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

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

1 Introduction

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

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

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

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

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

2 Reasons for introducing an e-krona and policy objectives

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

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

Risk-free money to the public, accessible to all

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

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

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

Enhanced competition

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

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

Resilience and crisis preparedness

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

Privacy and personal integrity

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

Efficient cross-border payments

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

3 Some models for an e-krona

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

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

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

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

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

## 3.1 Centralized e-krona provision without intermediaries

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

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

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

Figure 1. Centralized solution without intermediaries
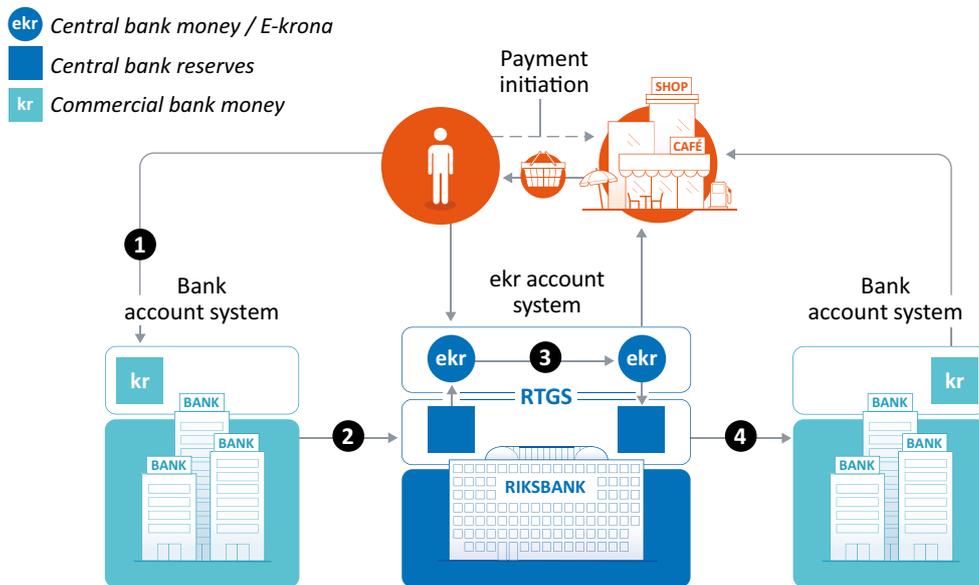
Source: The Riksbank

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

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

3.2 Centralized model with intermediaries

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

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

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

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

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

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

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

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

7   Under the assumption that the PSP has required authorization according to Swedish implementation of PSD2.

Figure 2. Schematic view of the centralized model with intermediaries
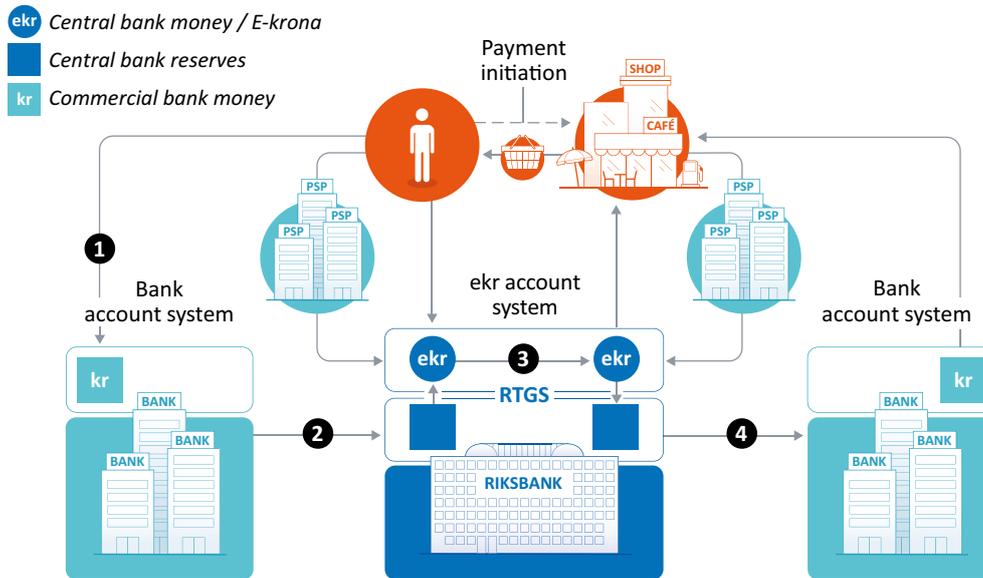
Source: The Riksbank

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

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

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

BOX   Token- vs account-based models

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

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

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

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

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

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

3.3 Decentralized solutions with intermediaries

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

Figure 3. Flow of e-kronor in a decentralized ledger system
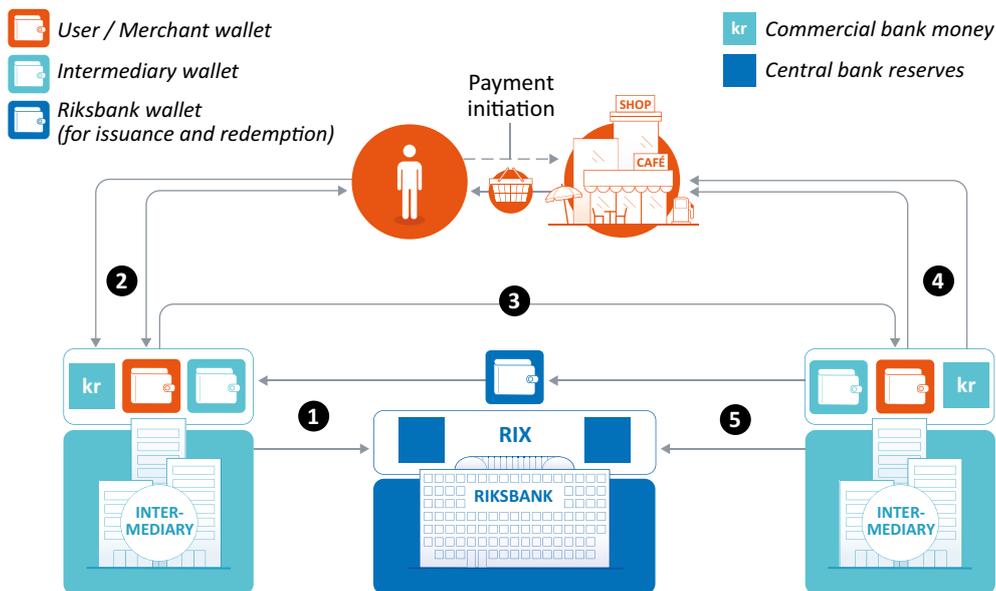
Source: The Riksbank

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

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

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

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

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

- <u>Licensed proprietary technology</u> requires intermediaries to acquire and run a specific software solution. Requires license fees and builds on specific technology. A potential weakness is vendor lock-in. An example of licensed technology is the operating system Windows from Microsoft.

- <u>Specific open source technology</u> requires intermediaries to run the solution provided by the designated open source community for the specific solution. A potential weakness is the risk of the community being abandoned or the build-up of dependence on open source consultants. The code is public and requires no license fees. An example of open source in operating systems is Linux.

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

3.4 Synthetic e-krona

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

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

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

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

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

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

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

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

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

Figure 4. Synthetic e-krona
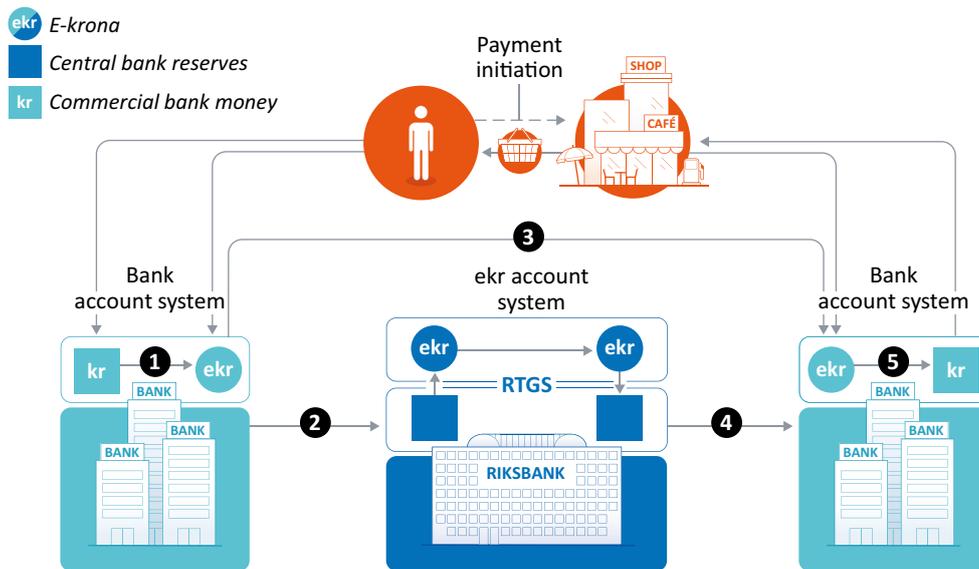
Source: The Riksbank

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

4 Concluding evaluation and trade-offs

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5 Economic design issues

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

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

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

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

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

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

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

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

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

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

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

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

6 Conclusions

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

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

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

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

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

References

Adrian, Tobias and Tommaso Mancini-Griffoli (2019), 'The Rise of Digital Money', Fintech Notes no. 19/01, IMF.

Armelius, Hanna, Paola Boel, Carl Andreas Claussen and Marianne Nessén (2018), 'The e-krona and the macro economy', *Sveriges Riksbank Economic Review*, no. 3, pp. 43-62.

Armelius, Hanna, Carl Andreas Claussen and Scott Hendry (2020), 'Is central bank currency fundamental to the monetary system?,' *Sveriges Riksbank Economic Review*, no. 2, pp. 19–32.

Armelius, Hanna, Gabriela Guibourg, Andrew T. Levin and Gabriel Söderberg (2020), 'The rationale for issuing e-krona in the digital era', *Sveriges Riksbank Economic Review,* no. 2, pp. 6–18.

Auer, Raphael and Rainer Boehme (2020), 'The technology of retail central bank digital currency', BIS Quarterly Review, March, pp. 85-100.

Bank of England (2020), 'Central Bank Digital Currency: opportunities, challenges, and design', Discussion Paper, March.

Bank for International Settlements (2019), 'Proceeding with caution – a survey on central bank digital currency', BIS Papers, no. 101, Bank for International Settlements.

Bergman, Mats (2020), 'Competition aspects of the e-krona', *Sveriges Riksbank Economic Review*, no. 2, pp. 33–54.

FSB (2020), 'Enhancing Cross-border Payments – Stage 1 report to the G20', Financial Stability Board report, April.

Kumhof, Michael and Clare Noone (2018), 'Central bank digital currencies - design principles and balance sheet implications', Bank of England Staff WP no. 725.

Sveriges Riksbank (2017), 'The Sveriges Riksbank's e-krona project: Report 1', September.

Sveriges Riksbank (2018), 'The Sveriges Riksbank's e-krona project: Report 2', October.

Tobin, James (2008), 'Money' in *The New Palgrave Dictionary of Economics*, edited by Steven N. Durlauf and Blume Lawrence, Palgrave Macmillan, London.