Master Thesis

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Monetary Policy Implications for the trade-off between a Private Digital Currency and a Central Bank Issued Digital Currency

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Abstract: This thesis looks into the consequences for monetary policy when traditional currency is (partly) replaced by e-currency. Both the consequences of a significant important private e-currency, such as Bitcoin, and a government controlled e-currency are discussed. Maintaining price and financial stability are the major objectives for central banks, which they achieve with their monetary policy. Therefore the risks for price and financial stability resulting from e-currency are investigated. The main finding is that a private e-currency reduces the effectiveness of monetary policy while government controlled e-currency increases the effectiveness via additional monetary instruments. The introduction of government controlled e-currency also leads to substantial economic growth as the cost of government financing is reduced, leading to a higher government budget.

Key words: Cryptocurrency, virtual currency, Bitcoin, blockchain, private e-currency, Central Bank issued Digital Currency, monetary policy, regulation, policy implications, digital currency, future of banks, future role of banks.

Content

1. Introduction

Nowadays cryptocurrencies are a hot topic, and its popularity is still rising sharply (Barlin, 2017). Cryptocurrencies are virtual currencies that use cryptographic encryption, the most famous example of such a currency is Bitcoin. Bitcoin is a virtual currency that was introduced in 2008 as a private e-currency outside the regular banking system (Brito & Castillo, 2013).

The rise in popularity of e-currency raises important issues on how governments and policymakers should react to this rise. They have to decide on their policy choices. One of these important issues is their monetary policy. Besides this, also legal and political issues play an important role, however these do not fall within the scope of the economic domain and thus will only be mentioned but not discussed in this thesis.

Central banks all over the world are exploring options on how to react to this new and fast developing trend of cryptocurrencies. Both the central bank of Canada and England launched a special research agenda on e-currency (Bank of Canada, 2017) (Bank of England, 2015). The central bank of Sweden even goes further and is currently exploring options to actually introduce their own virtual currency, the E-Krona (Skingsley, 2016). The reason that central banks are looking into these alternative ways of payment and explore the options for cryptocurrency is two-sided. On the one hand the central banks want to get a hold on cryptocurrencies where possible and on the other hand they want to benefit from the technological and economical advances cryptocurrencies bring with them.

These policy implications are interesting for policymakers because Bitcoin for example is mostly unregulated and therefore could be used for activities outside the banking system. On the other hand, central banks are observing a trend where more and more payments are made electronically. In some countries, for example in Scandinavia, cash is barely used anymore and most transactions are conducted electronically (Riksbank, 2016). So far the general consensus among central banks is that private e-currencies such as Bitcoin "are commonly held to be undesirable from the perspective of policymakers, but the innovation embodied in the payment systems of such schemes is held of some interest" (Barrdear & Kumhof, 2016, p. 4). This illustrates why central banks are exploring their options on how to deal with cryptocurrencies.

The purpose of this thesis is to provide a better understanding of the policy issues related to this new virtual currency but also what the possible advantages are and how this advantages can be exploited. After establishing the background of cryptocurrencies the focus is on what can be expected in the future of cryptocurrencies and what policy implications are brought with it. Insight in the implications and risks that the new technology of digital currency brings for policymakers is given. In the literature different approaches are used, for this thesis the focus is on the impact of e-currency on the central bank's monetary policy. Two core articles are used to investigate the effects, both articles assume that a government interference via the central bank is necessary to maintain stability. As the new situation of a rise in popularity of e-currency affects the government interference, the core articles focus on what the consequences of this new situation will be. The first core article by Sauer (2016) looks into the consequences for the central bank of a significant important private e-currency. The second core article assumes a government controlled e-currency, referred to as CBDC, by Barrdear & Kumhof (2016), it looks at the consequences of a CBDC regime for monetary policy and the economy. These approaches and its pro and cons will be compared, contrasted and discussed. Policymakers can use these insights to get a better understanding of the possible implications and to decide about their policy on e-currency.

This thesis is a theoretical research, a theoretical research method is the most suitable for this topic as there is only limited data available on cryptocurrencies. This is mostly because of how new cryptocurrencies are. Because of the limited role of cryptocurrencies at this moment and despite its huge potential in the future, the available literature is very limited. Luckily, there is still some good quality literature available and therefore a few articles are picked to be discussed and analyzed in this thesis. The articles have a broad variety, some are written from a central bank perspective (Camera, 2017 and Barrdear & Kumhof, 2016) whereas others are written by research departments of universities (Dwyer, 2014 and Sauer, 2016). This gives a broad overview of the matter and provides the opportunity to link the findings and contribute to the literature by giving new insights and a better understanding in the fast developing world of cryptocurrencies from an economic perspective.

This thesis is structured as follows. Section 2 is the literature review that gives an introduction to e-currency and its government implications. Section 3 analyzes the risks of private e-currency for central banks. Section 4 analyzes the CBDC model and its policy implications. Section 5 discusses the findings and section 6 concludes.

2. Literature review on e-currency and government implications

Before going in-depth and analyzing the two core articles, background knowledge regarding private and government controlled e-currency will be established. This section is a literature review which firstly consists of an explanation about e-currency and how blockchain is the basis for a cryptocurrency. Secondly, a better understanding will be established about the issues regarding government implications of the rise of e-currency. Attention to monetary policy is also paid. This literature review will be used to discuss the rise of e-currency and the issues that central bankers and governments face when new payment methods, such as Bitcoin, gain in popularity. The questions and implications that arise in this literature review will be further researched and discussed in the remainder of this thesis.

Technology is developing at a rapid speed in the late 20th and early 21st century. After life-changing inventions such as computers, the internet and smartphones we might be witnessing another highly impacting breakthrough in the digitalization of the financial system: e-money. But what exactly is meant with e-currency? To get this straight some terminology needs to be explained first. Cryptocurrencies, virtual currencies and e-currencies are often used interchangeable for the same thing. Citing Sauer (2016) virtual currency is “money which does not exist in reality as coins, banknotes or bank deposits, but rather exists in digital form” (p. 118). Regarding cryptocurrencies she adds: “Cryptocurrencies are physical precomputed files utilizing a public key/private key pairs generated around a specific encryption algorithm. … The decentralized nature of open source protocol ensures that the control of the network remains in the hands of the users” (Ahamad et al. 2013, p. 43). Basically, a cryptocurrency is a virtual currency with an additional security feature: it is encrypted. Because of this encryption the added value of the traditional role as a middleman, often fulfilled by banks, might become redundant. In the rest of this thesis cryptocurrency and private e-currency is used interchangeably.

Cryptocurrency (and other digital money such as bank deposits) are typically files on computers that people consider having a certain value and is seen as money. The nature of money consists of building trusts among the strangers who use money to trade. One must be confident that others are willing to accept their money in the future and that the money will keep a certain value so that it can be used for future trades (Camera, 2017). Money has three functions, these are store of value (saving), unit of account (provide a common base for prices) and medium of exchange (trade) (Asmundson & Oner, 2012). With traditional money people attach a certain value to a paper banknote and the government and central banks make sure that the money remains valuable and that trust is remained. For private e-currency there is not an authority that fulfills this task of maintaining stability and thus it is one of the reasons that the value of private e-currencies is very volatile.

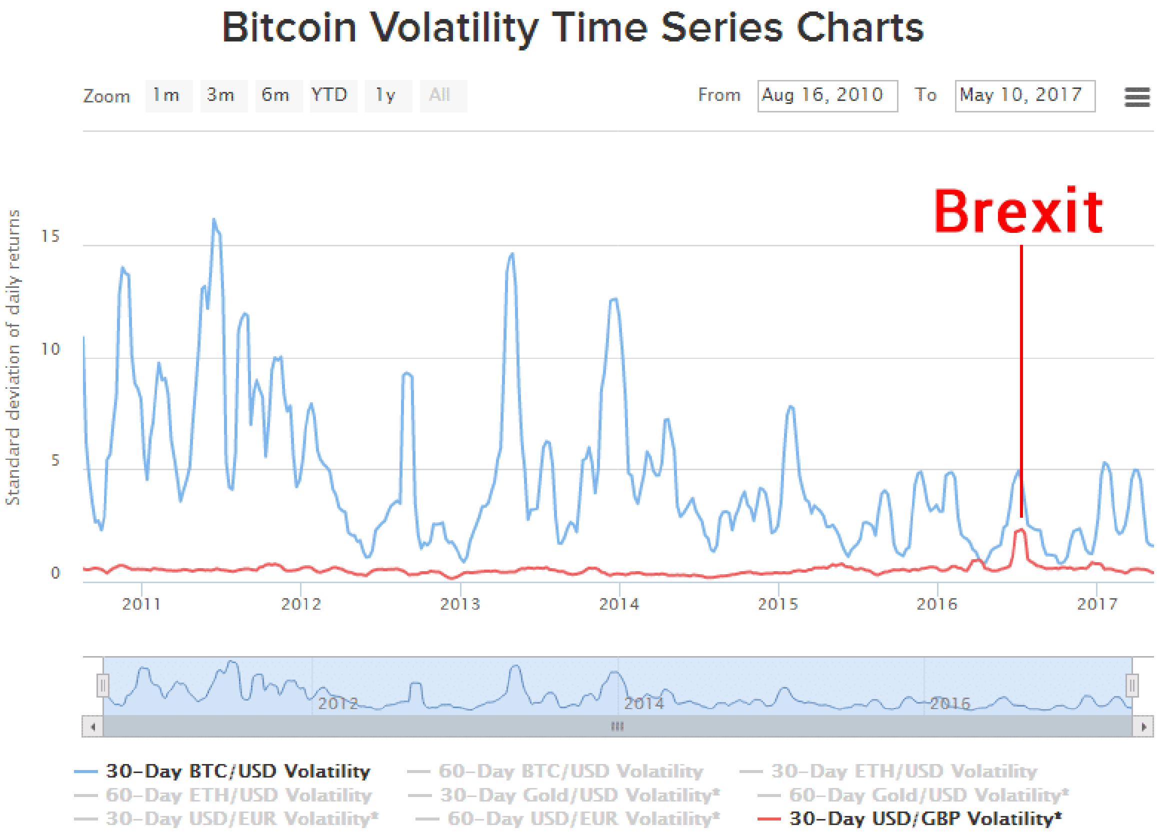
Two important distinctions that should be made are the differences between sovereign and non-sovereign digital currency (Camera, 2017). With sovereign digital currency the digital form of cash is meant, which can be for example commercial bank deposits at the central bank, but also a Central Bank issued Digital Currency (CBDC) regime. Whereas non-sovereign currency is private currency, such as Bitcoin. For this research non-sovereign private e-currency is compared with a sovereign version of e-currency, the CBDC.

2.1 The blockchain & Bitcoin

Now that the terminology about cryptocurrencies is established, the most famous example of a cryptocurrency, namely Bitcoin is used to explain how an e-currency works. Bitcoin was introduced back in 2009 and since then the usage of Bitcoin has been growing rapidly, from 6.56 million users in 2014 up to 11.05 million one year later in 2015 (Weber, 2016).

Bitcoin works with a blockchain, a blockchain is a new technology that uses encryption. The blockchain is a ledger that is updated constantly and maintained by computers. Thus, eliminating the traditional role of a middleman, for example banks that are supervised by authorities. An important feature of the blockchain is that it is public and everyone can see it (as it acts as a public ledger, which is updated after every transaction). Everyone owns their own copy of the ledger, although this might imply a lack of privacy, this is not entirely true as the transactions and accounts in the blockchain are anonymized by recoding it, a technical computerized process. The main advantage of the public ledger is that you don’t have to trust a third party or middle man anymore. Every transaction becomes a block which is then checked by others’ computer and approved, these verifiers are the so called miners (Dwyer, 2014). After it is approved the transaction is added to the chain of blocks (the blockchain) and goes through. Every transaction is public and if someone tries to corrupt it, the mathematics behind it would flag it and prevent a consensus among all the ledgers and thus basically preventing fraudulent transactions. So the middlemen, banks for example are (partly) replaced by cryptographic verification (Swan, 2015) (DutchChain, 2014) (Financial Times, 2016). The existing blockchain technology used for private e-currencies could also be the basis for a central-bank issued cryptocurrency.

Bitcoin's main function seems to be as a mean of payment, transaction costs for Bitcoins are kept very low, making it easy and affordable to transfer sums of money with fast speeds all over the world (Sauer, 2016). Transactions are executed almost instantly and 24/7 (Bitcoin, 2017). However, Bitcoin is still considered as a complement and not a substitute for traditional currency (Sauer, 2016). Nowadays Bitcoins are mainly used for speculative purposes rather than a mean of payment, resulting in a lot a volatility that is much higher than similar derivatives, such as currency exchange rates, as shown below in graph 1. The graph shows the volatility of Bitcoin (blue line) compared to the volatility of the USD/GBP exchange rate (red line). This volatility results in uncertainty about Bitcoin value, making it a risky investment and even riskier as a substitute for traditional currency (Hay, 2017).



Graph 1: comparing Bitcoin volatility with GBP volatility. Source: (Hay, 2017).

The **supply side** of bitcoins is based on the blockchain network that creates and transfers the bitcoins among its users, without an authority controlling it. Supply of Bitcoins is limited to 21 million. When this amount is reached no new Bitcoins can be issued. Issuance of Bitcoins takes place when transactions are verified by the so called “miners” (Dwyer, 2014). When the maximum supply is reached the only way to acquire Bitcoins would be by trading. The Bitcoin supply was rapidly issued in the first years after introduction, reaching 10.5 million (50% of all available Bitcoins) already in 2013, merely 4 years after its introduction. What happens when this 21 million is reached, and money supply will be fixed at this 21 million, is unclear. On the Bitcoin (2017) websites they state: “The number of new Bitcoins created each year is automatically halved over time until bitcoin issuance halts completely with a total of 21 million bitcoins in existence. At this point, Bitcoin miners will probably be supported exclusively by numerous small transaction fees”[1]. This suggests that Bitcoin trading and verifications can still take place because “miners” will verify transactions in exchange for transaction fees. Although there is no underlying theory supporting this and a back-up plan if this does not happen.

Regarding the 21 million supply cap another implication arises. Sauer (2016) argues that the real supply of Bitcoin will actually never be 21 million, because Bitcoins can be lost forever, for example when people lose their Bitcoin key (combination of password and account) and therefore Sauer uses a 18 million cap for Bitcoin supply in her research. Another implication which is related to the loss of Bitcoins is that bitcoins can be stolen by hackers, this is something that actually already happened in the past. According to a Bitcoin skeptical, approximately 10% of the Bitcoin supply “has already been pilfered by computer hackers” (Yermack, 2013, p. 8). These security threats are something to keep in mind when a government wants to either regulate private e-currencies or issue their own virtual currency.

An important feature of Bitcoin, and possibly one of the main reasons why it is so popular, is that it is operated outside the regulated payment environment and that Bitcoin has no identifiable centralized issuer. These features bring full anonymity and untraceable transactions with them. Although full anonymity on itself is not a bad character, especially nowadays with privacy becoming more and more important for people, it can also attract criminal activities. That is one of the reasons why policymakers are exploring opportunities on how to overcome those complications.

[1] Bitcoin (2017) themselves say this, this is their opinion and is not confirmed in the literature yet.

The popularity of Bitcoin mainly results from the anonymity it provides and the fast and cheap way of transferring all over the world. Bitcoin is sometimes associated with criminal activities, for example with ransomware hacks where the hackers ask for payments in bitcoins (Thomson Reuters, 2013). On the other hand, bitcoins are sometimes stolen by hackers as well. When bitcoins are stolen this is done by acquiring the password of a Bitcoin accountholder and transferring the funds to another account via (almost) untraceable ways. To some extend contradicting Sauer and despite some of the risks associated with Bitcoin, Dwyer (2014) concludes that Bitcoin can become widespread and should therefore be treated as a possible replacement to some extent. But he does not see Bitcoin as a substitute for the US-dollar or other well established currencies. He sees Bitcoin more like a substitute for international trading on foreign currency exchanges. Mainly because of the risks such as limited supply, criminal activities and vulnerability for hackers Sauer (2016) and other authors (Yermack, 2013) in the literature conclude that Bitcoin is not (yet) a substitute for traditional currency. Next the implications for policymakers regarding a private e-currency such as Bitcoin and a Central Bank issued Digital Currency regime that are mentioned in the literature will be discussed, the focus will be on monetary policy implications.

2.2 Government implications

2.2.1 Introduction

Now that prior knowledge of Bitcoin and the blockchain is established this subsection focusses on the discussion about the implications of these new technologies for policymakers. The focus is on cryptocurrencies such as private e-currencies and the possibility that governments introduce their own cryptocurrency, for example Central Bank issued Digital Currency (CBDC). Important risks for central banks and policymakers are the price and financial stability risks. The two core articles by Sauer and by Barrdear & Kumhof both mention those two risks as the most important ones. This literature review gives an overview on issues that relate to these risks and in the sections that discuss the core articles these risks will be analyzed and discussed again.

The relatively new phenomena of non-sovereign (private) e-currency brings new challenges for policymakers. Suddenly private e-currencies emerge which can compete with governmental traditional money. This brings a lot of questions and policy implications.

Governments are challenged on how to react on the fast growth and rapid expansion of e-currency. Should central banks play an active role or should they let private issuers (such as Bitcoin) lead the way (Camera, 2017)?

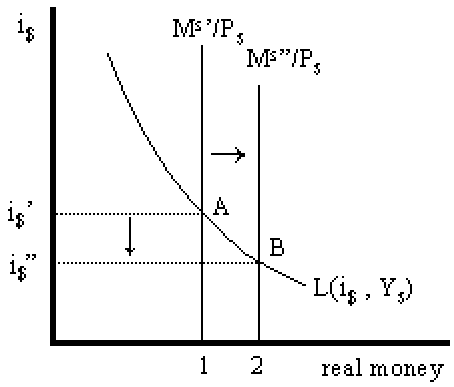
With the introduction of the blockchain technology and Bitcoin the need for a virtual currency that could deliver fast and affordable global transactions could finally be fulfilled. As this need could not be fulfilled by the traditional banking system it paved the way for the rapid expansion of private digital currencies. Another reason why the popularity of private e-currencies grew so fast was the speculation possibilities it brought with them. Nowadays, most trades in private e-currencies are conducted for speculative reasons and success stories lead to more people engaging in this speculative behavior. In a sense the private e-currencies could be seen as (an early stage of) a bubble (Bouoiyour, Selmi, & Tiwari, 2014). But the speculation is inherent to the fact that private e-currencies can fulfill the earlier mentioned need of fast and affordable global transactions. Currently more and more societies are slowly abolishing cash payments and the populations of for example the Scandinavian countries are embracing digital payments and moving towards a cashless society. This is where the digital currencies, currently only in a private form, can step in and fulfill the need for this fast, affordable and digital payment method on a global scale.

When private e-currencies such as Bitcoins can provide in this need, why would the government not be able to try to provide it as well? They might as well be organized centrally by the government rather than proliferation of private e-currencies, such as Bitcoin and others. A private non-regulated/controlled e-currency can bring negative effects such as shadow economies, tax evasion, money laundering and other criminal activities (Thomson Reuters, 2013). The questions raised here will be further discussed by using the existing literature. First, the monetary policy and the central bank its role is described after which the implications of e-currency for policymakers are discussed.

2.2.2 Monetary policy

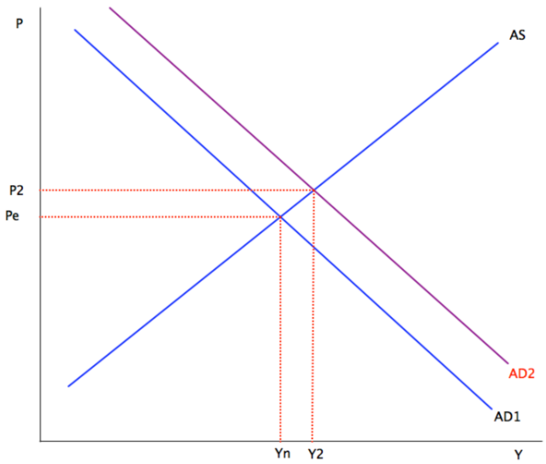
Monetary policy is defined as follows: “monetary policy determines the rate of growth of the nation’s money supply and is under the control of a government institution known as the central bank” (Bernanke & Abel, 2005, p. 10). In other words, monetary policy is the way a central bank tries to influence the economic direction by making use of its monetary instrument: the money supply. Controlling the money supply results in letting the economy grow while at the same time preventing excessive inflation.

The central bank can control the money supply via their monetary policy in different ways. The most important one is controlling the money supply by setting the interest rates, referred to as policy interest rates, in order to control inflation targets (Wickens, 2008). In order to influence the interest rate the central bank can adjust the money supply. This leads to a new money market equilibrium and a new real interest rate, as can be seen in graph 2. This way the central bank can control the interest rates and raise or lower the costs to borrow money, the cost of borrowing determines the money demand. For example, when the interest rate is reduced from 1.5% to 1.0%, the money demand will drop accordingly. In order to achieve equilibrium again the central bank needs to adjust (increase) money supply, graph 2 illustrates this.



Graph 2: Money market equilibrium (Suranovic, 2017).

The central bank can adjust the money supply by buying government bonds (to expand money supply) or selling government bonds (to reduce money supply). Buying government bonds is known as open market operations and is something that the United States Federal Reserve Bank and the European Central Bank use as an important monetary instrument to overcome the financial crisis that started in 2008 (Investopedia, 2017). The AS-AD model theory shows that this monetary expansion with decreasing interest rates leads to a rightward shift of the aggregate demand and results in higher prices and a stimulating effect for the economy for the short-run, as illustrated in graph 3. The central banks use their monetary policy to reach equilibrium in the economy between the money demand and money supply in order to achieve its primary objective, which is to maintain price stability (ECB, 2017). As achieving price stability, and with it controlling the inflation, is the main objective of the central bank, thus risks to maintaining this price stability should be taken seriously. Another important objective of the central bank is to maintain financial stability. “Financial stability is a state whereby the build-up of systemic risk is prevented”, examples of systematic risk can be shocks to the economy, financial imbalances and contagion across markets (European Central Bank, 2017). In the next subsection the implications of e-currencies will be discussed and possible risks to the stability of the monetary system will be mentioned.



Graph 3: short-run effect of monetary expansion (mnmecon, 2011).

2.2.3 Policymakers implications

As mentioned before, one of the features of private e-currency is that it exists outside the regulated payment environment. This can be an issue for central banks, as their monetary policy cannot influence private e-currency effectively. For example achieving price stability and controlling inflation is harder to achieve when the percentage of money supply consisting of private and unregulated e-currency increases. This is confirmed by Sauer (2016) her model, which shows that when virtual currencies remain increasing in popularity and central banks do not react on this they “may lose money supply control and therefore one of the main instruments at their disposal to regulate inflation or maintain price stability” (p. 128). The rise of e-currency as a parallel currency will have macro-economic consequences. Policymakers should react on this development. They should not simply prohibit or restrict (private) e-currency without properly thinking about the consequences and thus the question is how they should react on it. Forcing strict regulation on the use of e-currency might be a waste of a golden opportunity. Maybe governments can contribute to a faster growth when they exploit the opportunities e-currency has, in order to stimulate their economies. This is one of the important questions that central banks all over the world are trying to get answered nowadays (Wild, 2016). When policymakers want to exploit the possibilities e-currency has to offer they can roughly choose among two scenarios. The first one is allowing and facilitating private e-currency. The second one is to come up with a central bank initiated e-currency. The remainder of this thesis focusses on these two scenarios, with the discussion of two core papers which both look at one of those situations and its implications for central banks and the economy. Therefore, policy implications for both situations will be discussed here.

A correctly working monetary system where trades and transactions take place easily and which is trusted by the population is the responsibility of the central banks (Bank for International Settlements , 2009). Therefore the task of the central bank should be to take a leading role in exploiting the opportunities of e-currency, rather than letting private e-currencies take a leading role. Central banks should take this lead as the monetary system is a public good in most developed nations and the central bank its responsibility (Camera, 2017). This leading role would be reflected by introducing a CBDC regime for example. A CBDC regime is a government controlled Central Bank issued Digital Currency (CBDC), as proposed by Barrdear and Kumhof in the second core article. The implications associated with both a private and a government controlled e-currency are, in short, discussed here, in order to prepare for the in-depth analysis. Four categories of implications are discussed, these are stability, trust and confidence, safety and criminality and other issues.

<u>Stability</u>

If the blockchain technology is used for private e-currency the situation arises that the role of the central bank can be questioned. The decentralized nature of cryptocurrencies using blockchain may question the position of central banks regarding essential central bank functions such as monetary policies to control inflation. Citing Sauer: “Central banks will need reliable empirical evidence to figure out the necessity for changing monetary policy as it gets much harder for a central bank to control inflation or to target price stability”. With a private e-currency it would be more complex for central bankers to control money supply, as they are not the only issuer of currency anymore. A parallel, private, currency would emerge and central banks will have to “share” the market for currency issuance. This could result in problems where at least one of the currencies (either private e-currency or traditional) is not fully accepted by everyone. This would result in fragmentation of payment methods and competition among the currencies, which can result in inefficient selection of money payment methods (van der Horst & Matthijsen, 2013). Camera (2017, p. 139) concludes from this that "there is scope for a public institution to serve as the sole issuer of a currency". Adding to this, Sauer (2016) concludes that there is no elastic supply reacting to economic changes, resulting in that it would be much harder for central banks to guarantee price stability and control inflation if a Bitcoin-like cryptocurrency would exists as a parallel currency. For a CBDC like regime the above mentioned issues are less severe as the central bank will be in control and can still implement their monetary policy, adjusted for CBDC existence (Barrdear & Kumhof, 2016).

As mentioned before, private e-currencies are very volatile. This volatility is another main drawback when it comes to private e-currencies, which is also associated with the limited supply that is a characteristic of private e-currencies, as explained for Bitcoin. A very volatile currency would eliminate the store of value concept that currency should have because people cannot rely on the its future value.

Another complication which has to do with stability is the role of traditional commercial banks within an environment where e-currency is issued by the central bank. If the government will issue e-currency they have the technical possibility to do so directly to the end users, households and businesses, by issuing interest bearing e-currency directly from the central bank its balance sheet (Broadbent, 2016). This would (partly) eliminate the role of the middleman, the commercial banks, who are currently the main provider of services such as depositing interest bearing money and facilitating the electronic payment environment (ING, 2017). This is something that policymakers should keep in mind when deciding on the design of e-currency.

<u>Trust and confidence</u>

"The reputation of central banks is a key element determining the effectiveness of their various policies, especially monetary policy. A reputation is hard to earn, but very easy to lose" (ECB, 2012, p. 45). This shows that it is important to investigate the consequences of e-currency for trusts and confidence in the monetary environment.

The use of currencies as we know it is based on trust, trust in the value that is printed on the banknotes and trust in the wide acceptance of the currency. When one possess a 10 euro bill we trust that the future value of this 10 euro is equal to what is printed on the banknote, 10 euro, and that it is accepted by any counterparty as a valid method of payment. This is the underlying characteristic of our money. However, in contrast to cash which consists of banknotes and coins, e-currency does not include the possibility of physical possession. Users of e-currency would need to rely on trusted institutions for the procession and record keeping of transactions (Camera, 2017). In most countries the central bank is an authority trusted by the majority of its population, whereas for the use of private e-currencies the users would need to rely on an intermediary providing this services. "The public can more easily monitor the actions taken by a central bank compared to those taken by a private issuer" (Camera, 2017, p. 137). This will give a public institution such as the central bank a competitive advantage over a private issuer for e-currency, also because central banks have a historical "track record" of well-established monetary use. Also, if policymakers decide not to regulate private e-currency and something goes wrong or fails common people without detailed monetary knowledge might blame the central bank for this (Sauer, 2016). Lack of trust leads to uncertainty and this can slow down trade and economic growth.

Safety and criminality

Cash money has the drawback that its bills can be counterfeited. Bitcoin users sometimes end up with their accounts plundered (Yermack, 2013), which could be compared with the traditional money equivalent of a robbery or internet banking fraud. When looking at the electronic environment of traditional banks it can be observed that from time to time there are widespread disruptions in electronic payments[2]. It is hard to say if and to what extend a parallel private e-currency or a government controlled e-currency could be immune for these kind of risks. These kind of risks is something that politicians should be aware of and take into account.

Currently, the characteristics of private e-currencies, being in a decentralized, unregulated and anonymous environment attracts attention from certain type of users. Private e-currencies are sometimes associated with criminal activities and the shadow banking system. Some of these include money laundering, ransomware hacks and other criminal activities (Thomson Reuters, 2013). This might be a reason for policymakers to restrict the usage of e-currency for some

[2] Most recently, on August the 10th 2017 there was a nationwide disruption of card payments in the Netherlands.

people, which is technically possible through limited participation. Limited participation is “the technical possibility of excluding non-compliant traders” (Chiu & Wong, 2015, p. 5). Criminals that use private e-currencies for their criminal activities could also be a reason for policymakers to prefer an e-currency system where the central bank is in control over a private e-currency, in order to minimize criminal activities.

Other issues

As mentioned under the safety and criminality subsection an important characteristics of private e-currencies is its anonymity. Trades taking place in a private e-currency that uses the blockchain is relatively anonymous compared to electronic payments made via for example wire transfers. It is uncertain to which extend a government controlled e-currency will be as anonymous as the current Bitcoin. Privacy is an important basic human right and should be preserved. It is important for policymakers to make a “tradeoff between advantages and disadvantages of a currency” when it comes to privacy (Camera, 2017, p. 143).

Another consequence of private virtual currencies can be that macro-economic forecasting models will become less accurate. Because it might be hard for economists, who calculate models and forecast for the economy, to correctly estimate the contribution and effects of private e-currency. The effects on the economy resulting from uncertainty regarding private e-currency might influence their models accuracy. Wrong forecasts could lead to a mismatch between the forecasted economic situation and the implemented policy for this situation, because the realistic economic situation significantly differs from the forecasted situation.

2.3 Conclusions and final remarks literature review

The general consensus in the literature is that the drawbacks from private e-currency, such as money supply issues, speculation problems and lack of a central authority for monitoring are why most authors in the literature (Camera, Barrdear & Kumhof, Sauer) point towards a more prominent role of the central bank. This paves the way for a CBDC-like regime. The blockchain technology could serve as a basis for a central-bank issued cryptocurrency. It would need some adjustments to guarantee safety and anonymity and to keep to some extend track and control of the transactions where desired.

The literature review provided an overview of risks for monetary policy and other policy implications of e-currency, both private and government controlled. The next section focusses on two models. One model by Sauer and another one by Barrdear & Kumhof.

A model is an instrument to analyze a certain (complex) situation. The objective of such an analysis is to forecast the effects of the situation, but also to come up with arguments to support policy choices. Policymakers can use economic research, models and its results to come up with policies on e-currency, in the end it is up to them to make the final decision about e-currency based on their political views and interpretation of economic forecasts. The rise of e-currency is such a complex new situation. Monetary models help central banks to perform their tasks: achieve price stability and limit inflation. With regard to the rise of e-currency there is not really an existing model that captures the possible consequences. Sauer (2016) starts with a model to capture some of the consequences for monetary policy. Also Barrdear and Kumhof (2016) come up with a model to capture the consequences, they focus on the entire economic environment of a CBDC-regime[3]. The next sections focusses on these articles and their models. Monetary consequences of private e-currency and government controlled e-currency (CBDC) are analyzed and the risks for policymakers and possible benefits are discussed. First, the next section analyzes the risks of private e-currencies for central banks. After that, section 4 looks at the risks and benefits of CBDC and section 5 discusses both private and government controlled e-currency.

[3] Both Sauer and Barrdear & Kumhof use the keynesian framework.

3. A model that captures the risks of e-currency for central banks, Sauer (2016): “Virtual currencies, the money market, and monetary Policy”

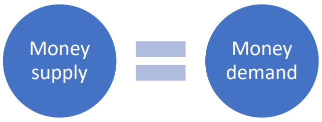
In this article Beate Sauer investigated the rise of private e-currencies and its implications. The article starts by explaining the importance of private e-currencies and it states that “in principle, virtual currencies have the potential to become parallel currencies to national” (Sauer, 2016, p. 118). In order to investigate the possible consequences of private e-currency she thought about a model that captures the changes resulting from an introduction of e-currency on supply and demand of money. She implemented the virtual currency supply and demand into the Keynesian money market framework by using variables that measure the replacement rate of traditional money. Her work is a contribution to the discussion about the rise of private e-currency from a theoretical economic perspective. The results from the model summarize possible consequences of a rising private e-currency. These consequences are expressed as risks for the central bank.

3.1 Model

The article aims to integrate the virtual currency supply, which refers to the supply of private e-currency, and demand into the Keynesian money market framework. It is written by Beate Sauer from the department of Economics and Law at the Munich University, but it does take into account the official standpoints of the European Central Bank (ECB) and the Bank of England (BoE).

For this model, Bitcoin is used as a benchmark for private e-currency and all consequences are based on Bitcoin. The model assumes a fully operational Bitcoin that exists as a circulating parallel currency next to traditional government currency, such as the Dollar, Euro or Sterling. Currently this is far from reality because Bitcoin is by far not a substitute for traditional currency.

The starting point of her model is the Keynesian money market theory, where supply and demand are in equilibrium. Shown by the formula beneath:

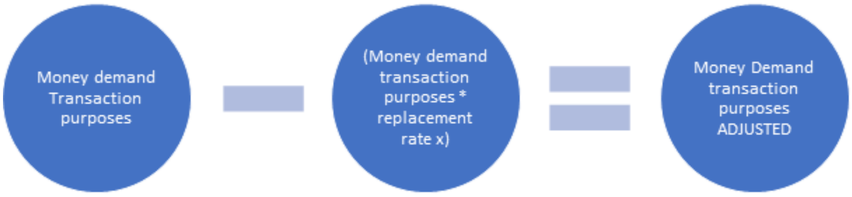


The next formula shows the national money market, where money demand consists of money demand for transaction purposes and money demand for speculation purposes. Money demand for transaction purposes depends on the real income Y. Money demand for speculation purposes depends on the interest rate i. This is formula (1).

(1). Money supply = Money demand for transaction purposes depending on real income Y + Money demand for speculation purposes, depending on interest rate i.

In order to get the demand for transaction purposes function adjusted for the existence of virtual currency the model takes the money demand for transaction purposes and subtracts the loss of money demand due to virtual currency. This loss of money demand is calculated by money demand transaction purposes times the replacement rate x. This is illustrated with formula (2).

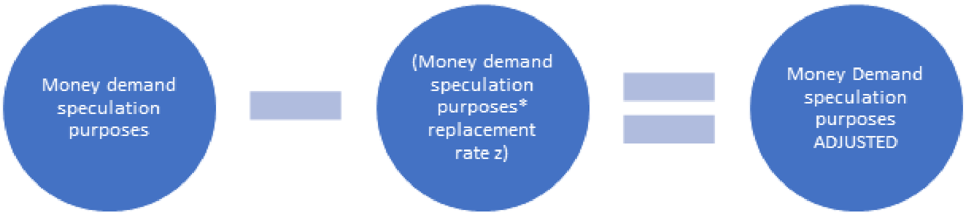
*(2) Money demand for transaction purposes in national currency adjusted for the existence of virtual currencies = Money demand for transaction purposes – (money demand for transaction purposes * replacement rate x).*



The x refers to the replacement percentage; thus the percentage of traditional money transactions being replaced by virtual currencies transactions.

Formula (2) calculates the money demand for transaction purposes adjusted for virtual currency. Formula (3) calculates the money demand for speculation purposes adjusted for virtual currency. This is done in a similar way, subtracting the loss of money demand due to virtual currency (money demand speculative purpose times replacement rate z) from the money demand for speculative purposes. This gives the adjusted money demand for speculative purposes.

*(3). Money demand for speculative purposes adjusted for the existence of virtual currency = Money demand for speculative purposes – (money demand for speculative purposes * replacement rate z)*



Replacement rate z refers to the percentage of reduction in money demand for speculation purposes because of its replacement by speculation trades in virtual currencies.

These formulas (2 and 3) both assume that that the overall money demand stays the same, only the composition changes. When formula (2) and (3) are merged it results in formula (4), this is the new money market equilibrium. These formulas and adjustments bring Sauer to a simplistic national money market equilibrium model, adjusted for the existence of virtual currency:

(4) Money supply adjusted for existence of virtual currencies = Money demand for transaction purposes in national currency adjusted for the existence of virtual currencies + Money demand for speculative purposes adjusted for the existence of virtual currency

Regarding formula (4) Sauer notes that this equation “implies that money supply has to be reduced by the central bank to satisfy the decreased demand for the national currency to avoid adjustments via the interest rate” (Sauer, p. 122). This implication will be further discussed under the subsection risk, where it shows that an increased private e-currency reduces the central bank its control and thus the effectiveness of monetary policy.

Another way to calculate money supply adjusted would be with formula (5):

*(5) Adjusted money supply = Money supply (before adjustment) * (national share of virtual currency supply n * Bitcoin supply * Bitcoin price).*

With n = replacement share of supply; thus that part of supply that is replaced by bitcoins.

This in turn would lead to the equilibrium:

Adjusted money supply = adjusted money demand

This model shows that adding the variable “replacement percentage” (illustrated with x, z and n) into the familiar Keynesian framework results in a basic model to determine effects of a parallel virtual currency. In order to get results, and thus consequences, for this model she uses her theoretical model combined with the risks as identified by the European Central Bank. The next subsection focusses on these risks and Sauer’s thoughts on these risks. Although being relatively simple, this model paves the way for a new thinking about how to react on changes such as the rise of private e-currency and its policy implications. It is a good first path for policymakers to get a better understanding about possible effects of private e-currency and how they could exploit some of the benefits of the technology behind it.

3.2 Risks

Nowadays the share of private e-currency as part of the economy is still very low, in the article Sauer finds a replacement rate n of about 0.03-0.04%. Although this rate was based on a Bitcoin price of $200 and the maximum supply of 18 million. The $200 Bitcoin prices rose towards $4000[4] in the summer of 2017, but even with a price of $4000 the replacement share would be far away from being significant. Bitcoin is, however, not the only private e-currency around and private e-currencies are still sharply on the rise. Therefore it is still useful and

[4] The price of Bitcoin was at $4100 on August the 13th 2017

important to determine the possible risks in the event that private e-currencies will become more important in the future. In the article Sauer suggests that private e-currencies have the potential to become significantly important in the future. The consequences of a significant important private e-currency will be discussed according to three important risks for central banks, those risks are:

- Risks to price stability
- Risks to financial stability
- Risks to payment system stability

Price stability risk

The main price stability risk of private e-currency is the adjustment of the quantity of national money. The quantity of national money supply will be reduced when private e-currency gain a more significant share of the money supply. The total quantity of both national and private e-currency money needs to stay equal despite the share of replacement, thus the higher the replacement rate the lower the share of national money in the economy. This lower share of national money would result in a loss of control for the central bank and with it a main instrument in regulating inflation and price stability. This risk of losing control on monetary policy to control inflation is influenced by the percentage of national money replaced by e-currency. Because supply of Bitcoins is fixed at 18 million, the central bank can only control price stability and inflation by adjusting monetary policy for the share of the money supply that is controllable by the central bank, thus only the traditional national money supply. Central banks can still control this part, but not the part of private e-currency. Therefore, with an increasing percentage of national money being replaced by private e-currencies it becomes harder for the central banks to control it. This would result in the need to adjust their monetary policy more rigid. Sauer notes that at this moment private e-currencies are too insignificant to affect real economic indicators, however they have the potential that they could become significant in the future.

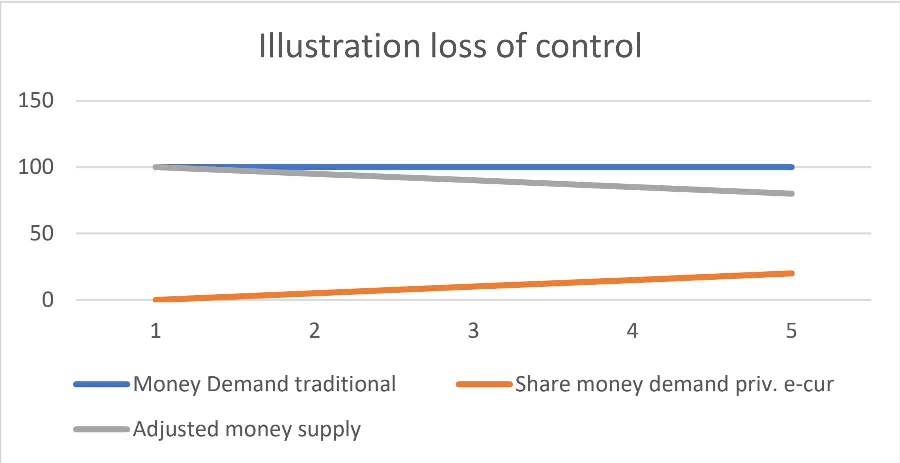
Financial Stability risk

Financial stability can be influenced by private e-currencies when they influence the foreign exchange rates of currencies among countries. Another risk to financial stability is the vulnerability of virtual currencies to fraud and hackers. But at this moment the share of virtual currencies in the economy is too low to have any serious impact.

Payment system stability risks

The main risk to the payment systems is volatility of private e-currencies, but similar to the previous discussed risks, also the payment system stability risk is not applicable in the current situation as private e-currencies still have a minimum share in the economy.

Sauer's model is about the national money market equilibrium, where demand and supply should be similar in order to achieve equilibrium. Money supply = National currency supply + Virtual currency supply. Also, when virtual currency supply is increasing the share of national currency supply decreases and thus the effects of monetary policy by the central bank has to be of a higher magnitude before achieving equilibrium again.



Graph 4: illustration loss of control.

Graph 4 shows that when the share of private e-currency in the economy rises, the adjusted money supply (and demand) will go down. Thus the central bank its monetary policy has to be of a higher magnitude in order to achieve the same effect as it would have without the existence of a significant important private e-currency.

3.3 Conclusion

Despite mentioning earlier that virtual currencies have the principle to become parallel currencies Sauer concludes that Bitcoin and other virtual currencies at this moment are not ready to become a substitute for, or parallel currency next to, traditional currencies and thus do not form an important risk for central banks at the moment. The current replacement rates (in the formulas variables x, z and n) are still very low and thus do not form a real threat for the central bank at the moment. She does however recognize the potential threats and challenges it could cause for policymakers when an increasing percentage of national money will be replaced by private e-currencies. She states that an increasing percentage of e-currency would result in a reduced ability for the central bank to control monetary policy. The author recommends central banks to respond much stronger to money demand changes if a private parallel virtual currency becomes relevant, in order to remain an equilibrium in the money market. Also, it is recommended that the central bank monitors the development of virtual currencies closely and collect data of its development in order to be able to react accordingly when necessary.

3.4 Limitations

The author makes a simple model based on a lot of assumptions. For example, one of the assumptions made is that private e-currencies are regulated and thus private e-currencies are treated as a perfect substitute for traditional currency. In the current situation this is absolute not the case as Bitcoin for example is not regulated and decentralized. Despite this, Sauer herself argues that Bitcoin in the current situation is far from being a perfect substitute.

Although the author bases her recommendations on the simple model it might seem that because of the not so realistic assumptions, the created model is not very worthwhile at the moment. This is not correct as the model provides a guideline on what a fully implemented private e-currency could mean. The main focus of the article should be on the consequences and risks for the central bank. These risks are important to keep into consideration when discussing the future of e-currency.

Central banks have a reputational risk that can be influenced if a private e-currency, like Bitcoin, fails or if something happens, for example hacking. People could be assuming it is the government and central bank their responsibility to act and regulate private e-currency and thus preventing failures like that from happening. Although Sauer concludes reputational risk is not present for central banks, it could be considered present for part of the general population. A vast majority of the population may seem to think that the central bank is the main responsible party IF a private e-currency fails. A failing private e-currency might result in a similar situation as a bank run with traditional banks, which is losing trust in the entire financial system.

What is missing in the article is a clear illustration of how further development of private e-currency will affect the central bank its controlling power. In section five, the discussion, a graphical illustration is given which will elaborate on this.

In the next core article a Central Bank issued Digital Currency (CBDC) is assumed. The contributions from this paper, about the potential dangers and risks for the central bank, are used to see how this affects CBDC.

4. Economic consequences of central bank issued digital currency, Barrdear and Kumhof (2016): "The macroeconomics of central bank issued digital currency"

This section starts with an overview and explanation of the Central Bank issued Digital Currency (CBDC) regime. After that the qualitative part of the analysis focusses on the theoretical potential risks and benefits of a CBDC regime. This is followed by the quantitative analysis where the model behind CBDC will be elaborated on. After this the main part of this section consists of the implications and advantages of CBDC for (monetary) policy. It will finish with some critique on and limitations of the article. This section gives an in-depth analysis of the consequences of CBDC implementation for policymakers. The findings of this section will be used to discuss these consequences of a CBDC regime for policymakers and compare it with the findings from Sauer (2016) in the discussion, section 5.

4.1 CBDC regime

In this paper the authors, who work for the bank of England, assume a model with a CBDC regime. This regime consists of a single government-defined unit of account. Thus, there is no competition from other private (e-)currencies. In order to better understand the implications for monetary policy the CBDC regime will be described. CBDC is interest bearing 24/7 universal access to the national currency denominated balance sheet of the central bank. CBDC is issued and exchanged against government bonds, for the CBDC-regime the authors assume that 30% of GDP is issued as CBDC by the central bank and can be obtained by exchanging government bonds until the 30% threshold is reached. Thus, in order for a person to obtain one unit of CBDC a government bond of the same one unit value must be obtained first, for example via a broker, and offered to the central bank in exchange for CBDC. Their CBDC regime would be a decentralized system with distributed ledges. The authors do not have an opinion about who keeps the ledges, but it can be assumed that CBDC would work with a distributed but commissioned system. A commissioned system would mean that the central authority, the central bank, can appoint third parties who verify transactions. The verifier of the transactions receives a commission for doing this, similar to the mining fee for Bitcoin verifications. Thus this commissioned system would be in between a fully centralized (such as traditional cash) and a fully decentralized (such as Bitcoin, which is described in section two) system. Ledgers would be distributed, but the central authority will keep control about who participates. Universal access to the balance sheet of a central bank is not new, it already exists via banknotes for example. However, an important difference between CBDC and traditional money is that traditional money does not bear interest while CBDC does bear interest. This interest rate is set by the central bank.

4.2 Qualitative part: potential issues and benefits

In order to find out the potential consequences of CBDC issuance for monetary policy, the consequences of CBDC for the two most important objectives in monetary policy should be discussed. Recalling from the literature review, these objectives are maintaining price stability and financial stability. Next to this, some structural issues regarding CBDC will be described.

4.2.1 Structural issues

The structural consequences of CBDC issuance are described here. An introduction of CBDC will lead to a lower interest rates on government bonds. This lower interest rate is due to lower interest burden as the government now uses both CBDC and government bonds to finance its debts, rather than only government bonds. And the interest paid on CBDC is lower than they pay on their bonds. This thus leads to a general lower interest rate on government bonds because the debt is more sustainable. Also, the central bank can use CBDC to buy government bonds (QE, open market operations) and thus lowering the interest rate. As described in the literature review, this leads to lower interest rates in general, resulting in reducing the costs of borrowing and a stimulating effect on the economy. Because CBDC is issued against government bonds and supply can be adjusted this can be used to countercyclically stimulate or slowdown the economy when needed. The “savings” on the lower interest burden could be used to reduce taxes or can be used to facilitate government spending, which both contribute to a positive effect for the economy as a whole.

Another contribution of CBDC is that it reduces costs for operating the payment system and lowers transaction costs due to improved settlement efficiency because of its technological advances. The increased competition among payment providers for verifying CBDC transactions and for account services, such as deposit accounts, would lead to lower fees and faster adoption of technologies.

A decentralized system, such as proposed in the CBDC, would allow 24/7 operations, because transactions can be verified at any time via the blockchain structure, which also contributes to lower costs and more efficient usage of the payment system.

The conclusion regarding structural issues is that the "implementation of a CBDC system would be a net positive for the steady-state economy" (Barrdear & Kumhof, 2016, p. 12). This is because CBDC issuance gives the central bank additional opportunities to use their monetary policy in order to stimulate the economy. And in addition the government will lower taxes or increase its spending, which can all contribute to a better performing economy.

4.2.2 Price and output stability

Next the consequences of CBDC on maintaining price stability, which belongs to the main objective of the central bank, are described.

First of all, CBDC gives the central bank the opportunity to control money quantity relative to GDP and the spread between policy interest rates and interest on CBDC (as opposed to deposit interest rates). This gives the central bank additional measures to stimulate the economy and influence inflation rates. If the central banks needs another measure to stimulate the economy, then a countercyclical open market operation or quantitative easing (QE) of CBDC has a **potentially** greater efficacy than traditional QE because it goes directly into the economy rather than via commercial banks (Barrdear & Kumhof, 2016). This feels intuitively wrong when the multiplier effect of traditional QE is taken into account. A discussion about this is held under the critique subsection of this article .

Also the zero lower bound (0% interest rate) could vanish, as CBDC cannot be easily converted to be in physical possession, which will not incur a negative interest rate. CBDC cannot be just withdraw from the central bank balance sheet as you can do with your debit card. There is no physical form of CBDC, it is merely digital, thus CBDC remains digital until the moment it is spend on something. If the interest on saving deposits at a commercial bank becomes negative it will rationally be cheaper to withdraw the money and put it under your mattress. CBDC can be converted back to government bonds and government bonds into cash, but this is not easily done and thus CBDC provides central banks with the possibility of removing the lower interest bound. Therefore it is possible to have a negative interest rate on

CBDC.

Another advantage of CBDC is the possibility for data mining through data availability. CBDC offers real time insight in economical reactions to shocks or policies, giving the policymakers opportunities to observe the consequences of their policies faster and adopt their policies quicker.

The conclusion of this part is again positive for CBDC, the most important contribution comes from more monetary policy instruments via interest spread and quantity control.

4.2.3 Financial stability

Until now the consequences of CBDC merely looked positive, however there are also negative consequences possible. There are two main risks that could result from CBDC issues. The first risk is associated with the transition from a conventional to a CBDC regime, such as a reliable infrastructure and hacker-proof systems. In general, uncalculated introduction problems. The second risk has to do with possible economy wide runs from bank deposits to CBDC. The authors try to develop their model to minimize this risk via a flexible CBDC interest rate. A possible scenario when commercial bank's balance sheets shrink is when banks own a large portion of government bonds and sell these to households to give them the opportunity to trade these bonds against CBDC. But this scenario would not impact banks negatively in general. Another way for households to acquire bonds to trade against CBDC would be to buy bonds from financial investors. Also related to risks for commercial banks is the partial removal of too big to fail concerns for commercial banks. With the introduction of a CBDC-regime a bank failure would not necessarily lead to huge disruption for the payment system. With CBDC the central bank has a backup system and could put a resolution in place, for example offering deposit holders CBDC for their deposits, in case something goes wrong. This could be a benefit for the tax payers (who do not have to bail out banks that are too big to fail) but for commercial banks it could mean that the risks they can take in their daily business will be reduced.

A positive consequences of CBDC is that it could serve as an alternative when a bank its system fails. For example when there is an IT-disruption with a bank its payment system the CBDC distributed payment system offers a robust alternative. And lastly, similar as for price stability the huge pile of data can help in achieving financial stability by analyzing the interconnectedness of financial systems.

When it comes to financial stability there are benefits (alternative payment system, data availability) but also risks. The most important one being the transition to an unknown and untested new monetary and financial environment, when introducing a CBDC regime.

4.3 Quantitative part

In the previous subsection a qualitative overview of the risks and benefits of CBDC introduction is given. In order to get a better understand of the consequences of CBDC the quantitative consequences of a CBDC-regime are now discussed. Barrdear and Kumhoff use a macroeconomic model to which they add CBDC specific variables. The authors describe their model in detail in the model subsection of the paper. They go in-depth about how they create the CBDC framework model. It is mainly based on a DSGE model with extensive calculations. They say: “Our model should be familiar to central bankers and academics, because it starts from a canonical New Keynesian monetary model with nominal and real frictions”. With this model they are able to provide detailed forecasts for the introduction of a CBDC-regime. In this subsection some of the main assumptions of the model are explained after which the focus is on the results of the Barrdear and Kumhoff paper and what these mean for policymakers.

4.3.1 The model

Their model consists of four agent categories and a government that determines policies. These agent categories are commercial banks, households, financial investors and unions and together they influence and form the basic upon the monetary policy can be conducted. Each agent maximizes their objective function and all the objective functions together form the framework for the CBDC model. This article describes a broad range of implications for each category. Because of time related considerations this thesis mainly focusses on the government policy implications and the consequences of a CBDC-regime on the central bank’s monetary policy, as this better contributes in answering the main question of this thesis. Therefore the elaboration of the individual agent categories is limited to explaining the objective function. After which a discussion about the government setting their fiscal and monetary policies and how an equilibrium is reached with this model is held. However, in the appendix a more extensive overview of additional characteristics and elaboration on the model is provided per category.

Commercial banks

The objective of banks is to maximize their pre-dividend net worth, given by

(4) $pre\ dividend\ net\ worth = Gross\ returns\ loans - (interest\ expenses + loan\ losses + penalties\ paid)$

Maximizing this objective is subjected to the penalty cutoff constraint. This penalty cutoff constraint is:

(2) $$Net\ worth < Y * risk\ weighted\ assets$$

Where Y refers to the minimum capital adequacy ratio. So, banks maximize (4) subjected to (2) in order to reach their objective.

Households

For household the objective is maximizing their lifetime utility function, given by (7). This utility depends on shock to marginal utility of consumption, degree of habit persistence, the labor supply elasticity and the utility weights of hours worked and land. Maximizing lifetime utility is subjected to the budget constraint (16), demand for output constraint (17) and capital accumulation (18)[5].

Financial investors

The utility function of financial investors is similar to those of households, with the absence of land and the presence of monetary transaction balances. Thus, financial investors their lifetime utility function (48) is maximized and subjected to budget constraint (51)[6].

Unions

The unions category is managed by households and financial investors. The unions optimization problem depends on the budget constraints of financial investors and households. Thus, unions maximize (56) subjected to (57) and (58)[7].

[5] The formulas (7), (16), (17) and (18) are shown in the appendix

[6] These can be found in the appendix

[7] The full formulas can be found in the appendix

Fiscal policy

The fiscal policy of the government is based on the deficit to GDP ratio. The government sets a target for this ratio and its spending and tax rates depend on this. A simplified version of its fiscal policy is:

$$Deficit\ to\ GDP\ target = Tax\ incomes - Spending$$

This is the baseline fiscal policy for a pre-CBDC regime. When calculating fiscal policy for a CBDC regime the deficit to GDP ratio is adjusted for CBDC by adding a variable to the formula. This variable is the change of CBDC stock which is added to the government debt. As explained under fiscal calibration the total government financing will consists of 50% government debt and 30% CBDC. This results in a lower average costs of government financing, these lower costs are used to reduce the distortionary taxes or increase government spending. The authors choose to only look at the consequences of one of the two scenarios and decided to apply the “savings” due to a lower cost of government financing towards a reduction in distortionary taxes. They did not further elaborate on why they chose this. Thus, the fiscal policy after introducing a CBDC regime consists of lower distortionary taxes for labor income, capital income and consumption taxes.

Monetary policy

The monetary policy under the pre-CBDC regime is the same as the current familiar conventional monetary policy as described in the literature review. Thus, this subsection focusses on how the monetary policy looks like under a CBDC-regime.

Monetary policy under CBDC consists of two instruments. The first instrument is the same inflation forecast-based interest rules as traditional non CBDC-regimes, with the policy interest rate as an instrument to control the economy. It gets interesting with the second monetary policy instrument, which is either a quantity or a price rule for CBDC.

The first option for the additional monetary instrument that is proposed in the model is **the quantity rule for CBDC**. The quantity rule for CBDC enables the central bank to fix the ratio of CBDC to GDP at a target value (in steady economic state) and to let this ratio fluctuate according to countercyclical needs. For example, when inflation is expected to be above its target, CBDC will be removed from circulation by selling government bonds for CBDC, this will have a countercyclical effect. This effect has more impact than solely changing the policy rate because the removal of CBDC from circulation result in a withdraw of liquidity which can only be replaced with more expensive bank deposits[8]. This leads to a decrease in economic activity. The scarcity of CBDC, after withdrawing it from circulation, will eventually lead to a lower interest rate on CBDC.

As an alternative to the quantity rule the authors propose **the price rule for CBDC**, which gives the central bank the opportunity to determine the interest paid on CBDC. The steady state refers to the situation with a fixed spread between the interest on CBDC and the policy interest rate. During times of higher inflation CBDC interest rate will be lowered, making CBDC less attractive and agents will exchange it back to government bonds. The consequences for the economy are the same as under the CBDC quantity rule, because both situations lead to a lower interest rate on CBDC and thus a decrease in economic activity.

The quantity and price rules work for CBDC because CBDC supply is not controlled by commercial banks but by the central bank, opposed to traditional money supply. Traditional money supply consists of M1 (banknotes, coins and overnight deposits), M2 (M1 + short term saving deposits) and M3. Only part of M1, the banknotes and coins, is controlled by the central bank and M2 and M3 are generally controlled by commercial banks (ECB, 2017). Thus with these quantity and price rules an additional instrument for monetary policy becomes available for the central bank. In order for this new monetary instrument to be effective the quantity of CBDC must be large enough to conduct sizeable CBDC quantity withdraws when deemed necessary, for example to cool down an economic boom and prevent overheating. The authors choose a CBDC quantity equal to 30% of GDP[9] in order to make the steady state calculations. A sufficient large amount of CBDC needs to be available to be used by the agents in order to exploit the benefits and consequences of CBDC.

Equilibrium and market clearing

Markets clear and equilibrium is reached for CBDC when every agent maximizes their objective function subjected to their constraints. Banks maximize pre-dividend net worth subjected to the penalty cutoff constraint. Households maximize their lifetime utility function subjected to their budget constraint. Financial investors also maximize their utility function

[8] Interest rates on CBDC are lower than deposit interest rates, this will be elaborated in the calibration/result subsection.
[9] 30% is also similar to the magnitude of QE's conducted by central banks over the last decade.

subjected to their budget constraints. The government follows their fiscal and monetary policies. The new fiscal policy under CBDC is adjusting the deficit to GDP ratio by adding the consequences of CBDC stock in the economy. The monetary policies are the traditional inflation-forecasted interest rate rule together with one of the two new instruments, price or quantity rule for CBDC. When all these elements come together an equilibrium is reached, markets clear and the effects of a CBDC regime become visible.

4.3.2 Calibration

Now that the main assumptions of the model and how it effects monetary policy is described it is time to assign parameters to the model and run it, in order to get results which show how CBDC effects the economy and particularly, the monetary policy. This is called calibration, in order to do so three phases are assumed, the pre-CBDC, transition to CBDC and fully implemented CBDC phase. This subsection shows which values are assigned to the parameters in the three models. Some parameters are mentioned but not each of them is discussed in detail. For the calibration the United States pre-crisis setting with normal economic times is used to implement the model. Data from the period 1990-2006 is used.

Pre-CBDC economy (baseline)

This reflects setting the parameters during a traditional economy without a CBDC regime, for example a 2% growth rate and a 3% inflation target is used. Government spending to GDP is set at 18%, its historical average. The initial tax rates are set at historical average percentages respective to GDP, which imply tax rates of 31.7% for labor, 24.8% for capital income and 7.3% for consumption, it is good to take those into account as the authors expect that CBDC would result in reduced taxation. The fiscal output gap, which is characterized by "the magnitude of automatic stabilizer effects" is set at 0.34 (Barrdear & Kumhof, 2016, p. 43). Total government financing (Government debt + CBDC) will be put at 80%, both during pre-CBDC as well as after CBDC introduction. Although the government debt will be less risky after CBDC introduction. The Elasticity of Real Risk-Free Rate w.r.t. Gov.Debt/GDP will be calibrated at 2 basis points per percentage change.

Interest rate margin (difference between policy rate and bank deposit rate) is set at 1.00%. This will lead to a policy rate of 3% and a deposit rate of 2%. This is based on the average margin in the sample period of 1.34% and adjusted downwards to correct for higher interest rates on non-financial assets which were not taken into account for the average margin in the sample period.

CBDC-transition phase

For this phase the baseline parameters are used and, where applicable, CBDC-specific parameters are added to this baseline model. The introduction of CBDC takes places with an instantaneously issuance of CBDC equal to 30% of GDP through an exchange of government bonds against CBDC. One of the parameters that changes is government debt. Government debt will be reduced from 80% to 50% after the issuance of CBDC, but the total government financing remains unchanged at 80% as government financing now exists of 50% government debts and 30% CBDC. Because the government debt is substantially reduced after CBDC implantation the interest paid on government bonds will likely drop.

Regarding Fiscal policy the fiscal output gap, which was put at 0.34 for the pre-CBDC phase, will be increased to 0.50. This is done to account for the higher economic output in the long run. The interest rate spread between commercial bank deposits and CBDC is set at 80 basis points for this phase. Which implies a CBDC interest rate of 1,2%, when the deposit rate is kept at 2.0%.

CBDC post transition phase

For the post transition phase the allocation of CBDC is determined. In order to do this the combined parameters of the pre-CBDC phase and the transition phase are used. The main finding here is the interest semi-elasticity of 34% between CBDC and deposits. This implies that for every one percentage point "increase in the CBDC interest rate relative to the deposit rate, and holding deposit rate constant, demand for CBDC would increase by around one third, or 10 percent of GDP" (Barrdear & Kumhof, 2016, p. 50). Thus, when the CBDC interest spread between CBDC-interest and deposit interest changes, this adjusts the demand for CBDC, which is relevant in order to execute monetary policies via a price rule.

4.3.3 Results

Next up the results of the model, and thus its economic consequences will be discussed.
The results will be discussed by using the following categories:

- Steady state effects of the transition to CBDC

- Quantity or Price Rules for CBDC
- Countercyclical CBDC policy rules
- Fiscal policy interactions with CBDC

When discussing these categories the focus is on the monetary and policy implications. Deviations are mentioned as a deviation of the trend, so if GDP growth deviates 1% upward of the trend it would mean that instead of the 2% target the growth is 3%.

Steady state effects of the transition to CBDC

GDP growth is forecasted to rise 2,94% after CBDC introduction, with the monetary assumption of inflation forecasted based interest rule and 30% of GDP as CBDC, as well as the lower distortionary taxes discussed under the model subsection. The four main reasons for this GDP growth are reductions in real policy interest rates, increases in deposit rates relative to policy rates, reductions in distortionary taxes and reductions in liquidity tax rates.

Executing the model will result in a drop of the policy rate from 3.0% to 2.4%. The spread between deposit and policy rates is determined by financial investors trading their government bonds for deposits with households upon introduction of CBDC. Households can use those acquired government bonds in order to obtain CBDC. Because households will supply their deposits (in order to exchange them with financial investors for government bonds) the interest rate for these deposits relative to the policy rate will increase. The deposit rate will only decrease 0.3% to 1.7%, setting the spread at 0.7%. These lower interest rates will reduce the cost of borrowing and thus stimulate the economy, partially contributing to the nearly 3% increase of GDP.

The other part of the contribution to the GDP growth comes from tax reductions. These tax reductions are possible because of lower financing costs for the government. As mentioned before the government debt financing after CBDC implementation consists of 50% government debt and 30% CBDC. After implementing CBDC the government pays 2.4% instead of 3.0% on their government debt part and 0.9% instead of 1.2% on their CBDC part[10]. These lower interest rates lead to a lower cost of financing the government as explained under the fiscal policy and can be used to cut back on tax rates. The authors find

[10] Calculations are based on elasticity formulas in the Barrdear and Kumhof article

that labor income tax can be reduced with 1,32%, capital income tax by 1,03% and consumption tax by 0,3%. These lower taxes in turn lead to more purchasing power and thus higher spending for the population, which stimulates the economy, contributing to the increase of GDP.

Quantity rules or price rules for CBDC

This paragraph examines the difference in economic results, measured as GDP growth, between the quantity rule and the price rule for CBDC. In general the differences are small and both rules show similar results which are both countercyclical. For real economic shocks the difference between quantity and price rule are in particular small. The largest observed difference is when only the central bank can provide liquidity and interest rates on CBDC under quantity rules differ from interest rates on CBDC under policy rules. Although, this difference is still relatively small. The main conclusion is that it would be hard for policymakers to establish a spread between policy and CBDC rate under a price rule quickly upon introducing CBDC. Therefore they suggest starting with a quantity rule in order to determine the spread and after a reasonable amount of time switching to the price rule.

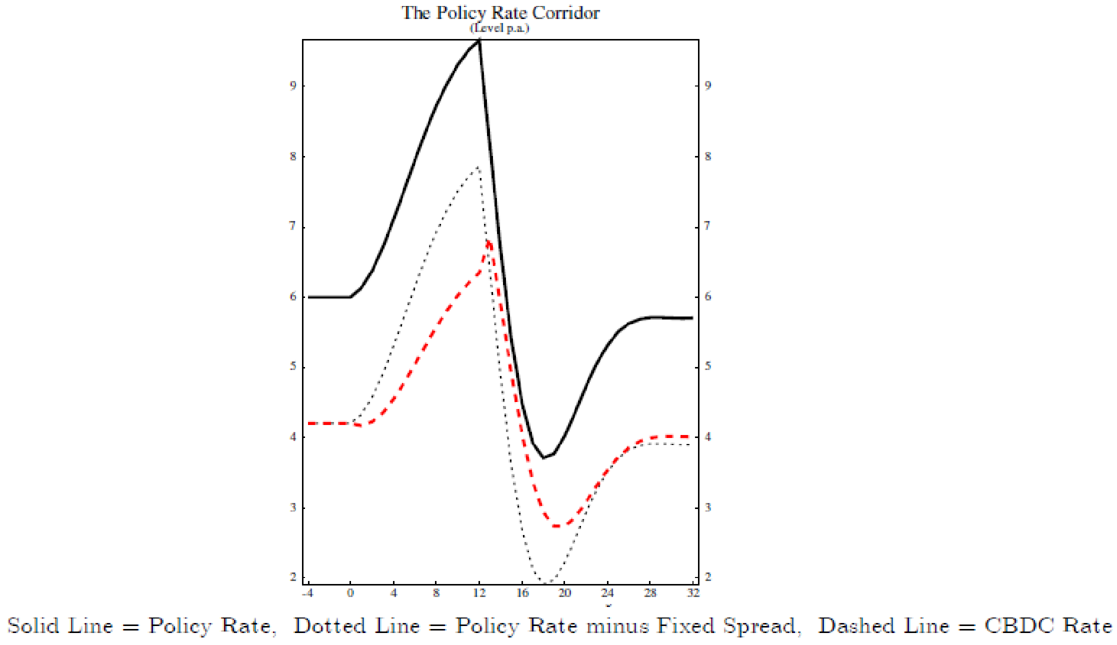
Countercyclical CBDC policy rules

Countercyclical policy refers to the monetary policy of using inflation forecasted based interest policy and one of the additional instruments, either quantity or price rules. An important finding is that both quantity and price rules have similar effects to shocks. Two examples are now given, the examples are hypothetical and based on the quantity and policy rules as described in the model.

Assume a quantity CBDC rule where a one percentage point inflation deviation above the inflation target results in 8% of CBDC is being withdrawn from circulation. If the expected inflation is 2% above the target this means that 16% of CBDC needs to be withdrawn by selling government debt/bonds. This leads to scarcity of CBDC and thus a lower interest rate, making CBDC less attractive. After the expected inflation is reduced and it drops below the target, extra CBDC is injected into circulation. This will tamper the booms and weaken the crashes.

For a price rule, the effects are very similar. Recall that a price rule lets the government fix the spread between CBDC interest rate and policy rate for the steady state and the government is able to adjust the spread during booms and busts. Assume that for every percentage the inflation deviates above its target the CBDC interest rate is lowered by 80 basis points (0.8%). Assume the same situation as discussed under the quantity rule, with expected inflation 2% above the target. This would result in the central bank lowering the CBDC interest rate with 1.6%, increasing the spread between the policy rate and the CBDC interest rate. This increased spread will result in CBDC being less attractive and thus a tampering effect on the economic boom. Note that the CBDC does not have a zero lower bound as CBDC cannot be easily converted into cash and thus the CBDC interest rate can be negative.

The degree of quantity and price rules can vary, thus the numbers in the above examples can be lower, but also higher. Graph 5 illustrates how a monetary policy under a CBDC could look like. It shows that the policy rate rises during a boom while the spread between CBDC-rate and policy rate drops, as explained in the two examples above this results in a withdraw of CBDC from circulation and results in a tampering effect of the boom, thus preventing overheating of the economy. During a downturn the opposite happens and the bust is weakened.



Graph 5: Sketch of the price rule under CBDC regime (Barrdear & Kumhof, 2016, p. 82).

Fiscal policy interactions with CBDC

Countercyclical monetary policy will tamper the influence of fiscal policy on GDP growth. The above mentioned countercyclical monetary policy, reducing CBDC quantity in a boom and injecting CBDC in a bust, leads to lower government interest expenses (because less government debt) in good economic times and higher interest expenses in bad economic times. Figure 1 below shows the CBDC quantity rule at work in both good as bad economic times. The authors find "sizeable gains in the effectiveness of systematic or discretionary countercyclical monetary policy" (Barrdear & Kumhof, 2016, p. 66), showing that monetary policy becomes more effective under CBDC. Thus the conclusion from the results is that CBDC can contribute significantly to economic growth and it gives new opportunities for monetary and fiscal policy.

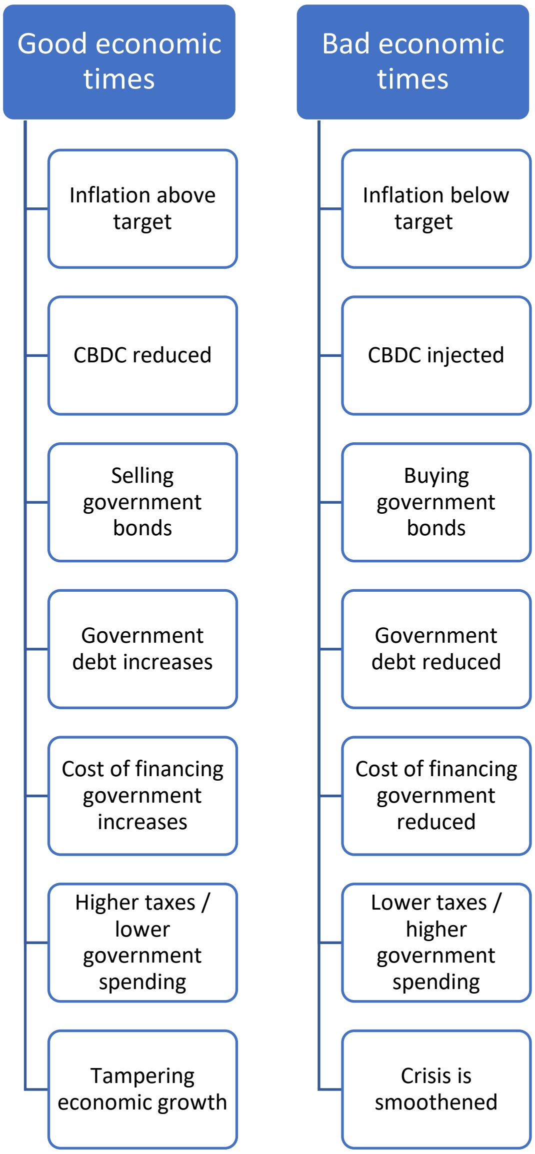


Figure 1: schematic overview of how the quantity rule for CBDC works.

4.3.4 Role of private e-currency and other issues

Under a CBDC regime the central bank is in charge of the money supply. This will result in a limited or nonexistent role of other private currencies. The only role given to private currencies is in the form of deposits at commercial banks. This implies that a private e-currency such as Bitcoin does not exists in their economy, as the only one who can issue money is the central bank.

Currently a private e-currencies like Bitcoin can only facilitate 3500 transactions per hour, which is not that much. Next to this, the total electricity usage is high (Barrdear & Kumhof, 2016). When implementing a CBDC regime on a bigger scale it should be able to facilitate all the transactions that are demanded. A suggestion might be to find another method for transaction verification. This could be a central authority or a commissioned system where different verifiers work together.

As mentioned under financial stability, transitioning to a new untested system can cause significant risks. One of these risks is the possibility for a bank run from bank deposits at commercial banks to CBDC. The assumed situation would be that a lot of people want to convert their bank deposits to CBDC, similar to how the Guilder or Deutsche Marks was converted to the Euro in 2002. This conversion could result in a huge decrease of bank deposits and thus a “bank run”. However, the authors argue that this is not the case with CBDC because CBDC can only be issued against government debt, thus a CBDC issuance would cause a significant drop in private government debt and only a small reduction in commercial bank deposits.

4.4 Conclusion

The qualitative part of the analysis concluded that regarding structural issues the CBDC system would be positive for the steady-state economy and it will give the central bank additional instruments to execute their monetary policy. This has been confirmed by the quantitative part of the analysis which showed an overall GDP growth of 3% when 30% of GDP is issued as CBDC. This 3% GDP growth is originating from a higher government budget, which is used to cut back on distortionary taxes, and a stimulating effect which is caused by lower costs of borrowing resulting from lower interest rates. The additional instrument for the central bank to execute monetary policy has also been confirmed in the quantitative part. In addition to the traditional inflation forecasted based interest policy, the central bank can choose between a quantity or a price rule for CBDC in order to more effectively conduct their monetary policy.

So CBDC will not only be beneficial for economic growth, but it will also improve the effectiveness of monetary policy, giving the government a chance to smoothen the economic business cycle. This sounds very promising, however, there are also drawbacks to the implementation of CBDC. The most important one being the transition to an unknown and untested new monetary and financial environment and the uncertain new role of commercial banks. These drawbacks/risks will be further discussed in the discussion section.

4.5 Limitations

A limitation of the paper might be that they only use the forecasted based inflation rate to determine their monetary CBDC policy rules. They do not look at other financial variables that can be of influence.

Also did they not thoroughly investigated the possibilities of a bank run after the introduction of a CBDC regime. They mention that a bank run is not very likely after CBDC introduction. In the discussion section bank runs after the introduction of an e-currency are further discussed.

Regarding setting the parameters a point of critique can be that they use relatively old data, because they assume the US economy in the 1990-2006 period. Although they mention that they use recent values, it is unclear what they mean with recent values. Recent values can either refer to recent as in more towards the end of the of the sample period (until 2006) or recent as in that they use values from the last few years (2015 for example).

The authors suggest that under CBDC countercyclical policy, such as QE, becomes more effective because it is injected directly into the economy. Their main argumentation for this is that commercial banks might have an incentive not to use the injected money for lending out money or stimulating activities. Under regular or traditional QE, where liquidity is injected into the economy, the multiplier effect plays an important role. The multiplier can be described as “the short run change in total output resulting from a one unit change in that type of spending” (Bernanke & Abel, 2005, p. 411). A multiplier can be both greater or smaller than 1, and is mostly assumed to be greater than 1 by Keynesians. To illustrate the effect of a multiplier assume the situation that the central bank has a QE program where 50 billion dollar is used to stimulate the economy, this 50 billion can be used to provide cheap borrowing for commercial banks. These commercial banks can use their borrowed funds from the central bank to loan out money to companies and households, which in turn will generate more economic activity. Thus with a multiplier effect greater than 1 the initial 50 billion dollar invested into the economy will result in a greater effect on the economy then just this 50 billion dollar.

The efficiency of QE depends however on the incentives of the commercial banks and how they use their cheaply borrowed funds from the central bank. Commercial banks might have other incentives to partly offset the economic stimulus resulting from the increase of their balance sheets caused by QE. Banks might choose not to lend out money but use the money that they borrowed against a cheap interest rate from the central bank to do other things, for example to fund their deficits and comply with higher capital requirements in times of economic stress. During the aftermath of the financial crisis in 2008 the capital requirements were becoming stricter, and in order for banks to comply with these stricter capital requirements they had an incentive to use the funds from quantitative easing to increase their reserves rather than lending out money (Spaltro, 2013). For CBDC, this is not the case, as CBDC goes directly into the economy without the interference of a commercial bank with possibly other incentives. Thus, the potential of a countercyclical injection of CBDC might have a potentially higher efficacy than traditional QE.

During regular economic times the multiplier effect of commercial banks will be greater than 1 and thus the countercyclical injection of CBDC will have less effect than a countercyclical traditional QE. During extraordinary times, for example a crisis with low bank deficits and higher capital requirements, commercial banks can have the incentive to use injected money for other purposes. In that case the efficacy of CBDC countercyclical injection could **potentially** be higher than traditional QE.

5. Discussion

This section discusses the issues raised in the thesis. It starts with a general discussions about private e-currency, after which the focus is on the stability and monetary policy both under private e-currency as well as its government controlled variant, Central Bank issued Digital Currency (CBDC). One of these issues, the role of commercial banks under CBDC, will be further examined.

5.1 Discussion about private e-currency

The literature review elaborated on private e-currencies, and in particular Bitcoin. After reading the literature and this research one can argue that Bitcoin has flaws such as its limited supply, the degree of anonymity and the huge volatility resulting from speculative trading. Risks resulting from these flaws are crucial when Bitcoin is bound to become a parallel currency and a substitute for conventional money. Bitcoin its potential for becoming influential is overestimated. Bitcoin's role is still very limited, although it has been growing enormous lately. The technology behind Bitcoin currently can only handle circa 3500 transactions per hour, equivalent to the transaction needs of a small city, this is by far not near the rates it should have when becoming influential. Therefore private e-currencies such as Bitcoin should be treated as a speculative mechanism rather than a possible substitute for money. Bitcoin, when looked at on a national scale, does not fulfill the three functions of money, it is not a good method to store value or function as a unit of account because of its volatility and neither is it a suitable medium of exchange because of its limited 3500 transactions per hour and its scarce acceptance (Betlem, 2017). Therefore it can be argued that private e-currencies are overhyped and they might even form a bubble (Betlem, Beursgang met cryptomunt lijkt de nieuwe tulpenmanie, 2017). This does not mean that the technology behind it cannot be of good use for central banks. It will however be important to keep the characteristics and flaws of private e-currency in mind when a government wants to develop their own e-currency based on technology similar to that of Bitcoin. The technology behind e-currency, the blockchain, can be used in order to develop a Central Bank issued Digital Currency which does have the benefits but not the risks that private e-currency has.

5.2 The tradeoff between private e-currency and CBDC

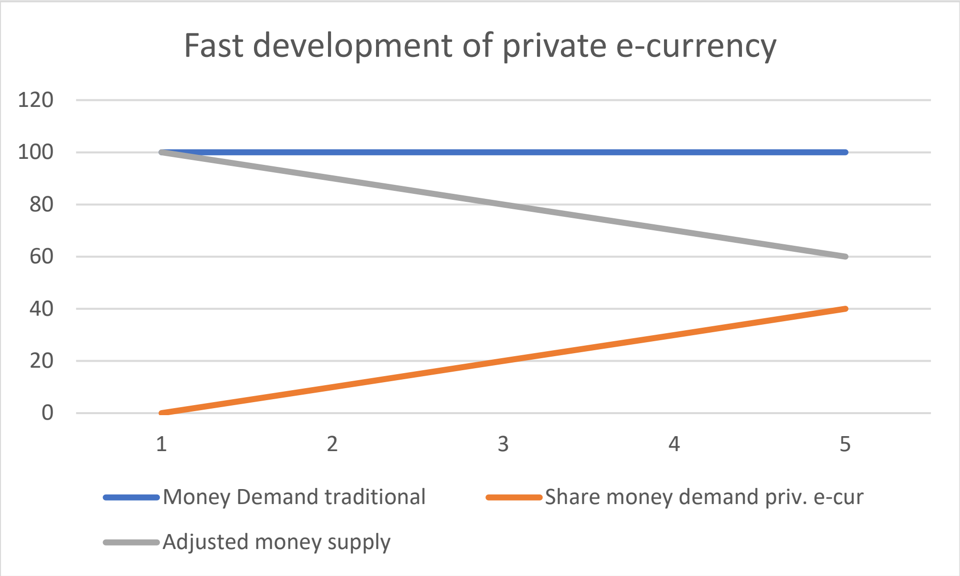
Next, the consequences for the monetary system stability under private e-currency and under CBDC are discussed. Both core articles describe potential consequences for stability. Core article 1 focusses on risks of private e-currency becoming too influential, whereas core article 2 focusses on risks, but also benefits, of implementing CBDC.

5.2.1 Price stability

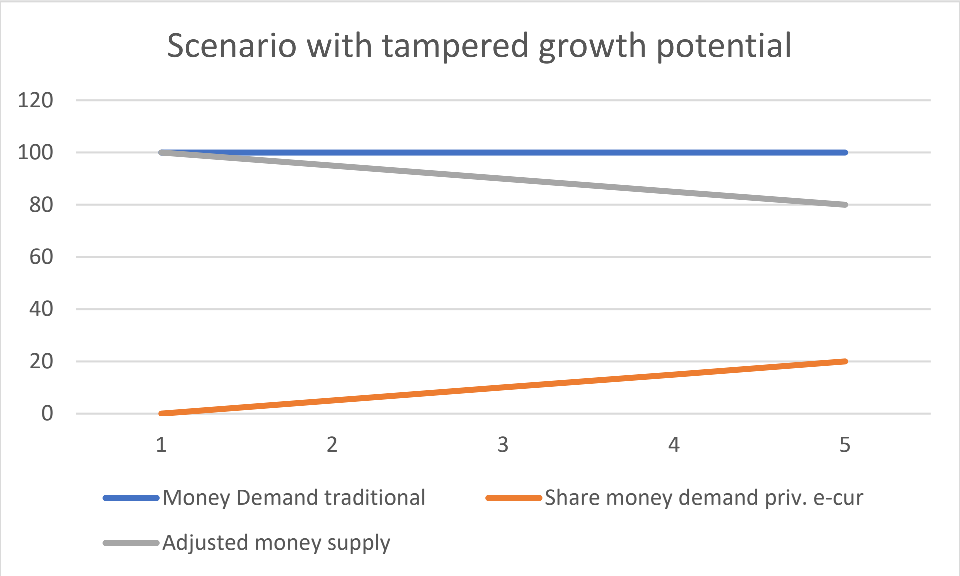
The result on price stability for a situation with an increased role of private e-currency will be compared with the situation where a CBDC-regime exists.

When private e-currency becomes important and influential this adjusts the money supply, as described in Sauer. When money supply gets adjusted by an outside factor, such as a private e-currency, central banks lose their "monopoly" on adjusting the money supply. This leads to the situation that central banks can lose their control on money supply. Therefore they will not be able to execute their monetary policy effectively. Assume for example that 30% of the money supply consists of private e-currency and 70% of central bank money, this would mean that a central bank can only control inflation by adjusting their own supply of money, they do not have control over private e-currency as private e-currency has a fixed supply. This means that when the share money supply consisting of private e-currency increases, the central bank loses more control and their monetary policy becomes less effective.

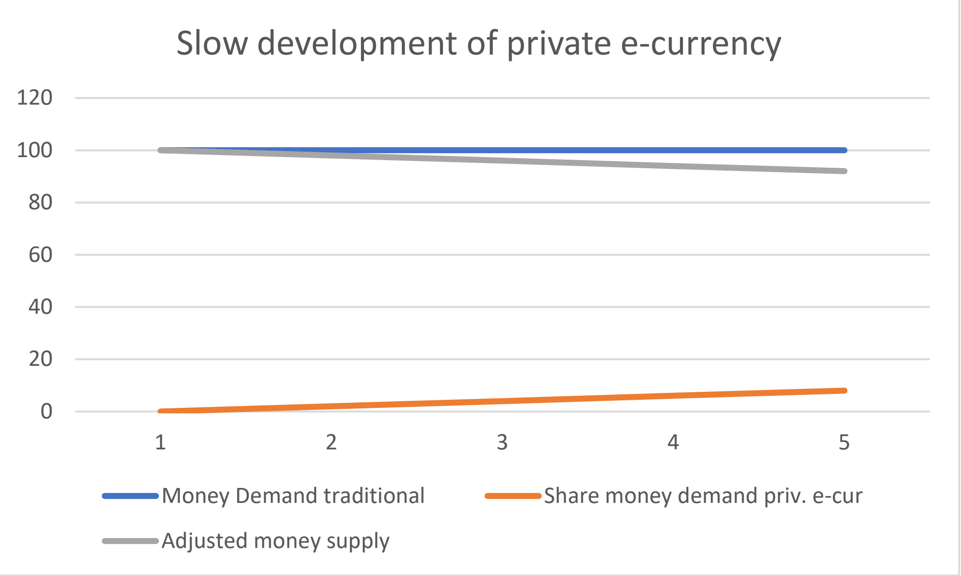
The graphs below illustrate what loss of control can mean for the central bank. The grey line shows the supply of conventional money, the orange line shows the supply of private e-currency and the blue line the total supply of money. Central banks can only control the supply of the grey area, thus the lower this line is, the more the government loses control and the less effective their monetary policy becomes. In these graphical overviews three scenarios are shown: 1) a scenario where private e-currency develops itself fast and becomes increasingly popular, this scenario is what some of the Bitcoin enthusiastic assume will happen on very short notice. This scenario is based on the expectations that Bitcoin can become of huge influence and a substitute for conventional money in the future (Dwyer, 2014). 2) A tampered growth scenario, as assumed in Sauer her article, where the potential for growth is realistic and at the same time the expectations of the degree of this growth are tampered. 3) A scenario where private e-currency does not develop itself, this scenario is assumed by some journalists that are pessimistic about Bitcoin. Those journalist (such as Betlem) assume Bitcoin is a bubble and its influence will not grow significantly in the near future.



Graph 6: scenario 1: fast developing private e-currency.



Graph 7: scenario 2: tampered growth potential.



Graph 8: scenario 3: slow development of private e-currency.

On the other hand, a government controlled e-currency, such as a CBDC regime, would lead to increased control for central banks as they will get an additional instrument, the quantity or price rule instrument, to conduct their monetary policy. Therefore one could argue that CBDC increases price stability through a more effective monetary policy while private e-currency can lead to a less effective monetary policy.

Most of the above mentioned risks for price stability that hold for a private e-currency are omitted for a CBDC-regime because of the fundamental differences. A private e-currency can be seen as a threat to the central bank monetary policy whereas a CBDC-regime is based on the principle of increasing the possibilities and effectiveness of the central bank monetary policy. Considering the fact that a CBDC-regime would lead to more effective monetary policy and private e-currency has a negative impact on the effectiveness of monetary policy it could be argued that private e-currency should be prohibited when implementing a CBDC-regime. Barrdear and Kumhof state in their article that government controlled currency, such as traditional money and CBDC, should be the only legal (crypto)currency and that other currencies only exists in the form of bank deposits. They thus suggest that private e-currencies such as Bitcoin should be prohibited as a form of transaction method. The question arises whether this is possible at all. Bitcoin is something that exists partly in the shadow and is a global phenomenon. It would be a challenge to prohibit the usage of it and to actually enforce this legislation. Bitcoin can have a negative effect on the CBDC-regime and it probably should be prohibited when implementing a CBDC regime. How Bitcoin should be prohibited and if this regulation can be enforced at all because of Bitcoin's worldwide existence are things to keep in mind. Policymakers should think about this issue and how they want to enforce any new legislation on private e-currencies.

5.2.2 Financial Stability

Financial stability issues exists for both private e-currency and for CBDC. When it comes to private e-currency the high volatility of its exchange rate to traditional currency is a risk. Another risk is the vulnerability of fraud and hacking. A CBDC regime deals with similar safety issues and vulnerability to hacks.

Regarding the safety issues that private e-currency deal with, such as the estimate that approximately 10% of the Bitcoin have already been hacked, stolen or lost it is important to gain trust under the population that these risks are very limited before implementing an e-currency on a national scale. The safety risks also holds for government controlled digital currency, such as a CBDC-regime. However, governments have the possibility to use one of their advanced personal identification systems. In the Netherlands for example Digi-D is used, which could be linked to one's CBDC-account. Sweden has a similar system, which might be even closer to this idea, because in Sweden a bankcard and pin code can be used to log on to the online government services, this is called e-ID and is similar to the Dutch online identity, with the innovation that it is already linked to your bank account (European Commission, 2017).

Another risk, and maybe even more important than safety risks, of implementing a CBDC-regime is the risk of transitioning to an unknown and untested monetary system and the changing role of commercial banks under this regime. Implementing a substitute for e-currency, whether it is a private or Central Bank issued, could cause wide bank runs. For a CBDC-regime a bank run would mean that households exchange their savings into CBDC, resulting in a drain from commercial banks reserves. Sauer does not describe the possibility of bank runs from deposit holders to private e-currency. This might have to do with the fact that this risk of bank runs is limited because private e-currencies do not bear interest and thus there will not be a rational reason to exchange saving deposits for a private e-currency besides using private e-currency as means of payment/exchange, which argued before is currently not the case. A CBDC-regime will undoubtedly change the role of commercial banks as we know it now, more about this is discussed under section 5.3.

5.2.3 Role of monetary policy

The introduction of e-currencies in our monetary system will undoubtedly have consequences for the monetary policy. It would result in a division of the money supply, namely a traditional part of money supply and a digital or e-currency part. The traditional part of money supply would consists of the money supply of the central bank as we know it currently. The digital part of money supply will either consists of the share of private e-currency or the share of CBDC of the total money supply. In the situation of private e-currency the share of for example Bitcoin currencies is meant, while for the CBDC the share of government controlled e-currency is meant. The traditional and digital money supply together form the total money supply in the economy.

Regarding monetary policy under the situation with both digital and traditional money supply, the central bank needs to control both the traditional as well as the digital money supply in order to control the total money supply. The traditional money supply can be controlled via inflation-forecasted monetary policy as is currently done by the central bank, not much will change here. For the digital part of money supply the distinction between private e-currency and government controlled e-currency (CBDC) makes a lot of difference. Under private e-currency the digital supply cannot be controlled by the central bank via monetary policy, thus this will be an uncontrolled part of the money supply. The central bank will therefore try to conduct a more rigid monetary policy on the traditional money supply part, in order to have an effect on the total money of the same magnitude as it would have without a digital money supply part. If the digital money supply consists of the government controlled e-currency (CBDC for example) it would give the central bank an additional instrument to conduct their monetary policy. Because CBDC enables the central bank to conduct a price or quantity rule for CBDC, resulting in a more effective monetary policy as it can control the digital part and the traditional part separately with different monetary instruments. Figure 2 illustrates the differences between traditional and digital money supply and the monetary policy instruments the central bank can use to control it.

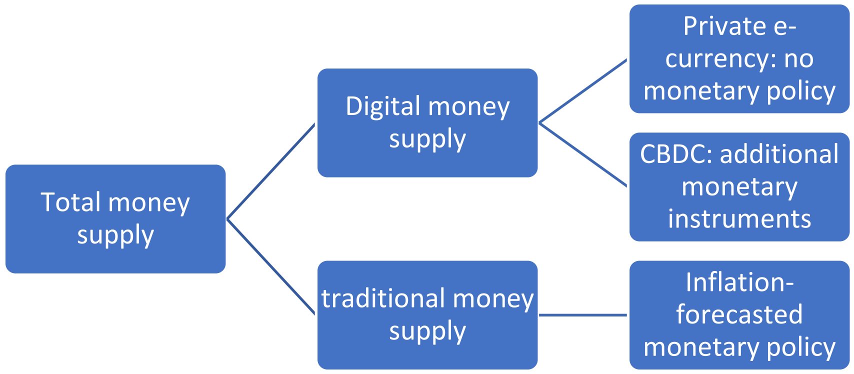


Figure 2: monetary policy with digital and traditional money

5.2.4 Control of the government

The previous subsection showed that a government controlled e-currency enables the central bank to conduct a more diverse monetary policy, leading to a central bank with more control and a more effective monetary policy. This raises the questions if a central bank with more control is desired by the population and why would it be beneficial for the population of a country if their central bank can conduct an effective monetary policy because of additional measures resulting from a CBDC-regime.

Most developed countries have a well-established central bank that is trusted by the majority of its population, next to this the central bank has a historical proven track record of stimulating the economy after crises with their monetary policy (Lothian, 2009). On the other hand, with private e-currencies there would not be a central bank to guarantee stability. History showed multiple examples where failed monetary policy did not benefit the population, and resulted in economic chaos. Thus it could be argued that a central bank should be the one in control and that monetary policy is needed in an effective economic system. This would be beneficial because an effective (countercyclical) monetary policy of a central bank can prevent an overheating economy and weaken economic crises. It can help to maintain price stability and keeps inflation around its target. This will help achieving an overall steady growth of the economy without big cyclical shocks to economic growth. In general people need a government to maintain stability and peace in their country, without a government there is no enforcement of rules and an anarchy can evolve. This is assumed prior knowledge in the literature as can be seen in both core articles. Both articles implicitly assume that interference via the central bank is by definition better than no interference at all.

5.3 Role of commercial banks

To close off the discussion, the changing role of commercial banks under a CBDC regime will be discussed. As earlier argued, a CBDC regime would be beneficial for the monetary policy of a central bank because it brings an additional monetary instrument with it. On the other hand, CBDC can cause some tension when it comes to guaranteeing the financial stability of the monetary system because it changes the current role of commercial banks.

The current main roles of commercial banks is to firstly attract savings from agents with an abundance of money and lending out money to people who have a shortage, banks basically fulfil the middlemen role here. Secondly banks provide a payment service and offer checking accounts and internet banking service to their customers. But under CBDC, it can be assumed that these roles will (partly) change. With CBDC, households will be able to directly store their money on the central bank its balance sheet and it bears interest, which intuitively could result in the above mentioned bank runs. Although the authors from the CBDC model argue that because of CBDC contributing to a GDP growth, the introduction of CBDC would actually lead to an increase of deposits at commercial banks. This argument is supported by the literature, Patrick (1966) already confirmed his demand-following hypothesis, confirming a correlation between economic growth and increased deposits at commercial banks. Another plausible explanation for bank deposits not decreasing under a CBDC-regime is the interest rate margin between the deposit rate and the CBDC rate. A savings deposit at a commercial bank bears 1% more interest in a steady economic state than CBDC bears at the central bank (Barrdear & Kumhof, 2016). As CBDC can only be acquired by exchange government bonds for CBDC, it would not be possible to borrow CBDC from the central bank, thus agents who need to borrow money are still dependent on commercial banks. In other words, the middlemen role of commercial banks will be able to exists without much trouble under a CBDC-regime.

It gets more tricky when it comes to the second role of commercial banks, providing payment services. Because the CBDC-regime is a payment system that enables agents to make payments with CBDC it will directly compete with the traditional banking services, such as providing current accounts, internet banking services and debit cards. It is unclear to which extend CBDC will “take over” these tasks from commercial banks. Commercial banks might need to alter part of their business model. One of the possible new tasks for a commercial bank might be to help the central bank with verifying the CBDC transactions in the blockchain. The CBDC regime by Barrdear and Kumhof is based on a distributed ledger where different kind of payment providers compete for verifications, thus similar to the current blockchain system behind Bitcoins. Banks could fulfill a role in this verification process and compete with each other for the verifications of CBDC transactions. This is one of the many new tasks that future commercial banks might have. This is contrary to the repeatedly used argument that e-currencies eliminate the role of the middleman, often referring to the role of commercial banks. With private e-currencies, there is a bunch of middlemen, the miners, who verify transactions and compete among each other. This makes the verification process slow. When a bank would fulfill this role of verification as a middleman for a CBDC-regime it could become easier and faster. Further research on the new role of banks is important in further developing and fine-tuning the future of our digital payment systems.

According to Barrdear and Kumhof another consequence of the CBDC regime will be that it provides a backup system in the event of a failure of a commercial banks. This would lead to a partial removal of the too big to fail concept for commercial banks which is existent in much of the financial industry in developed countries nowadays. Whether this is positive or negative for financial stability can both be argued. On the one hand it can lead to uncertainty among households that the central bank will not do whatever it takes to rescue a commercial bank that is about to go bankrupt, on the other hand it might benefit financial stability as it would force banks into maintaining higher financial reserves and preventing the risk of bank failures.

6. Conclusion

The potential of private e-currencies such as Bitcoin is overestimated, especially by the Bitcoin enthusiasts. Private e-currency is mainly used for speculative motives and not as a mean of payment. A more realistic scenario is that the benefits of cryptocurrency, such as the blockchain technology, will be used in a government controlled e-currency, like a CBDC regime. The benefits of CBDC, for example the economic growth resulting from cheaper government financing after CBDC introduction, outweigh the potential risks, such as the transitioning to an untested new monetary system. The future will probably show governments experimenting with CBDC-like regimes to test if it works for them. The long run will probably show that cryptocurrencies will become part of our monetary system. Additional research regarding the exact and most efficient implications of a CBDC-like regime should be conducted.

Looking at the tradeoff between the monetary policy consequences of private e-currency and CBDC a further rise of private e-currency will have a negative impact on the government its ability to control and conduct their monetary policy. On the other hand a government controlled CBDC-regime leads to a better and more effective monetary policy with the government in control. With the quantity or price rule, CBDC provides the central bank with additional measures to control their monetary policy. The introduction of a CBDC regime will affect the role of commercial banks, their role of providing payment services will be partly replaced be the CBDC regime. This could mean a changing business model for future commercial banks by giving the commercial banks a role in the verification process of CBDC transactions. Future research could focus on the changing role of commercial banks upon the introduction of a government controlled e-currency. Taking everything together, a CBDC regime would be more effective in achieving the central bank its main objectives, maintainig price and financial stability.

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Appendix

Appendix 1: agent categories CBDC model

Commercial Banks

- Different kind of loans and deposits
- Only solvency risk and regulation (capital requirements) is assumed, liquidity risk is ignored.
- Wholesale lending rate is at a premium over deposit rates (regulatory spread). This spread depends on the capital requirements. Retail lending rate is at a premium over wholesale to compensate for credit risks.
- Banks maximize (4) subjected to (2).

Households

- Households income consists of real labor income and asset returns.
- Households borrow against real collateral and financial collateral. Financial collateral after CBDC introduction consists of deposits and CBDC balances.
- The household lifetime utility function (7) is maximized, which depends on shock to marginal utility of consumption, degree of habit persistence, the labor supply elasticity and the utility weights of hours worked and land. This is referred to as the Households optimization problem.
- In general the assumptions are derived from the basic DSGE model. For example when it comes to determining the retail lending rates for consumer loans: “the bank will set the unconditional nominal retail lending rate such that its expected gross share in collateral values is equal to the expected sum of monitoring costs and the opportunity costs of the loan” (Barrdear & Kumhof, 2016, p. 28) .
- Something new they add is the optimal condition for CBDC (34), which is very similar to their optimal condition for deposits (33).
- Consumption tax and capital income tax will become the two most important liquidity taxes in the CBDC regime. This means that changes in quantity of CBDC or bank balance sheets (and with it the monetary transaction balances) will be transmitted to the economy via adjusting these liquidity taxes. (So it acts as a monetary policy).
- Liquidity Generating Function: trade-offs 1) borrowing from banks to create money via

bank deposits 2) holding CBDC vs bank deposits. Focus on 2) where costs (lower interest rates on CBDC compared to deposits) versus benefits of no spread between borrowing and lending, scarcity of CBDC gives an advantages and technological advances (such as faster transactions for example). CBDC implementation exists of three phases (pre-CBDC, implementing CBDC and fully implemented CBDC). The first phase only uses bank deposits, the second phase both CBDC and bank deposits generate liquidity with a high elasticity of substitution among each other and in the third phase where different elasticity of substitution can be used once CBDC is fully implemented.

- Household maximize their lifetime utility (7) subjected to their budget constraint (16), demand for output constraint (17) and capital accumulation (18).

$$Max \quad E_0 \sum_{t=0}^{\infty} \beta_c^t \left\{ S_t^c \left(1 - \frac{v}{x}\right) \log(c_t^c(i) - v c_{t-1}^c) - \psi_h \frac{h_t^c(i)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \psi_a \log(a_t(i)) \right\} , \tag{7}$$

$$\begin{aligned}
& \Sigma_{x\in\{c,a,y,k\}} \left(d_t^x(i) + m_t^x(i)\right)\left(1 + \phi_b\left(b_t^{rat} - \bar{b}^{rat}\right)\right) + p_t^a a_t(i)\left(1 + s_t^a(i)\right) + q_t k_t(i) \\
& -\Sigma_{x\in\{c,a,y,k\}} \ell_t^x(i)\left(1 - \frac{\varphi_x}{2}\left(\frac{L_t^x(i)}{P_t T_t} - \frac{L_{t-1}^x}{P_{t-1}T_{t-1}}\right)^2\right) - \Psi_t^c(i) \\
= \; & \Sigma_{x\in\{c,a,y,k\}} \left(r_{d,t} d_{t-1}^x(i) + r_{m,t} m_{t-1}^x(i)\right) + ret_{a,t} p_{t-1}^a a_{t-1}(i) + ret_{k,t} q_{t-1} k_{t-1}(i) \\
& -\kappa_{t-1}^{xr} \kappa_{t-1}^{xf} \Sigma_{x\in\{c,a,y,k\}} \Gamma_{x,t}\left(r_{d,t} d_{t-1}^x(i) + r_{m,t} m_{t-1}^x(i)\right) \\
& -\kappa_{t-1}^{ar} \Gamma_{a,t} ret_{a,t} p_{t-1}^a a_{t-1}(i) - \kappa_{t-1}^{kr} \Gamma_{k,t} ret_{k,t} q_{t-1} k_{t-1}(i) \\
& -\kappa_{t-1}^{cr} \Gamma_{c,t} r_{n,t} 4 w_{t-1}^{hh} h_{t-1}^c(i)\left(1 - \tau_{L,t-1}\right) - \kappa_{t-1}^{yr} \Gamma_{y,t} r_{n,t} 4 y_{t-1} \left(\frac{P_{t-1}(i)}{P_{t-1}}\right)^{1-\theta_p} \\
& -c_t^c(i)(1 + \tau_{c,t})\left(1 + s_t^c(i)\right) + w_t^{hh} h_t^c(i)\left(1 - \tau_{L,t}\right) + \frac{\iota}{1-\omega}\Omega_t(i) \\
& +y_t\left(\frac{P_t(i)}{P_t}\right)^{1-\theta_p} - \left(w_t^{pr} h_t^h(i) + r_{k,t} K_{t-1}(i)\right)\left(1 + s_t^y(i)\right) - \frac{\phi_p}{2} y_t \left(\frac{\frac{P_t(i)}{P_{t-1}(i)}}{\pi_{t-1}} - 1\right)^2 \\
& +q_t I_t(i) - I_t(i)\left(1 + s_t^k(i)\right) - \frac{\phi_I}{2} I_t \left(S_t^i \frac{(I_t(i)/x)}{I_{t-1}(i)} - 1\right)^2 .
\end{aligned} \tag{16}$$

$$y_t \left(\frac{P_t(i)}{P_t}\right)^{-\theta_p} = \left(T_t S_t^a h_t^h(i)\right)^{1-\alpha} \left(K_{t-1}(i)\right)^{\alpha} \quad . \tag{17}$$

$$k_t(i) = (1-\Delta) k_{t-1}(i) + I_t(i) \quad . \tag{18}$$

Difference between CBDC model and Bernanke macro-economic:

- bank deposits and CBDC serve as financial collateral
- Collateral coefficients on real collateral differ from one
- The retail lending rate is assumed to be pre-committed in period t, rather than being determined in period t+1.

Financial investors

- The utility function is similar to those of households, with the absence of land and the presence of monetary transaction balances. (48) formula.
- The financial investors category is to generate arbitrage conditions between bank deposits and government bonds.
- Deposit rate relative to policy rate spread is critical for the CBDC simulations as it one of the two determinants of the change in banks average funding costs when CBDC is introduced in the economy via an exchange for government bonds. And financial investors due to their arbitrage position are the group of agents who determine this spread at the margin.
- Because financial investors have a high elasticity for returns the lower return on CBDC relative to bank deposits will result in the share of CBDC held by financial investors towards zero. Therefore the authors decided to omit the share of CBDC from the model resulting in the LGF for financial investors being just bank deposits.
- Financial investors maximize 48 (utility function) subjected to their budget constraint (51).

$$Max \quad E_0 \sum_{t=0}^{\infty} \beta_u^t \left\{ S_t^c (1 - \frac{v}{x}) \log(c_t^u(i) - \nu c_{t-1}^u) - \psi_h \frac{h_t^u(i)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} + \psi_f \frac{\left(\frac{f_t^u(i)}{T_t}\right)^{1-\frac{1}{\vartheta}}}{1-\frac{1}{\vartheta}} \right\} , \qquad (48)$$

$$\begin{aligned} & \left(b_t^u(i) + d_t^u(i)\right)\left(1 + \phi_b\left(b_t^{rat} - \bar{b}_{ss}^{rat}\right)\right) \qquad (51) \\ = \; & r_t b_{t-1}^u(i) + r_{d,t} d_{t-1}^u(i) + \Psi_t^u(i) \\ & - c_t^u(i)(1+\tau_{c,t})(1+s_t^u(i)) + w_t^{hh} h_t^u(i)(1-\tau_{L,t}) + \frac{1-\iota}{\omega}\Omega_t \; , \end{aligned}$$

Unions

- managed by households and financial investors, their intertemporal marginal rate of substitution is the average weighted by current labor supply rate of the two agents households and financial investors.

- Unions buy labor from households against nominal household wage and sell it to producers at producer wage.

- The unions optimization problem depends on the budget constraints of financial investors and households.

- Unions maximize (56) subjected to (57) and (58)

$$\underset{\{W_t^{pr}(i)\}_{t=0}^{\infty}}{Max} E_0 \left\{ \Sigma_{t=0}^{\infty} \mathfrak{D}_{0,t} \left[\left(W_t^{pr}(i) - W_t^{hh} \right) h_t(i) - W_t^{pr} \mathfrak{C}_{W,t}(i) + \Psi_t^w(i) \right] \right\} , \tag{56}$$

$$\mathfrak{D}_{0,t} = \frac{\omega h_0^u}{h_0} \beta_u^t \frac{\Lambda_t^u}{\Lambda_0^u} + \frac{(1-\omega) h_0^c}{h_0} \beta_c^t \frac{\Lambda_t^c}{\Lambda_0^c} , \tag{57}$$

$$\mathfrak{C}_{w,t}(i) = \frac{\phi_w}{2} h_t T_t \left(\frac{\frac{W_t^{pr}(i)}{W_{t-1}^{pr}(i)}}{\frac{W_{t-1}^{pr}}{W_{t-2}^{pr}}} - 1 \right)^2 , \tag{58}$$

Fiscal policy

- The government budget constraint (60) is adjusted for CBDC issuance with mgt > 0, government spending is equal to a fixed fraction of GDP.

$$b_t^g + m_t^g = r_t b_{t-1}^g + r_{m,t} m_{t-1}^g + g_t + trf_t - \tau_t , \tag{60}$$