	Borrowing from the central bank	450	
Lending to the real sector	6 100	Retail deposits	1 900	
		Long-term issuance	3 300	
Total	9 200	Total	9 200	

Panel C. Swedish banks' balance sheet after the outflow of retail deposits and banks' own compensatory measures				
Assets		Liabilities		
Reserves at the Riksbank	0	Short-term issuance	1 300	
Other liquid assets	3 100	Other short-term liabilities	1 350	
of which pledged to the Riksbank	450	Borrowing from the central bank	450	
Lending to the real sector	6 100	Retail deposits	1 900	
		Long-term issuance	4 200	
Total	9 200	Total	9 200	

The issuance of new market funding to compensate for a loss of liquidity and funding stability also leads to the question of which debt is exactly issued and who are the investors. The major Swedish banks issue their current long-term funding either in the form of covered bonds that are secured by some specific assets, such as retail mortgages, or in the form of senior unsecured bonds. Since deposit funding is unsecured, it is reasonable that the lost retail deposits are replaced by senior unsecured bonds. These bonds are predominantly issued to foreign investors in foreign currencies, such as EUR and USD. So, banks can choose either to issue in domestic or foreign currency.

¹¹ Whenever a loan is granted, new deposits are created. Whenever a loan is paid back, deposits are destroyed.

If bonds are issued in domestic currency, then the issuance means that domestic asset managers, such as pension and mutual funds, simply convert their existing short-term wholesale deposits into senior unsecured bonds denominated in domestic currency (see Figure 3).

If bonds are issued to foreign investors in foreign currency, then the issuance is more complicated since banks must hedge their resulting currency risk (see Figure 3). The new issuance of bonds in foreign currency would mean that banks first get an inflow of the foreign currency. This foreign currency would then be lent further via the so-called foreign currency swap market.¹² In the swap market, counterparties would first do a so-called spot transaction, exchanging currencies using the spot rate. At the time of the spot transaction, the counterparties would also agree on a forward rate that would be used when currencies are exchanged back at some pre-defined point in the future. The second part of the swap contract is needed to balance potential losses and profits that might stem from having assets and liabilities in different currencies.



Figure 3. A schematic illustration of the issuance of unsecured senior bonds in domestic and foreign currency

Note. The starting point here is the same as the end-point in Figure 1, but we have excluded central bank borrowing for simplification. Note that the forward contract would not be visible on the balance sheet, since it has a zero value at a time of origin. Source: Author's own illustration

A natural counterparty to banks on the swap market would be a domestic asset manager interested in investing in foreign assets without taking an exchange rate risk. The asset manager would then buy the foreign currency from banks via the swap market and use this to buy foreign assets. The asset manager would pay for the foreign currency with its existing wholesale deposits in the domestic currency. At the end of the contract, the counterparties would either reverse the flows using the predefined forward rate or simply settle their remaining obligations depending on the actual realization of the exchange rate.

We can conclude this section by commenting on the generality of the analysis. The Swedish banking sector already relies on short- and long-term market funding. But would the results carry through to another country where banks exclusively rely on deposit funding because there is no existing market for domestic bonds? Banks in these countries could issue bonds in foreign markets and hedge their resulting foreign currency risks. To hedge currency risks, someone has to be willing to take the other side of the trade. This could be an export or import firm, or any asset manager exposed to foreign assets. This suggests that the results are fairly general and not necessarily specific to the Swedish context.

12 For an in-depth analysis of the foreign currency funding by Swedish banks, see Eklund et al. (2012).

4 The demand for e-krona in normal times and effects on banks' funding cost and lending rates

So far, we have taken the size of deposit outflows into e-krona as given and studied the resulting changes in balance sheets of banks and the Riksbank. We have also shown how banks could restore their funding and liquidity profiles by issuing additional market funding. In this section, we discuss the demand for e-krona together with the impact on banks' funding cost and lending rates. Our focus here is on normal times, that is, times when there is no significant stress in the banking sector.

4.1 Quantifying the demand for e-krona in normal times

To be able to discuss the demand for e-krona, we need to be clear about the assumed features of an e-krona. In this article we assume the following:

- an e-krona is a direct claim against the Riksbank denominated in SEK;
- e-krona can be used to make real-time payments in 24/7;
- e-krona has its own independent payment platform;
- e-krona can be held for saving purposes;
- there are no restrictions on who can hold e-krona and on how much they can hold;
- interest rate treatment of e-krona is consistent with monetary policy implementation.

All these features mean that e-krona is a close substitute for retail deposits. Both retail deposits and e-krona offer a similar level of credit risk protection and immediate availability. Retail deposits typically come from households and small and medium-sized companies which means that they would be fully covered by the deposit insurance guarantee.¹³ There are also some real sector deposits, such as those from larger non-financial corporations, that are too large to be entirely covered by the deposit guarantee. However, the level of credit risk in these deposits can still be considered to be negligible in normal times since banks' creditworthiness is positively correlated with economic activity. Credit risk in these large deposits can also be mitigated by diversification and monitoring, that is, by spreading deposits across a number of different banks and tracking the creditworthiness of individual banks.

Due to small differences in credit risk between retail deposits and e-krona in normal times, it is the relative interest rate between the two that is an important driver behind the demand for e-krona in normal times. An e-krona will have an unattractive pricing in comparison to retail deposits for two reasons.

First, if an e-krona is to be consistent with the implementation of monetary policy, it must be consistent with the pricing of the deposit facility that is offered to monetary policy counterparties. In Sweden, the deposit facility is currently priced 75 basis points below the repo rate. This implies that an e-krona should be priced at least 75 basis points below the repo rate to avoid interference with the current stance of monetary policy.^{14/15}

Second, banks can adjust their deposit rates to retain retail deposits.¹⁶ Banks have strong economic incentives to increase deposit rates until the cost of deposits is equal to the cost of alternative funding in the form of long-term market funding. Historically, the cost of deposits

¹³ The current level of the deposit guarantee in Sweden is up to 950 000 SEK per client and bank, see the Swedish National Debt Office's website https://www.riksgalden.se/en/Deposit_insurance/About-deposit-insurance/.

¹⁴ Note that this can be achieved both with an interest-bearing and interest-free e-krona. If an e-krona is designed to be interestfree, then it will be the level of the repo rate that dictates the attractiveness of an e-krona. In normal times, the repo rate will be positive which means that an e-krona will have an interest rate that is below the repo rate. If an e-krona is actively priced as a spread to the repo rate, similarly to the Riksbank's deposit facility, then it is this spread that will make an e-krona less attractive in relation to the repo rate.

¹⁵ See also Nessén et al. (2018).

¹⁶ For a similar argument, see also Meaning et al. (2018).

has been under the repo rate, while the cost of long-term market funding has been over the repo rate (see Figure 4). This means that banks have room to adjust their deposit rates to make the interest on deposits higher than the interest on e-krona.

E-krona can be viewed as a deposit facility offered to the public by the Riksbank, similar to the current deposit facility offered to monetary policy counterparties. Actual use of the current deposit facility is rare and has historically taken place in significant volumes only in extreme cases of distress.¹⁷ This limited use is due to the unattractive pricing of the facility: in normal times, the existing market solutions offer better ways to deal with short-term liquid savings than using the safe deposit facility offered by the Riksbank. In the same way, since an e-krona would have an unattractive pricing vis-à-vis market solutions, its actual use could be expected to be limited in normal times.

E-krona can also be held for reasons that are not directly related to credit risk or return. For instance, there may be some groups that don't wish to use commercial banks. E-krona could offer these clients a solution, since e-krona could be used to carry out services that are currently available only via bank deposits. E-krona could also be held to improve resilience against technical risks. Having some liquidity in e-krona could increase technical resilience, since e-krona could be used as a back-up payment system in situations when other forms of payments do not work due to idiosyncratic shocks. In addition, e-krona could also be demanded for pure payment purposes.¹⁸ If an e-krona offered payment solutions that were easier and cheaper than existing market solutions, the demand for e-krona could also come from payments.

All the factors mentioned above could play some role in determining the demand for e-krona in normal times. To get some sense of the magnitudes involved, we have carried out a back-of-the-envelope calculation under the following assumptions:

- 10 per cent of non-guaranteed real sector deposits are substituted for e-krona to enhance risk-management and lower credit risks;
- 2 per cent of household deposits are substituted for e-krona to satisfy the demand from clients who wish to be bank-free;
- 10 per cent of all payments are carried out via an e-krona system.¹⁹

Under these assumptions and using 2017 data, the demand for e-krona would be up to 120 billion, which is less than 3 per cent of nominal GDP. This magnitude can be compared with the absolute demand for cash that peaked at about 100 billion and with the relative demand for cash that peaked at about 10 per cent of nominal GDP.

4.2 The effects of an e-krona on the cost of funding and lending rates

Banks' funding costs would be affected if banks met the demand for an e-krona by replacing cheap retail deposits with more expansive market funding. Their funding costs would also be affected if they increased deposit rates to disincentivize depositors to move their deposits into an e-krona. In this section, we quantify these effects on the cost of funding and discuss the implication for lending rates and macroeconomic activity.

4.2.1 The impact on the cost of funding when retail deposits are replaced by market funding As shown by Figure 4, the cost of deposit funding has been below the repo rate, aside from the most recent period with the negative repo rate, and the cost of relevant long-term market funding has been above the repo rate. The data also show that banks have not

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¹⁷ See data on the Riksbank's balance sheet.

¹⁸ See Segendorf (2018) for a discussion of the demand for e-krona from payments.

¹⁹ Segendorf (2018) finds that the transaction demand for e-krona would stay below 45 billion if e-krona has 10 per cent of the payment market.

fully passed on increases in the repo rate to their deposit rates. Instead, as the repo rate has increased, the so-called deposit margin, defined as the gap between the repo rate and the deposit rate, has tended to increase.²⁰ Even the cost of market funding has fluctuated significantly over time in relation to the repo rate. However, if one focuses on stable financial and economic times, the cost of market funding is rather stable in relation to the repo rate.

The historical cost of market funding and deposit rates suggests that an outflow of cheap retail deposits increases banks' funding costs if an outflow of retail deposits is compensated by an increased issuance of market funding. We can quantify this effect for different levels of repo rates. The assumptions we use are presented in Figure 5 and the total cost of funding with and without an outflow of deposits into an e-krona is presented in Figure 6.



Note. Relevant market funding refers to the cost of senior unsecured bonds with a two-year maturity and floating coupons. The cost is derived using the major Swedish banks' CDS spreads for unsecured debt issued in EUR, which is then swapped into SEK.

Sources: Bloomberg, Statistics Sweden and the author's calculations





Note. Based on historical data, we assume the following deposit margins: -50, 25, 50 and 75 basis points for the level of repo rate -50, 50, 150 and 250 basis points, respectively. The cost of market funding is taken to be 50 basis points above the repo rate, which is in line with the historical cost in recent non-stressed times. The current funding structure is based on data presented in Table 1: lending to the real sector is equal to 6 100 billion and is funded by retail deposits of 2 800 billion. Source: Author's own calculations

²⁰ For an in-depth description of deposit margins, see Gibas et al. (2015).

To begin with, note that the total cost of bank funding, measured as a spread over the repo rate, will fall as the repo rate increases (see blue or red bars in Figure 6). The magnitude of this fall depends on the share of deposits in banks' funding as well as on the assumed deposit margins for any given level of the repo rate. Under current funding structure, banks' funding costs would fall from 50 basis points above the repo rate to about 10 basis points below the repo rate if the repo rate increased from -50 to 250 basis points (see blue bars in Figure 6). An e-krona that leads to an outflow of deposits reduces the share of deposits in banks' funding structures. As a consequence, banks' cost of funding would still fall as the repo rate increases, but to a smaller extent (see the red bars in Figure 6). An exact increase in banks' funding costs due to e-krona depends on the level of the reporate at the time of an outflow. For every 100 billion of deposits that are converted into e-krona, banks' funding costs would increase between 0 to 2 basis points depending on the level of the reporate at the time of the outflow (see the difference between blue and red bars in Figure 6).



Note. The current funding structure is based on data presented in Table 1: lending to the real sector is equal to 6 100 billion and is funded by retail deposits of 2 800 billion and market funding of 3 300 billion. Source: Author's own calculations

The analysis above is conservative in the sense that it assumes that the historical deposit margins will be valid even going forward. This may be a rather strong assumption since competition for retail deposits is likely to intensify due to fintech. Specialized fintech companies can target retail deposits and help retail clients allocate deposits to those banks that offer the best rates. This is likely to limit banks' ability to have deposit rates that are significantly below the repo rate in the future. Lower deposit margins would reduce the impact of an e-krona on banks' funding costs since the difference between the cost of deposits and market funding would be lower.

4.2.2 Banks' incentives to retain their retail deposits

The analysis so far has quantified the effect of an e-krona on the cost of bank funding when an outflow of bank deposits into e-krona actually takes place and banks choose to issue market funding to restore their funding profile. But as argued before, an e-krona can also trigger a situation where banks increase their deposit rates to disincentivize the outflow of deposits into e-krona. If this were to happen, banks' cost of funding might be affected even if no outflows of retail deposits into e-krona actually took place.

The need to raise deposit rates is economically relevant in circumstances where the interest rate on e-krona would be high enough to act as a binding floor for deposit rates. Therefore, this effect depends on the exact pricing of e-krona as well as on deposit margins (see Figure 7).

To illustrate this, suppose the interest rate on e-krona was closely tied to the repo rate, say 25 basis points below. In this case, the interest rate on e-krona would act as a binding floor to deposit rates when the repo rate is larger than 50 basis points. For instance, at times when the repo rate is equal to 150 basis points, banks can no longer have their historical deposit margin equal to 50 basis points and pay 100 basis points for their deposits. Instead, banks must offer deposits rates that are at least equal to 125 basis points, the interest rate on e-krona.

As can be seen in Figure 7, the largest increase in deposit rates takes place when the repo rate is 250 basis points and the pricing of e-krona is 25 basis points below the repo rate. An e-krona would in this case lead to an increase of 50 basis points in deposit rates which translates into an increase of 22 basis points in total funding cost with the current funding structure.



Note. The same assumptions as in Figure 5: historical deposit margins are -50, 25, 50 and 75 basis points for the level of repo rate -50, 50, 150 and 250 basis points, respectively. Source: Author's own calculations

Finally, note that even this analysis is conservative in the sense that it uses banks' historical deposit margins as estimates for future deposit margins. However, as we argued before, specialized fintech firms can intensify competition for retail deposits and push deposit rates closer to the repo rate going forward. If this were to happen, then the exact pricing of e-krona would have little or no effect on banks' deposit rates.

4.3 The impact of the changed cost of funding on lending rates and macroeconomic activity

A potentially higher cost of funding due to an e-krona raises the issue of who bears it: would it be banks, in the form of lower profitability, or their customers? There are some good reasons to believe that the increased cost of funding due to a lower share of retail deposits will be at least partially absorbed by banks, and not entirely by the customers.

There are natural limits on how much banks can increase their lending rates to compensate for lost retail deposits. These limits are set by banks that use little or no deposit funding as well as other non-bank sources of funding that compete with deposit-taking banks. For instance, the corporate bond market as well as direct lending by institutional and retail investors can partially act as a substitute for bank lending to companies and

households. This type of non-bank lending has become increasingly important in Sweden, especially after the financial crisis.²¹

In addition, the cost of deposits is not in practice used to determine the internal cost of funding for different lending products; instead the benefits that are obtained from cheap retail deposits are typically allocated to business units that have collected these deposits.²² Even from a normative perspective, it is not clear why banks should lower their lending rates simply because they receive a subsidized source of funding; after all, lending rates should reflect riskiness of lending and not the cost of funding that is guaranteed by the deposit guarantee system.

Another important question is how potentially higher lending rates due to an e-krona would affect macroeconomic activity.²³ Recall that an e-krona may affect lending rates by increasing funding costs in relation to the reporate (see Figure 6). It is therefore possible to offset an increase in absolute lending rates via a more expansionary monetary policy, if deemed necessary. An e-krona may also have a positive effect on long-term economic growth. An outflow of retail deposits into an e-krona reduces the use of guaranteed funding in banking. In this way, an e-krona contributes to lower distortions created by these guarantees, facilitating a more sustainable long-term growth (see also Section 6).

5 The demand for e-krona in times of distress

One of the main arguments against the introduction of an e-krona is that it could open up for large-scale runs on banks, especially at times when confidence in the banking sector falls.^{24,25} It is important, however, to understand that runs on banks can and do take place even in the current system without an e-krona. The relevant policy question is therefore how much additional stress an e-krona may cause and what tools and measures can be used to manage this additional stress.

5.1 Runs with and without an e-krona

5.1.1 Risk of bank runs in the current system

In the current system, a typical run manifests itself as creditors fleeing banks that are perceived risky. This can take a number of different forms, depending on the claim of the creditors and the asset that is used for a run:

- 1. Creditors, who fund banks via debt with some maturity, can run the bank by not rolling over their maturing debt claims. In practice, this means that the troubled bank needs to make a payment to the bank of these investors.
- 2. Creditors, who fund banks via demand deposits, can simply transfer their deposits from the troubled bank to another bank.
- 3. Creditors can also use their funds to buy existing safe assets, such as government bills.²⁶ In this case, the troubled bank has to make the payment to the bank of the seller of the asset.

²¹ See Juks (2015) and Sveriges Riksbank (2018).

²² See Cadamagnani et al. (2015).

²³ See also Armelius et al. (2018).

²⁴ See Carney (2018).

²⁵ Note that runs into e-krona could also take place for other reasons than a crisis of confidence in the Swedish bank sector. For instance, if an e-krona was seen as a global safe haven, then the demand for e-krona could increase in times when foreign banking sectors were deemed risky. Such a scenario is not necessarily harmful for Swedish banks since there is no crisis of confidence in them. Such a scenario could, however, have implications for the exchange rate, something that in turn has monetary policy implications

²⁶ This case would even include reverse repos and collateralized lending.

4. Creditors can also use their funds to take out cash or move their funds to tax accounts²⁷. In this case, the troubled bank has to make the payment to the Riksbank or to the National Debt Office²⁸.

All these cases, except the last one, illustrate that a run on a bank in the current system means that the troubled bank needs to make payments to some other bank(s). These payments would typically be made through the central bank payment system with the help of intraday credit. Since the troubled bank would have a massive need to make payments, the outflows from the account would be larger than inflows leaving the bank with a negative end-of-day balance vis-à-vis the central bank. In normal non-stressed times, this negative balance would be small and can be covered by borrowing from other banks that have experienced more inflows than outflows. However, in stressed situations, banks with positive end-of-day balances would prefer to place their surplus into central bank deposit facility instead of lending it to the troubled bank. Therefore, the troubled bank subject to a run would inevitably need to borrow from the central bank to deal with the situation.

An e-krona would not change the end situation for the bank experiencing a run. Instead, it would offer an additional way to run since creditors of the troubled bank could now run directly to the central bank. However, the amount of liquidity that the troubled bank would need to borrow from the central bank would be exactly the same irrespective of whether the run took place via e-krona or through the first three ways described above.

Cases 1 to 3 mentioned above describe so-called individual runs. These runs take place within the banking sector, creating negative and positive positions for individual banks, but for the banking sector as a whole, there is no outflow. An e-krona may however create a so-called aggregate run, that is, a situation where the banking sector as a whole experiences an outflow. Even though aggregate runs are rare, they can take place even in the current system without an e-krona, either via cash or tax accounts.

Creditors could take out their funds in the form of cash. A run to cash would constitute a run on the entire banking sector since the banking sector as a whole would need to borrow from the central bank to manage the situation. An aggregate run could also take place electronically via tax accounts. If creditors moved their funds to tax accounts, the National Debt Office would experience an inflow into its account at the central bank and the banking sector as a whole would have a negative balance at the central bank. In the end, either the National Debt Office or the central bank would need to take measures to manage this aggregate run.²⁹

In short, the current system without an e-krona is already exposed to the risk of both individual and aggregate runs. An e-krona would introduce an additional way to run the banking sector. Given that a run with a certain magnitude takes place, the consequences for the concerned banks are the same irrespective of whether the run takes place via moving funds to stronger banks, buying safe assets, taking out cash, using tax account or buying e-krona.

5.1.2 An e-krona and the size of runs

An e-krona may however put additional stress on the system by increasing the number of banks experiencing a run. This will happen if an e-krona has features that make it significantly more attractive in crisis times than existing assets used for runs.

²⁷ Large institutional creditors could also indirectly rely on the reverse repo facilities offered by the National Debt Office. Dealers with access to the facility could use it to obtain government securities that could be lent further to large investors via repo transactions. In the end, these measures would lead to inflows into the National Debt Office simply as tax accounts.
28 The payment will be first made to the bank that has an agreement with the Tax Agency. But later on, the funds would move

on to the National Debt Office. See Finansiella Sektorns Privat-Offentliga Samverkan (2015).

²⁹ The National Debt Office could choose to place its extra liquidity in the Riksbank, which means that the Riksbank would need to take measures to manage the banking sector's negative position. The National Debt Office could also take measures that result in liquidity flowing back to banks, for instance via collateralized lending. Irrespective of what happened, banks would need enough good-quality collateral to manage the situation.

Whenever a confidence crisis occurs, creditors compare relative merits of different alternatives. In a system without an e-krona, creditors would evaluate possibilities of moving funds to different banks, buying safe assets, moving funds to tax accounts or taking out cash. Creditors would then choose the best possible option and act on this. This activity would lead to price adjustments if the supply of best-run assets is limited. For instance, prices of safe assets such as government securities with short maturities would typically increase until a resulting fall in expected returns discouraged additional purchases. Prices would adjust until creditors became indifferent to either buying these safe assets or implementing the next best alternative. This next best alternative in the current system would be bank deposits in the most creditworthy banks or, in case of a total crisis of confidence in banking, tax accounts and cash. We consider these two cases below and discuss how an e-krona could change the existing tradeoffs.

An e-krona may be perceived to be more attractive than bank deposits at the most creditworthy banks. It is therefore possible that an e-krona could trigger a situation whereby an outflow from a few risky banks transcended into an aggregate run in which even depositors from the relatively safe banks found it optimal to run to e-krona. The stress would be magnified in this case since an otherwise individual run would turn into an aggregate run, increasing the amount of liquidity that central banks had to provide to the system due to an additional number of banks experiencing a run.

An e-krona may be perceived to be more attractive than having cash or moving funds to tax accounts. Creditors might then choose to run to e-krona even at times when they would not have run to cash or tax accounts. Such a situation would be relevant if creditors deemed the entire banking sector to be unreliable but, without an e-krona, would still keep these deposits due to disadvantages that cash and tax accounts have in comparison to bank deposits. Cash cannot be used for online payments and it also has a storage cost either in the form of an insurance fee or the risk of theft. Tax accounts, even though electronic, cannot be directly used for retail payments. Due to these costs, stress in the entire banking sector has to be large enough to incentivize creditors to change their deposits into cash or move them into tax accounts. An e-krona could change this balance if deemed more attractive than tax accounts or cash. An e-krona may therefore become a valuable alternative to bank deposits at times when the entire banking sector is deemed risky, increasing the amount of liquidity that central banks need to provide to the system at these times.

All in all, an e-krona could create additional stress in times of crisis since it may more easily turn a run within the banking sector into a run from the banking sector, magnifying the amount of liquidity assistance needed to manage the situation.

5.1.3 Recent evidence on aggregate runs

An important step in understanding the magnitude of run risk associated with an e-krona is to look into historical runs that are as close as possible to potential runs with an e-krona in place. In this respect, we can refer to the National Debt Office's role as a commercial bank during the crisis of 2008/2009. Deposit accounts offered by the National Debt Office were probably the best run assets available to the general public at that time. We can therefore use the size of deposit inflows to the National Debt Office during the crisis of 2008/2009 to estimate how large runs to e-krona could be. This specific run is suited to estimate a magnitude of a run risk with an e-krona at times when a crisis of confidence is concentrated to a limited number of banks and there being banks still perceived as safe.³⁰

Figure 8 shows that the National Debt Office experienced a sudden inflow of deposits during September and October 2008. The total amount of deposits increased by 17 billion, from 28 to 45 billion during this two-month period alone.



Figure 8. The deposit run from commercial banks to the National Debt Office around the time of the Lehman bankruptcy

According to unpublished data from the National Debt Office, 70 per cent of the inflow came from households and 30 per cent from companies. Roughly half of the inflow came from new clients with no previous accounts. The data also show that the inflow tended to come from banks that needed to use government guarantees for their borrowing.³¹

This limited historical evidence suggests that an e-krona could create aggregate runs. However, the run was rather limited in scope, amounting to less than 2 per cent of total bank deposits from the real sector. There are some reasons to believe that a run to e-krona would have been somewhat larger than the flows into the National Debt Office. One such reason is that it took up to two weeks before the deposits were actually moved to the National Debt Office. Another such reason is that there was a daily limit on how much could be transferred. This limit was 30 million per day. Finally, these deposits were treated as saving accounts and depositors could not use these funds to pay directly at retailers.

5.2 Actions that could be taken to mitigate the adverse impact of an e-krona on banks in stressed times

Previously we argued that an e-krona may increase the magnitude of runs if it were perceived to be more attractive than existing run assets. It is therefore important to discuss what tools and measures could be used to control or manage this additional stress.

To start with, it is important to note that the Riksbank already has some standard tools in place to deal with individual and aggregate bank runs. The Riksbank can provide loans, either via its monetary policy tools or extraordinary measures such as those undertaken in 2008/2009.³² Due to its ability to create money, the Riksbank has no limits on how much credit it can grant. However, the volume of credit that can be offered by the Riksbank is limited in practice by the amount of suitable collateral that its counterparties have and the Riksbank's willingness to take financial risks.

5.2.1 Adjusting the current liquidity and funding regulations

The current liquidity³³ and funding regulations are based on the assumption that retail deposits, despite their short maturity, are relatively sticky: a rather moderate share of deposits is assumed to run away in a potential crisis. In practice, this means that banks need to hold a relatively modest amount of liquid assets against these deposits. The introduction of an e-krona may, however, change the presumed stickiness of these deposits in a crisis

³¹ For the list of banks that needed guarantees, see Swedish National Debt Office (2014).

³² See Elmér et al. (2012) and Sellin (2009).

³³ LCR requires banks to have enough liquidity assets to be able to meet the net outflow over the 30-day stress period.

since an e-krona may become a valuable alternative to bank deposits during stressed times. It may therefore be reasonable to adjust the current regulation so that banks have enough collateral to cover potential outflows of retail deposits into an e-krona in times of distress.³⁴

5.2.2 Actively managing the demand for e-krona

The central bank could also take active steps to adjust the attractiveness of an e-krona. One way to do this is to introduce time-varying pricing of an e-krona and in this way control its demand. An e-krona could be priced as a spread to the repo rate (for example, repo – x, where x > 0), where the size of the spread is time-varying. The spread could be decreased if the demand for e-krona needs stimulation and it could be increased if the demand for e-krona needs to be cooled off.

Active pricing would allow the central bank to introduce costs into owning e-krona, similar to the costs present for existing run assets such as cash and tax accounts.

5.2.3 Issuing e-krona against a specific asset class

Another way to reduce the adverse impact of an e-krona on banks in stressed times is by changing the supply mechanism of an e-krona. So far, we have assumed that only bank depositors could buy e-krona from their banks that in turn would buy e-krona from the Riksbank using reserves. An alternative supply mechanism would be to issue e-krona directly to the public against a specific non-bank asset class.³⁵ In practice, this would involve the Riksbank buying specific assets and paying the sellers in e-krona.

Such a supply of e-krona would not affect the total amount of deposits available to banks. Bank depositors, like any other investors, could still buy e-krona, but first they would need to purchase these specific assets. When depositors bought these assets from other agents, the total amount of deposits in the banking sector would not change since the seller of an asset would be paid with bank deposits.

Such a supply method would also mean that the central bank could create e-krona without being restricted to the availability of collateral owned by banks. An additional advantage is that such a supply method would not affect the amount of reserves available to banks.

A special case of this alternative supply mechanism is when e-krona is issued without buying an asset. The Riksbank could issue e-krona by directly debiting the e-krona accounts of either the private sector or the government without obtaining any asset in return. Such a supply mechanism would be especially useful in circumstances when e-krona is designed to have a zero interest rate and when central bank reserves and e-krona are treated as separate claims, without possibility of conversion between the two. In this case, e-krona would not incur any interest cost nor would it generate financial returns to the central bank.³⁶

6 The broader aspects of an e-krona on financial stability

An e-krona would change the current financial system in a number of important ways. It would represent a new payment system in which the general public could access electronic central bank money and make payments with it. An e-krona could also mean that bank lending would be more dependent on central bank funding and collateral policy, that banks may have less retail deposits and that they may need to issue more long-term market funding to maintain their funding stability.

³⁴ There may also be other reasons to reconsider the stickiness of retail deposits, such as a move towards real-time payments and the increasing role of different fintech players on the payment market.

³⁵ See also Kumhof and Noone (2018).

³⁶ This is similar to the proposals of 'sovereign money', or 'positive money', see for example Jackson and Dyson (2013).

These important changes lead to three fundamental questions:

- Is it desirable to create a new payment system in which the general public could directly access electronic central bank money and make payments with it?
- Is it desirable that commercial bank lending may become more dependent on central bank funding and collateral policy?
- Is it desirable that banks fund themselves less with retail deposits and more with long-term market funding?

The introduction of an e-krona as a means of payment and a new payment infrastructure can benefit the real sector and make the economy more resilient both to economic and technological disturbance. An e-krona as a means of payment could make the economy more resilient to economic shocks since an e-krona would maintain a stable value even in stressed times. An e-krona would maintain a stable nominal value in stressed times since it would be a direct claim against the central bank and therefore would not be exposed to credit risk. This means that an e-krona would be different from bank deposits, especially those not covered by the deposit guarantee. An e-krona would also provide a stable real value since the mandate of the central bank is to maintain price stability. This means that an e-krona would also be different from so-called cryptocurrencies that typically experience large price fluctuations in nominal and real terms. An e-krona as a payment infrastructure could also increase technological resilience since it could act as a redundant payment system in times when other electronic payments did not work. This would require an e-krona system to be based on an independent payment platform, and there should also be some amount of e-krona circulating in the system prior to a shock.

An e-krona may increase banks' reliance on central bank funding and its collateral policy.^{37,38} To accommodate the outflow of bank deposits into e-krona, central banks may need to create new reserves that could be used to buy e-krona. Central banks could create new reserves either by lending to banks or buying assets. These activities mean that central banks would be more exposed to financial risks, implying that central banks' risk management would become more important. In addition, these activities would also increase central banks' direct involvement in financial markets even in normal times. This increased involvement would create an opportunity for central banks, for instance, via an increased control over bank lending through collateral policy, but it would also increase the risk of undesired effects, for instance, due to unwanted price effects after asset purchases.

An e-krona may reduce the use of retail deposits as a stable funding source for banks. The reduced use of retail deposits in banking could enhance financial stability since these deposits are typically guaranteed and guarantees inevitably create distortions. Since guaranteed depositors do not bear the potential cost of bank failures, the cost of funding that these depositors provide would not be risk-sensitive. Therefore, guaranteed deposits would create incentives for banks to take higher risks than would be the case otherwise.³⁹ Another undesired effect of guaranteed deposits is that bank lending and other banking services have an unfair competitive advantage over alternative sources of funding and services, making the banking sector larger than it would otherwise be.

³⁷ This and the next point are mostly relevant when e-krona is issued in the same way as cash is, see also Section 5.2.3.
38 E-krona can be viewed as a special reserve requirement for banks. In the current system, bank lending requires an inherently small amount of own funds and liquid assets. The reason is that banks create their own funding, in the form of deposits, whenever a new bank loan is issued. Individual banks must still manage their liquidity situation whenever these new deposits are used and potentially moved to another bank. However, in normal times, the net flows among banks tend to be rather small and can be managed via interbank markets and a small amount of liquid assets. So the current supply of bank lending has relatively few inherent constraints and is ultimately determined by the demand and the interest rates set by central banks. E-krona could potentially change banks' current ability to create their own funding since newly created deposits might be converted into e-krona. This means that banks would need more central-bank-eligible collateral to deal with a potential outflow of deposits into e-krona, essentially constituting an implicit reserve requirement.

³⁹ For the empirical evidence, see, for instance, loannidou et al. (2010).

The decreased usage of retail deposits may also imply the increased issuance of market funding. It is sometimes argued that the increased reliance on market funding increases funding risks for banks.⁴⁰ This does not, however, have to be the case since market funding can be issued with long enough maturities so that the funding stability from market funding is similar to funding stability obtained from retail deposits.

7 Conclusions

The introduction of a central bank digital currency (CBDC) is often perceived to have farreaching implications for banks with adverse effects on financial and macroeconomic stability. How would banks fund their lending if deposits were converted into CBDC? What would CBDC mean for bank lending rates? And would not CBDC open up for large-scale bank runs? These are frequently asked questions in the context of CBDC.

To find answers to these questions, we study the effects of CBDC on banks in the Swedish context. We find that in normal non-stressed times, the magnitude of a potential outflow of retail deposits into e-krona would be low. An indicative calculation shows that the demand would be around 120 billion or below 3 per cent of nominal GDP under plausible assumptions. One reason for this low demand is that banks could disincentivize a potential outflow of retail deposits into CBDC by adjusting their deposit rates. Since deposit rates are typically under the repo rate, while the cost of alternative market funding is above the repo rate, banks have strong incentives to adjust their deposit rates if necessary to manage a potential outflow. We estimate that the impact of an e-krona on banks' funding cost via increased deposit rates would be up to 22 basis points.

Banks could manage an outflow of retail deposits into e-krona by using their existing central bank reserves or by borrowing new reserves from the central bank. Banks could also issue more long-term market funding to compensate for a loss of funding stability resulting from an outflow of retail deposits. Using the historical costs of deposits and relevant market funding, we show that the banks' funding cost would increase approximately 2 basis points for every 100 billion of additional market funding issued after an outflow of retail deposits.

The total increase in banks' funding cost due to e-krona is estimated to be up to 25 basis points. The macroeconomic impact that may result from this increased funding cost is deemed to be limited since non-bank funding sources would limit banks' pass-through of this increased cost to their lending rates and a potential increase in lending rates could be offset by a more expansionary monetary policy.

In stressed times, the demand for e-krona as a safe medium of exchange and storage may increase drastically, especially if existing alternatives become risky or unavailable. We explore various run mechanisms in the current system and compare them with an e-krona. We find that an e-krona would not add additional stress under a given magnitude of run. We do, however, find that individual runs may more easily transform into aggregate runs if an e-krona were to have more attractive features than those of existing run assets. This additional stress can, however, be managed by an appropriate design of an e-krona, for instance, by letting its pricing be time-varying or supplying e-krona directly to the public against specific assets.

In short, we do not find any decisive argument against the issuance of an e-krona. We do, however, see significant benefits that an e-krona could bring to the real sector in the form of economic and technological resilience. An e-krona has the potential to make the real economy more resilient to economic and technological shocks since an e-krona would facilitate continued access to a safe, generally accepted means of payments even when other means of payments became either economically or technologically unreliable.

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