DISCUSSION PAPER

Digital cash, the conduct of monetary policy and the monetary transmission mechanism

By

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Abstract

More and more central banks around the world are seriously considering introducing so-called Central Bank Digital Currencies (CBDC).

In this paper we discuss the implications of introducing digital cash for the conduct of monetary policy and the monetary transmission mechanism.

It is concluded that the introduction of digital cash will not necessitate a fundamental change in monetary policy operations, but it might nonetheless open the door for policy innovations.

The introduction of digital cash will, however, impact – potentially significantly – the size of the money multiplier and might increase the effective lower bound on interest rates. Both factors will cause an initial tightening of monetary conditions.

However, such tightening can and should be offset by a strict commitment to monetary policy rules and through measures to ease legal requirements for liquidity, capital and reserves.

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What is digital cash?

Since the introduction of bitcoin in 2009, global interest in so-called cryptocurrencies has exploded. Cryptocurrencies can generally be defined as privately issued digital currencies or, more broadly speaking, digital assets.

Most of this fascination with cryptocurrencies has been driven by an interest in high-risk investing in them, and while trading volumes have exploded surged since 2009, we haven't seen anything close to a commensurate increase in the actual usage of cryptocurrencies as a means of payment or unit of account.

To be sure, it certainly cannot be ruled out that privately issued digital cryptocurrencies may someday function, at least on a limited basis, on equal footing with traditional currencies issued by the world's central banks.

However, the truth is that in terms of their importance to the broader economy and the financial markets (and not least to the banks), privately issued cryptocurrencies are not the ones to keep an eye on. At least for the near term, what matters are the digital currencies being issued by central banks around the world.

Central banks have opened their eyes to digital currencies

In high-income countries, the outstanding money supply in the economy consists not only of physical banknotes and coins, but also of our bank deposits. In that sense, it can be said that the bulk of the money supply today is already digital.

A digital currency, on the other hand, is not currency deposited in a bank. Instead, it is more comparable to cash.

A key characteristic of cash is that, since it is not 'lent' to the bank, its owner does not get any return from holding it physically in a wallet or under the mattress. (Savers in countries like Denmark have it even worse, since they must actually pay for banks to accept their deposits).

Bitcoin may be the most talked-about digital currency, but it is not the most interesting.

Increasingly, the world's central banks have shown interest in issuing digital 'cash'. Since 2020, several have issued reports on the introduction of what has come to be known as Central Bank Digital Currency (CBDC)[2].

Some monetary authorities, ranging from China to the Bahamas, even have specific plans to introduce CBDCs in the near future[3].

This paper proposes to discuss theoretically the implications of introducing a CBDC – or what we will for simplicity's sake refer to here as an e-krona (based on the term used by the Swedish central bank) – for the conduct of monetary policy and the so-called monetary transmission mechanism.

Hence, the purpose of this paper is not to discuss the technology behind an e-krona or other issues such a privacy and money laundering.

Instead, one can say its aim is to discuss a digital currency's purely monetary elements in terms of policy and transmission.

What an e-krona could look like

Based on analysis and research already carried out by central banks around the world, it is possible to describe how a digital currency, the e-krona, issued by a central bank such as the Swedish Riksbank would function.

An obvious point is that the e-krona would have the same value as an 'ordinary' krona and could be exchanged one for one. It would also have the character of digital 'cash', in the sense that there would be no requirement for an e-krona ban deposit; instead, users would keep it in a

[2] See for example Riksbanken (2021) and Bank of England (2021).
[3] See People's Bank of China (2021) and Central Bank of the Bahamas (2021).

special e-wallet, where it would not earn interest or be lent out or invested. In that sense, money in a e-wallet is 'fully backed', making the e-krona comparable to physical cash.

Since bank deposits may be withdrawn and exchanged for e-krona, it is obvious many households and companies will certainly do so – if only to save fees or even negative interest rates – placing them in their e-wallets instead.

While this would certainly put pressure on the prevalent business model in commercial banking, it would also create a very cheap option for households and business to store value and make payments.

This seemingly natural consequence of technological development will clearly have potentially large consequences for financial stability and financial regulation. As a result, we can expect central banks to be vigilant and move very cautiously.

Even so, judging from the messages we have already received from the Bank of England and the Riksbank, among others, it will only be a matter of time before we begin talking about the e-pound and e-krona.

Monetary operations with digital cash

The fundamental task of central banks is to provide the means of payment, but in the process also to ensure that the value of that means of payment remains stable (for example, by avoiding excessive inflation). Central banks do that by controlling the size of the money base.

The monetary base (often termed M0) is the total amount of a currency that is either in general circulation in the hands of the public and or in deposits held by commercial banks in the central bank's reserves[4].

[4] For more on monetary policy operations see, for example, Jane Ihrig, Ellen E. Meade and Gretchen C. Weinbach (2015).

Central banks can increase or decrease the amount of base money by buying or selling financial assets (typically, government bonds) or by conducting so-called open market operations in the money market.

This effectively is what happens when we refer to central banks 'printing money'. In principle, there is no limit to how much base money a central bank can produce. In practice, however, the amount is limited by the central bank's monetary targets.

Furthermore, money can be produced 'on demand' when citizens, companies or investors – either foreign or domestic – buy domestic currency (for example, when they exchange foreign currencies). For example, the Swedish Riksbank will supply krona in return for US dollars at the market rate if so demanded.

In this sense, it would make no difference for monetary policy whether the Riksbank issues krona or e-krona. It could do so as much as it wants by offering to buy, for example, e-krona in return for Swedish government bonds.

Obviously, this transaction would require that the buyer of e-krona to have an e-wallet in which to 'deposit' them. This, however, is a purely technical (and perhaps also regulatory) rather than a monetary question.

In terms of the actual conduct of monetary policy, the introduction of an e-krona would not change much for most modern central banks.

However, it nonetheless raises interesting questions about who should have access to e-krona. For example, it might become an issue whether foreign citizens or companies should be allowed to hold this central bank digital currency.

From a monetary perspective, it would obvious be desirable to ensure that characteristics of CBDCs be as similar as possible to currencies in other forms – whether bank deposits or physical cash.

The reason for this is that if there is a difference in the quality – if, for example, a foreigner were allowed to hold the currency in physical cash but not its digital version in an e-wallet, then this discrepancy could well create a smaller or larger difference in the value of e-krona and physical krona, with obvious monetary implications, as it would impact the relative demand for e-krona versus physical krona.

Helicopter money and digital cash – it's mostly about fiscal policy

Sometimes it has been suggested that the introduction of an e-krona would make it easier to conduct monetary policy and particularly to implement monetary easing through what Milton Friedman termed a *'helicopter drop'.*

Friedman describes a helicopter drop in the following way:

> *Let us suppose now that one day a helicopter flies over this community and drops an additional $1,000 in bills from the sky, which is, of course, hastily collected by members of the community. Let us suppose further that everyone is convinced that this is a unique event which will never be repeated.*

It is easy to see that some could think of this in relation to an e-krona and some proponents have argued that this would be an advantage of central bank issued digital currencies.

For example, World Bank economists Biagio Bossone and Harish Natarajan (2021) write:

> *Evoking Milton Friedman's incisive image of 'helicopter money', CBDC could be used during crises as way to deliver stimulus packages to households and businesses. This would be especially useful when businesses are at risk of closing because they run out of money, or if people lose jobs, or become ill, and also run out of money.*

Note here that the authors focus on the practicalities of transferring money to households rather than the purely monetary effects of the operation.

The use of e-krona for stimulus would obviously be advantageous in economies with weak and underdeveloped banking sectors and payment systems – primarily, low-income countries.

However, if we compare this situation to that of a high-income economy with a well-developed banking sector and advanced payment technology, there would be little difference between making the stimulus payment directly to an e-wallet or a more traditional bank account. For the recipient, there would essentially be no difference.

An e-krona would thus not really make it easier to make a 'helicopter drop' in developed economies, as the authors acknowledge in the following passage:

> *An example is the recent proposal for a US House emergency Covid-19 stimulus bill, which referred to creating a 'digital dollar' to get stimulus payments to unbanked Americans. In practice, the US Treasury would make payments through direct deposits to recipient accounts (FedAccounts) held at Federal Reserve Banks (FRBs) or FRB-member banks through pass-through FedAccounts.*

This is an important example, as it illustrates how a helicopter drop would happen in practice.

And on close examination, the US Covid-19 stimulus bill was a fiscal rather than a monetary operation. The US government transferred money directly to citizens' bank accounts.

This same operation could easily be done with an e-krona. The government would go out and buy a certain amount of CBDCs in the open market and place the money in its own e-wallet, then make a direct transfer to the e-wallets of individual citizens.

Since this is a fiscal rather than a monetary operation, it differs little from any other routine social transfer, such as government payments of unemployment benefits or pensions.

This aspect of the 'digital-helicopter drop' is purely a *payment* issue. Governments can transfer funds to their citizens in different ways – for example, via bank transfers, physical handovers

of cash, by depositing e-krona in an e-wallet, or by providing goods or something tradeable for goods as in the US food stamp programme.

However, none of this is monetary policy, with the payment method being the only difference from an ordinary fiscal transfer.

What makes a direct cash transfer – either a bank deposit or an e-krona – monetary is how it is financed. If the government funds the transfer by issuing bonds which the central bank buys, then we have a parallel monetary operation where the money base is expanded.

Even so, there is no difference between this and any other situation where the central bank for whatever reason decides to expand the money base – actively, through so-called quantitative easing, or simply because the demand for money has gone up.

Nevertheless, we can imagine a situation in which fiscal and monetary operations are coordinated, and here the e-krona places a crucial role. This is our next topic for discussion.

A hypothetical e-krona-based monetary policy rule

Let us assume that the central bank's target is to stabilise real output growth in the economy while at the same keeping inflation close to an inflation target, say, of 2 percent.

This would be a Taylor rule-style monetary policy target (Taylor 1993) or what Robert Hetzel has termed a *Lean-Against-the Wind* policy (LAW rule)

Normally, central banks such as Sweden's Riksbank or the Federal Reserve follow (or try to follow) such types of monetary policy.

Targets are normally implemented by the central bank 'setting' a key policy rate and/or by conducting monetary operations to increase or decrease the money base.

These operations are traditionally executed through the banking system and the financial markets; however, there is nothing to prevent central banks from conducting them through other channel.

Hypothetically, one could imagine a central bank offering on a daily basis to buy used cars at a fixed price in the open market for used cars, changing the price to ease or tighten monetary conditions as needed.

Similarly, the central bank could purchase or sell e-krona, determining the amount bought or sold by a pre-determined monetary rule – which we will call here an eLAW-rule.

This policy would be implemented in close cooperation with the government.

Imagine the following steps:

First, the central bank would assess whether monetary policy should be eased, tightened or kept unchanged. This would be based on a pre-determined and known rule.

This eLAW-rule could take the following form:

$$c^d_t = c^* - \alpha \bullet (y_t - y^P) - \beta \bullet (p_t - p^T)$$

Where c^d_t is the annual growth rate of the supply of e-krona (digital cash) at time *t*.

y_t is the level of economic activity (real GDP) at time *t* and p_t is the actual (or expected) level of inflation at time *t*. α and β are coefficients larger than zero (e.g., 0.5).

y^P is the potential or structural level of real GDP, while p^T is the inflation target (e.g., 2 percent). Hence, $(y_t - y^P)$ is a measure of the output gap. Both y_t and y^P are natural logarithms.

c^* is the growth rate in the supply of e-krona when the output gap is closed and inflation is at its target level.

c^* could, for example, be 4 or 5 percent – an approximation of the average annual growth rate of nominal GDP in the US and the euro zone since the mid-1990s.

It follows from this rule that the central bank automatically will increase (slow) the growth rate (above c^*) when the economy slows (accelerates) and inflation is below (above) target.

There is little difference between this and other types of monetary policy rules. The main difference is in the rule's implementation through the issuance of e-krona.

This brings us to the *second step* in the implementation of the rule – the fiscal part.

Imagine that the central bank each month determines how much the e-krona supply should grow during the next month.

That amount (c^d_t) is calculated based on the rule above.

To get the e-krona into circulation, the government would issue bonds precisely equal to c^d_t. There would need to be a clear rule for how to conduct this monetary-fiscal coordination.

The central bank would then buy these government bonds for c^d_t, transferring the e-krona to the government's e-wallet.

The third step would be for the government to transfer the e-krona into each citizen's e-wallet.

This would mean that the growth rate of e-krona in each citizen's e-wallet would grow at a rate similar to the aggregate growth rate of e-krona in the economy determined by the rule.

This would be an *automatic and rule-based digital helicopter drop.*

Obviously, such a policy could also be implemented without the use of digital cash through a fiscal transfer from the government to citizens' bank accounts. Nonetheless, the introduction of

an e-krona might make it easier to implement in practical terms and would not require involvement of the traditional banking sector or the financial markets, which could be an important consideration[5].

This eLaw rule could be completely automatic, allowing the central bank to keep conducting monetary policy in the traditional way 'on top' of it. In this sense, the rule should be seen as a monetary version of the traditional automatic fiscal stabiliser.

While this example shows how a policy rule could be implemented using e-krona, it should again be stressed that there is a difference between the e-krona as a payment method and a given monetary policy rule.

As a payment method, an e-krona does not fundamentally change the central bank's monetary set-up or operations. It could be used in this way even as it is being deployed to implement a given monetary policy rule.

The money-multiplier with digital cash

The most direct impact on monetary conditions and the general monetary transmission mechanism would be through the so-called money multiplier.

Below, we discuss the money multiplier by incorporating digital cash into the general monetary supply[6].

Money created by a central bank is called the *money base* or *high-powered money*.

Commercial banks loan or invest their excess reserves to earn an additional return or interest.

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[5] An argument for 'circumventing' the banking sector when easing monetary policy would be to avoid potential moral hazard issues. If monetary transmission has broken down due to a banking crisis, there might also be arguments for injecting money directly into the economy to avoid the risk of it getting 'stuck' in the banking sector.

[6] This discussion of the money multiplier will use the standard formulation found in most elementary monetary policy textbooks such as Goodhart (1989).

Expanding the money base by one krona causes the money supply to grow by *more* than one krona. This increase is the money multiplier.

The money supply (M) consists of two elements – currency/cash (C) held by the public and bank deposits (D):

$$(1)\ M = C + D$$

Normally we think of C as notes and coins in circulation in the economy. However, if we introduce a central bank issued digital currency (C^d), then we should think of C as being the sum of digital cash and physical cash (C^f), so C is expressed by the follow equation:

$$(2)\ C = C^d + C^f$$

However, for simplicity's sake, here we use C to denote both physical and digital cash and hence maintain formulation (1) as a starting point.

Both the public and banks influence the *composition* of the money supply. This is because banks decide what share of the deposits entrusted to them is to be lent out, while the public decides what share of its money holdings is held in cash (physical and digital) or in bank accounts.

This is also known as the *cash-to-deposit ratio*. We here denote it as θ:

$$\theta = C/D$$

$$\Leftrightarrow$$

$$C = \theta \bullet D.$$

It therefore follows that:

(1') $M = (1+\theta) \bullet D$

We will discuss the importance of what determines θ and what the introduction of an e-krona means for its size below. First, however, we will continue deduction of the money multiplier.

Further, the money base (*B*) is either held by the public as cash (physical or digital) or held by the banks as reserves (*R*):

(3) $B = C + R$

As $C = \theta \bullet D$ *it follows that*

(3'') $B = \theta \bullet D + R$

One can think of the money base as being controlled by the central bank. Hence, if the central bank keeps *B* fixed, the withdrawal of one krona from the commercial banks will cause a one-to-one increase in the cash in circulation (either in digital or physical form).

To put it in another way, the central bank controls the total money base, but not the composition of the money base – at least, not directly.

Instead, the composition of the money base is determined by the sum of the public's choices between holding money in deposits and/or in physical and digital cash.

Furthermore, we assume that commercial banks hold a fraction (*f*) of the deposits they accept (*D*) as reserves:

(4) $R=f \bullet D$, where $0<f<1$

This fraction is a function of numerous factors, including the risk appetite of the banks' owners and the regulatory framework (e.g., legal reserve requirements).

It follows from (4) and (3'') that:

(3''') B = θ•D + f•D

⇔

(3''') D = B/(θ+f)

By inserting (3''') we get the following:

(1'') *M = m•B*

Where:

m = (1+θ)/(θ+f)

m is what normally is known as the money multiplier.

We see here that *m* depends on two factors – *f*, which is the reserve fraction, and θ, which is the cash deposit ratio.

Often when the size of the money multiplier is discussed, the focus is on the importance of legal reserve requirements and other types of regulations that influence *f*.

For digital cash, however, it is rather the cash deposit ratio we should focus on.

The reason for this is that we should expect the introduction an e-krona to increase the demand for digital cash relative to deposits. Or to put it more precisely, one should expect the demand for digital cash to increase relative to both physical cash and bank deposits. Expressed in terms of our equation, we should expect θ to fall when e-krona are introduced.

The size of this decline will ultimately depend on the design of the e-krona and the limits, if any, to its use. Nevertheless, it is clearly likely that many households, companies and even financial institutions (e.g., pension funds) would decide to cut back their bank deposits in favour of e-krona.

A simple simulation can give us an idea of how important such behaviour might be for monetary conditions.

Digital cash as a negative shock to the money supply – a simple simulation

Using the money multiplier model above, we can simulate the impact of introducing an e-krona on the overall money supply.

For the model's parameters, we will use a realistic assumption of what we would expect to see in a high-income economy with a well-developed banking sector.

Hence, we assume that θ initially is equal to 0.1, meaning that 10 percent of money holdings are held in cash (digital and physical), and we assume f equals 0.2, meaning banks keep 20 percent of deposits in reserves.

We assume the money base, B, is 100 units.

	Initial	Shock	% change
θ	0.1	0.2	+100%
f	0.2	0.2	0
B	100	100	0
m	3.7	3.0	-18.2%
M	366.7	300	-18.2%

The table above shows the results of a simple simulation which, given the parameters above, illustrates the impact of a shock to θ due to the introduction of an e-krona.

We here assumed that this would cause a doubling of θ from 0.1 to 0.2, which would then *decrease* the money multiplier, *m*, from 3.7 to 3.0, an 18.2 percent drop.

This in turn will reduce the money supply, *M*, from 366.7 to 300, also a drop of 18.2%.

A decrease of this magnitude would certainly constitute a substantial negative monetary shock in any well-developed economy, suggesting that we cannot and should not ignore such effects when analysing the impact of introducing an e-krona.

Obviously, these results are crucially dependent on our assumptions and particularly on the impact of an e-krona's introduction on the cash-deposit ratio, θ.

However, these assumptions do not seem totally unrealistic. Even as a theoretical exercise, they show how the introduction of an e-krona would not be a purely technical payment issue, but could have potentially impact monetary conditions if handled badly. Unmitigated, a negative money supply shock of this magnitude would very likely cause a deflationary and strongly recessionary shock.

That said, our calculations above assumed that other factors were kept unchanged. We could easily imagine policy measures could be implemented to fully offset any negative monetary effects from the introduction of an e-krona. For example, regulatory measures could be eased to reduce *f* and/or increase the money base, *B*.

We will discuss this option in more detail below, but first we will analyse another channel through which an e-krona could potentially affect monetary conditions.

Facing the Zero Lower Bound with e-krona

Central banks often implement monetary policy by setting a key policy rate. In practice, that rate is close to what is often referred to as the natural rate of interest.

The Swedish economist Knut Wicksell (1898/1936) defined the natural rate this way:

> *There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them.*

A modern-day version of this is for the central bank to set a rate of interest that ensures that the economy remains in 'balance', meaning that it operates at full capacity (the output gap is zero) and the rate of inflation is more or less equal to the central bank's inflation target.

Hence, if inflation is running above (below) and/or the economy is growing 'too fast' (too slow) then the central bank will push the policy rate above (below) the natural rate.

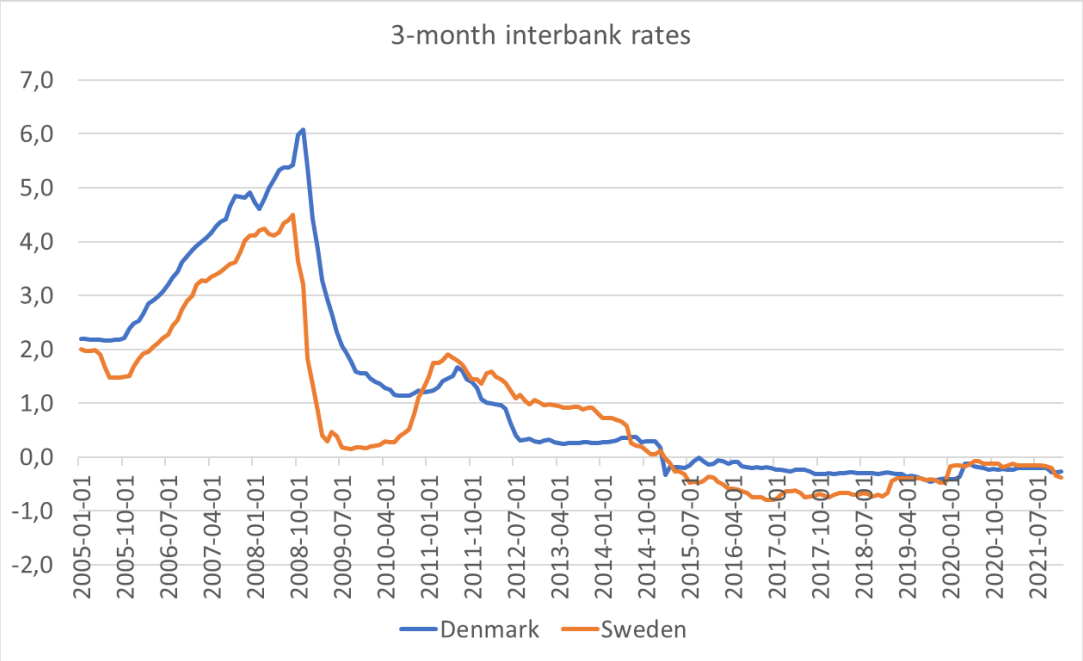
Since the early-to-mid 1990s, this has been the general operational framework for conducting monetary policy at most inflation-targeting central banks around the world.

However, since the Great Recession hit in 2008, central banks around the world have been forced to contend with a new problem – conducting monetary policy at what is known as the *Zero Lower Bound*.

A number of countries, particularly in Northern Europe and Switzerland, have had to slash their market and policy rates close to zero or even below[7].

Taking Denmark and Sweden as examples, we can see that three-month market rates have consistently been below zero, as the graph below illustrates.

[7] There are numerous reasons why global interest rates have dropped over the past couple of decades, among them demographics and regulatory changes. For a further discussion, see e.g., Christensen (2021).



Setting policy rates below zero will sooner or later cause the public to shift their money holdings into cash, which does not pay interest or charge negative rates either.

Similarly, as policy rates are kept below zero, reflecting a natural interest rate below zero, commercial banks will also have to offer negative interest rates on bank deposits. And this indeed is what we have observed in Denmark in recent years.

With deposit rates and the policy rate below zero, we should expect to see an increase in deposit outflows from banks and an increased demand for cash.

However, as Armelius, Boel, Claussen and Nessén (2018) note:

> *Holding and handling cash is risky and costly for firms and households and for banks. 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. Consequently,* [*Sweden's*] *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.*

Both Denmark's Nationalbank and the Riksbank have been able to keep their policy rates below zero, but at the authors observe, there are obviously limits.

There might not be a ZERO lower bound for the policy rate, but there certainly is a lower bound. Whether it is -1% or -2%, or perhaps even lower, is ultimately an empirical question.

The introduction of an e-krona would likely push up the *effective* lower bound as it significantly reduces the cost of holding (digital) cash. As opposed to physical cash, the digital variety does not entail storage, transport or security costs.

Consequently, inducing an e-krona would push up the effective lower bound for interest rates. In countries with policy rates close to or even below zero, this would make it even more challenging to conduct monetary policy using the interest rate instrument.

Even so, it must be acknowledged that this is a challenge many central banks have already been facing for more than a decade. Many of these central banks have accepted that money base controls or what is often termed quantitative easing are a necessary component in the monetary policy toolbox.

But for more traditional monetary authorities like Denmark's and Sweden's, the introduction of digital cash will further underscore the need to stop relying on 'interest rate control' as the key policy instrument and instead focus on money base controls.

Paradoxically, the introduction of an e-krona could speed up this process, not just by necessity but also because it might well be easier to implement operationally.

It is clear, however, that the induction of an e-krona could initially cause a *'deflationary impulse'* through at least two partly interconnected challenges – a drop in the money multiplier and an increase in the effective lower bound on interest rates.

Monetary targets to the rescue

The discussion above shows that the introduction of an e-krona *initially* could cause a negative monetary policy shock.

However, it is equally important to note there is nothing unusual about shocks to different monetary factors.

For example, gradual demographic changes probably have a significant impact on the natural interest rate, as well as on the demand for money. Similarly, the changes in global financial regulation since 2008 have also impacted monetary conditions greatly.

Therefore, the effects of an e-krona on monetary conditions would be no means be unprecedented, and central banks should be able to mitigate them fairly easily.

However, policymakers would need to be prepared and willing to make the necessary adjustments in monetary operations.

The best way for a central bank to commit to mitigating monetary shocks is by announcing clear, transparent and credible policy rules.

A simple rule could be for the central bank to commit to increase (decrease) the money supply, M^s, if price level, P, is below (above) the price level target, P^T.

(4) $M^s = \beta \bullet (P^T - P) + \varepsilon$

ε is a money supply shock that pushes the money supply away from the level desired by the central bank. β is a coefficient larger than zero[8].

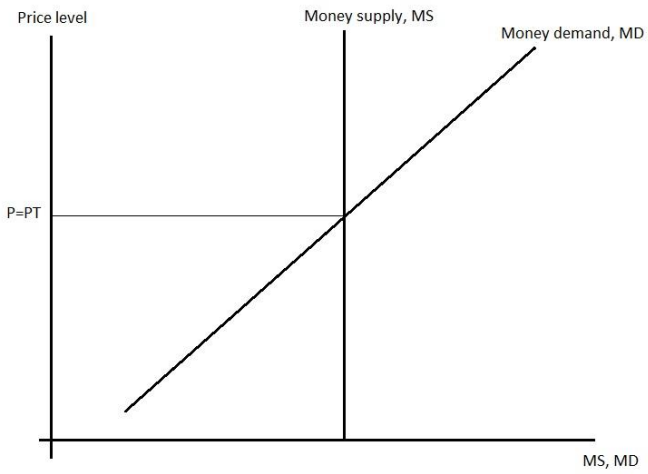
To find the money market equilibrium, we also need an equation for the money demand:

[8] Note we here assume the central bank has a price level target rather than an inflation target. This is done for simplicity, but the conclusions would basically be the same.

(5) $M^d = \delta \bullet P$

This rudimentary money demand function simply states that the demand for money, M^d, is a function of the price level. δ is a coefficient larger than zero.

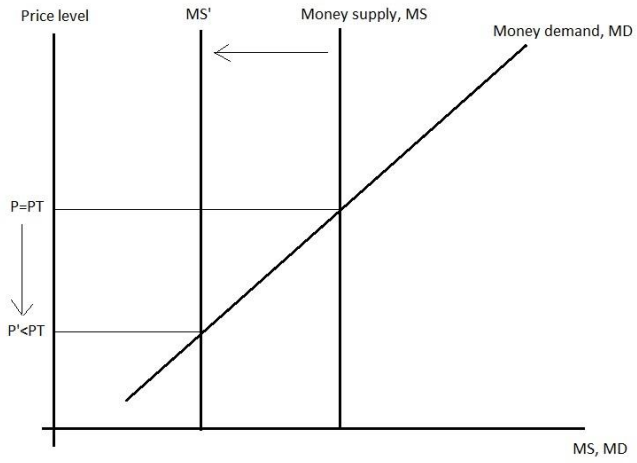
The price level, P, is determined as the equilibrium between (4) and (5), as the graph below illustrates.



In this initial state, the price level (P) is equal to the price level target (P^T).

Now assume that we introduce an e-krona into the economy, which causes a negative shock to the money supply through a fall in the money multiplier, as discussed above.

In this simple money market model, that is an *ε-shock* to (4), as seen below.



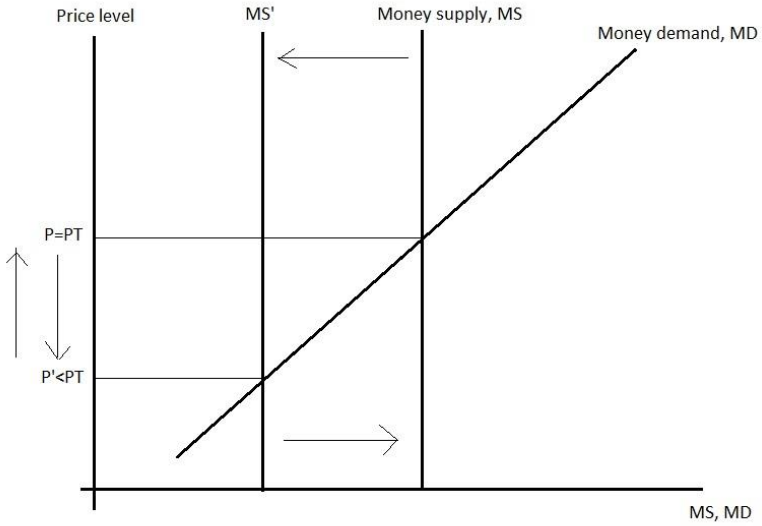
We see that a negative shock to the money supply causes the money supply curve to shift leftwards along the money demand curve. This causes the price level to drop from P to P' – that is, below the price level target, P^T.

The model shows what should happen if the central bank allowed the shock to the money multiplier to cause a 'passive' tightening of monetary conditions.

However, a central bank which targets a price level (or inflation) will not allow that to happen. Instead, it would act to *offset* the money supply shock. This we represent in the first part – $\beta \bullet (P^T - P)$ – of equation (4).

Hence, if P drops below P^T, then $\beta \bullet (P^T - P)$ becomes positive, causing an 'automatic' increase in the money supply, M^s.

In a dynamic version of this model, we would see the money supply increasing in each period until the price level returns to the target, as illustrated in the graph below.



To conclude, the introduction of an e-krona may cause an initial tightening of monetary conditions, but these contractionary effects can easily be offset by an inflation or price level targeting central bank by increasing the money supply.

One way of doing so would be through an expansion of the money base (for example, by increasing the digital currency base), but it could also be done by easing legal reserve requirements.

The important thing is for the central bank to be aware that introducing an e-krona will very likely cause an initial 'passive' monetary tightening that needs to be actively offset through policy measures.

It should be noted that the example above illustrates a negative shock to the money supply caused by the e-krona's downwards pressure on the money multiplier.

However, as discussed above, we should also expect the e-krona's introduction to raise the effective lower bound on interest rates. In the simple model above, this would constitute a positive shock to money demand, which would push the demand rightwards while keeping the supply fixed. The impact would thus also be deflationary (initially), necessitating an increase in the money supply to offset the deflationary shock.

Finally, we have here discussed a price level (or inflation) target as an offsetting mechanism to the negative monetary shock induced by the e-krona. It should be noted that a fixed exchange rate policy like Denmark's vis-à-vis the euro would have the same automatic offsetting effect as maintaining a price level (or inflation) target.

Hence, in the case of Denmark, a drop in the money supply would cause a tightening of monetary conditions, which in turn would cause the krone to strengthen against the euro. However, as the Danish central bank's policy is to keep the krone fixed against the euro, the central bank would intervene in the foreign exchange market to buy foreign currency and sell krone, thereby expanding the Danish money base.

In conclusion, strict price level inflation targets (and a nominal income targets) and fixed exchange rate regimes would function as mechanisms to automatically offset potential negative monetary shocks from the introduction of an e-krona.

Discussion

Central banks around the world are now seriously contemplating introducing so-called Central Bank Digital Currencies (CBDCs), or what we in this paper term digital cash or e-krona.

Our purpose has not been to discuss the technological aspects of digital currencies or for the matter the regulatory framework, but rather to focus on their impact on monetary policy and the monetary transmission mechanism.

Based on the foregoing discussion, we can draw several conclusions.

Firstly, the introduction of central bank-issued digital cash is not necessarily a monetary revolution, but rather a natural evolution made possible by technological advances.

Secondly, we show that the introduction of an e-krona brings no fundamental change to the manner in which monetary policy is conducted or to central bank targets (such as inflation).

Thirdly, we demonstrate that digital cash is not 'free money'. Often it has been claimed that introducing an e-krona would be equivalent to 'helicopter money' distributed to citizens. Our discussion shows, however, that there is no significant difference between how monetary policy can and should be conducted with an e-krona or without it.

Fourthly, however, we do consider how an e-krona could be used to implement a rules-based and automatic 'helicopter drop' of e-krona to citizens' e-wallets, noting that this would require close coordination of fiscal and monetary policy.

Thus, it should be recognised that while the introduction of an e-krona would not necessitate a fundamental change in monetary operations, it nonetheless opens the door to changes which might or might not be desirable.

Fifthly, we discuss the impact an e-krona's introduction would have on the monetary transmission mechanism, identifying the two main channels through which it would impact monetary conditions – the money multiplier and the so-called effective lower bound for interest rates.

Based on the discussion, we conclude that the introduction of an e-krona will likely cause an outflow from bank deposits into e-krona, which in turn will reduce the money multiplier and therefore the money supply, causing an increase in the effective lower bound on interest rates. Both of these 'shocks' will *initially* cause a tightening of monetary conditions sufficiently large that monetary policy makers could not afford to ignore it.

Sixthly, while an initial negative shock to monetary conditions seems probable, strict adherence to monetary policy rules – whether they be an inflation target or a fixed exchange rate – will offset its impact. These mitigating measures to expand money supply can be supplemented by an offsetting relaxation of legal requirements on liquidity, capital and reserves, helping offset any negative impact on the money multiplier.

The overall conclusion is that while introducing an e-krona could potentially have significant impact on the *payment technology*, by itself it is unlikely to change the conduct of monetary policy in any fundamental way.

Since the introduction of an e-krona will likely have a negative initial impact on monetary conditions, however, central banks and regulators should formulate plans to offset such effects. These measures should then be announced and implemented in a transparent, rules-based manner.

References

Armelius, Hanna, Paola Boel, Claussen, Carl Andreas and Nessén, Marianne (2018), "The e-krona and the macroeconomy", Payments Department and the Monetary Policy Department of the Riksbank.

Bossone, Biagio and Natarajan, Harish (2021), "Getting funds to those in need and enabling access to money during COVID-19, part 3: Central bank digital currencies and other instruments", VoxEU CEPR.

Bank of England (2021), "Central Bank Digital Currency: opportunities, challenges and design".

Central Bank of The Bahamas (2021), "Driving Financial inclusion and FinTech innovation in the midst of Covid-19".

Christensen, Lars (2021), "Financial regulation, demand for 'safe assets', and monetary conditions", Working paper, Center for Corporate Governance, Copenhagen Business School.

Friedman, Milton (1969), *The Optimum Quantity of Money* (Chicago: Aldine Publishing Co.].

Goodhart, Charles (1989), *Money, Information and Uncertainty* (Cambridge, Mass.: MIT Press).

Hetzel, Robert L. (2017) "The Evolution of U. S. Monetary Policy", Richmond Research Department, Working Paper No. 18-01.

Ihrig, Jane, Meade, Ellen E., and Weinbach, Gretchen C. (2015) "Monetary Policy 101: A Primer on the Fed's Changing Approach to Policy Implementation", Federal Reserve.

People's Bank of China (2021), "Progress of Research & Development of E-CNY in China"

Riksbanken (2021), "E-krona pilot Phase 1"

Taylor, John B. (1993) “Discretion versus policy rules in practice”, *Carnegie-Rochester Conference Series on Public Policy* 39 (1993), 195-214.

Wicksell, Knut. (1936), *Interest and Prices* (London: Macmillan), translation by R.F. Kahn of 1898 edition of *Geldzins und Güterpreise*.