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Central Bank Digital Currency and the Monetary Policy Fractal Trilemma

Definition of money, financial instruments and monetary policy tools according to Kantian categories

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Abstract

This paper is focused on central bank digital currency (CBDC) and on the consequences in the monetary policy following its issuance. Since it is yet to be decided upon, another methodology is requested. Firstly, I am going to define money, financial instruments and monetary policy tools via Kantian categories and the *mathematical conversion* concept in a *money-schemata theory*. That framework can also explain the major clashes between orthodox and heterodox theories of money and solve the endogenous-exogenous creation of money disagreement. Secondly, I will be discussing how the issuance of CBDC will transform the classic monetary policy trilemma in a new trilemma, called *fractal* because it originates by the combinations of two trilemmas, one within the other (a domestic and an international one), that figuratively recalls the Sierpinski triangle and its fractal structure. Finally, I am going to explain how, applying the rules of the fractal monetary policy trilemma, policy makers can use two domestic independent monetary policy instruments (CBDC and current main interest rate) to target distinctly inflation and economic growth rate, keeping parity between the two domestic currencies (and hypothetically address efficiently a scenario of stagflation).

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1. Introduction

Cash use is declining in most of the advanced economies. Logistically is a burden, it must be transported, guarded, tallied and registered (Comiteau 2016) and is one of the supporting means of tax evasion and money laundering. Since 2008, it has been sided by private cryptocurrencies, as alternative anonymous digital means of payment, or as ideological revolution of the relations that citizens have with monetary authorities. Yet, the market prices of cryptocurrencies are very volatile, and they have difficulties in becoming widely accepted and used.

On the public side, many Central Banks, such as the Federal Reserve, the Monetary Authority of Singapore, the Bank of England, the Sveriges Riksbank and even the International Monetary Fund (Wall Street Journal 2017), are trying to understand how to harness the ease of digital payments and develop a *Central Bank Digitally issued Currency (CBDC)* version.

Among central banks emerge different priorities for CBDC and the respective research groups have different approaches and solutions. Even if they agree that the Central bank version does not need to be based on Distributed Ledger Technology (BIS 2018), they also agree that CBDC can have very important monetary policy consequences, the most relevant being CBDC as a new tool and the possibility to break the zero lower bound. Doubtlessly, CBDC can be an opportunity to improve the efficiency, resiliency and accessibility of systems that facilitate monetary and financial transactions given that "many central bank-operated […] payment systems are at the end of their technological life cycles" (Bordo and Levin 2017).

The varieties of opportunities and possibilities, though, create confusions and disagreements on a CBDC definition and policy settings, also because this definition has to precede the synthesis of a financial instrument. That is also challenging the traditional and heterodox definitions of money – the only frameworks available for defining money – which fall short in understanding this phenomenon. Money is commonly defined as commodity, store of value, unit of account, medium of exchange (Ingham 2004), but the frictions between them and with social theories haven't been convincingly resolved, thus defining CBDC with them is even harder.

For those reasons, I am going to provide a definition of money basing my methodology on the philosophical tool used to define objects, namely *categories* and its "sensible concept of an object in agreement with the category", i.e. schemata, according to the Kantian philosophy (Kant 1998). I then define *money schemata* (1) using the basic model of asset market equilibrium, looking at price demanded, price offered, quantity offered, and quantity demanded, which are the logical elements of every transaction (exchange), and (2) accounting for *credit theory of money*, money as "social relation of debt (*agent-agent relations),* and for the endogenous versus the exogenous origin of

money discussion. In addition, I am going to provide a further concept, *mathematical conversion,* to account for exchange processes. Finally, I clear the distinction of money from other commodities, discussing *store of value as physical property* and *store of value as social construct*.

This endeavour is not merely justified by academic curiosity, because the ultimate goal is to look at monetary policy and analyse the broader spectrum of consequences that such an issuance might entail for the existing monetary policy setting, domestically and internationally. Simultaneously, the *reciprocal interaction* between price and quantities of CBDC *and* bank deposits, complicates the tasks faced by economists and monetary policy makers, and there is neither a model nor a theoretical framework that can account organically for it.

Hence, taking into consideration the *money-schemata theory* developed in Chapter 4 and traditional monetary policy literature, I synthetize the *monetary policy fractal trilemma* in § 5.2 for a small open economy adopting CBDC as *deposited currency account*. Its core rationale is that the exchange rate, monetary policy and the capital conversions between CBDC and deposits (or bonds and reserves) are not standalone elements, and they will depend on each other, and they will likely follow the dynamics I am going to define, based on the logic substantiating the traditional monetary policy trilemma. I briefly compare some CBDC literature results with my fractal trilemma in § 5.2.3.3.

Finally, I conclude in § 5.3 explaining how to manage this *reciprocal interaction* to *distinctly address inflation and economic growth rate*, hence I will narrate how it could work in tackling a stagflation scenario of a small open economy (but a large economy case would follow the same reasoning), a puzzling problem for economists.

1.1 Research question

The research question is:

How will a Central Bank Digitally issued Currency affect the monetary policy decision framework, with a special attention on the dynamics of (a) an independent domestic monetary policy, (b) the exchange rate, (c) controlling cross-border capital flows of a small open economy, while (d) considering the reciprocal influence of quantity-price of CBDC and the current domestic broad money aggregates – in a way that the Central Bank can at best steer the inflation and the economic growth rate?

A further question that I am answering in order to answer the core question above is (Chapter 4):

What is the definition of money?

2. Literature review

2.1 CBDC

2.1.1 Theories of CBDC, definitions and theoretical scenarios

CBDC is a new topic, in response to Bitcoin and decentralisation movement, and the academic literature is still at an exploratory phase since 2015. Commonly agreed definitions are still open to improvements, also due to the fact that CBDC sits at the nexus of a number of different areas of research such as computer science, cryptography, payments systems, banking, monetary policy and financial stability measures (Meaning, et al. 2018).

The best attempt so far in defining properties of money and CBDC is the *taxonomy* by Bech and Garratt (2017). Bech and Garratt's taxonomy (easy to visualize with a Venn diagram, called *money flower*) provides a pivotal matrix to understand this phenomenon from a broader perspective, which defines money according four *properties*: issuance, form, transfer mechanism and accessibility. They continue "CBCC [is] an electronic form of central bank money that can be exchanged in a decentralised manner known as peer-to-peer, meaning that transactions occur directly between the payer and the payee without the need for a central intermediary (cash exchange is the purest peer-to-peer: electronically, it means there is no need of a central server)" (Bech and Garratt 2017).

That is a very good starting point and the widespread framework used to talk about CBDC.

They use the term *cryptocurrencies* instead of *digital* and, as technical experts (BIS 2018) agree on the fact that this kind of CB currencies doesn't need to be cryptographed, I will continue to use the acronym CBDC (digital currency) instead of CBCC. Yet, the "digital" of CBDC is very broad and as Bech and Garrett (2017) identify in the flower, there are four different kinds of electronic CB money that are originated by the combination of being universally accessible and/or peer-to-peer.

If electronic CB money is peer-to-peer and not universal we would have what they call "wholesale CBDC" (1). The existing wholesale systems are old, a version of wholesale CBDC is an opportunity to improve the efficiency, resiliency and accessibility of systems that facilitate monetary and financial transactions (i.e. reduce settlement costs). Real project examples are Project Jasper (Canada, whose tokens are called CADcoins) and Ubin (Singapore, a Real time gross settlement system "where payments are processed individually, immediately and with finality throughout the day"). Even though the technology is not yet mature, respective central banks are "considering to keep the door open and make new systems inter-operable with DLT platforms" (Bech and Garratt 2017).

It goes without saying, if CBDCs are neither universal, nor peer-to-peer (i.e. they need a third party, the Central Bank), they are the plain version of the current reserves (2) – which are already digital no-universally accessible electronic CB money.

Next relevant option is to conceive the so-called "deposited currency account" (3) (Tobin 1987) – even though Tobin was politically driven and had a broader reform proposal like depriving guarantee to bank deposits. Two possible ways to look at this version is to figure that either as reserves, i.e. plain electronic money issued by CB that are universally accessible (Meaning, et al. 2018), or as deposit account held at the CB and that is universally (or partially) accessible (Kumhof and Noone 2018). Noteworthy, not highlighted enough by Bech and Garratt (2017) but emphasised in BIS (2018), is that this account-based version excludes peer-to-peer transactions and is mutually exclusive with having full anonymity. A real example of deposited currency CBDC is the dinero electrónico (Bech and Garratt 2017). It is also technically possible to pay negative interest rate. Barrdear and Kumhof (2016) and Kumhof and Noone (2018) define deposited currency account CBDC as "electronic central bank money that (i) can be accessed more broadly than reserves, (ii) potentially has much greater functionality for retail transactions than cash, (iii) has a separate operational structure to other forms of central bank money, allowing it to potentially serve a different core purpose, and (iv) can be interest bearing". I will return to Kumhof and Noone (2018)'s argumentations in the next sub-paragraph.

Finally, if electronic CB money is both peer-to-peer and universally accessible, we would have the so-called "retail CBDC" (4), "decentralised in transaction and centralised in supply" (Bech and Garratt 2017). It is characterised by utter anonymity features (at this stage it is unclear how users value anonymity, but this is going to be a conscious and important decision). An example of real projects is Fedcoin, considered as a third element of monetary base that has one-for-one convertibility in the U.S. This version it has also been called *e-cash* later by Meaning, et al. (2018) because it doesn't bear interests as the normal cash does, and I will stick to this signifier.

In the crypto-world, there are two main entities, tokens and coins. Coins are those mined and tied to public-open blockchain; tokens, which are representation of a particular asset or utility, that usually resides on top of another blockchain, can represent basically any assets that are fungible and tradeable, from commodities to loyalty points to even other cryptocurrencies. If there will be any Central Bank crypto-version, that would look like as a token, "representing" a Central Bank liability.

Then there is the dilemma between peer-to-peer (e-cash, token) versus the account-based version (deposited currency account) of CBDC, and Bordo and Levin (2017)'s first offered a solution suggesting that to function as an efficient medium of exchange, CBDC could be thought as an account-based system rather than a peer-to-peer digital currency, because the account-based version is much

cheaper and more efficient, ideal to compete against private DLT. BIS (2018) confirmed this line of thinking, with a more comprehending study, highlighting the fact that a token-based approach is not scalable and would demand huge amounts of computing and electric power for the verification process (due to trillions of transactions per day in the current financial system). In this way, facilitated by small fees to convert CBDC into paper currency, cash is likely to achieve a gradual obsolesce, which will in the end discourage tax evasion, money laundering and other criminal activities.

2.1.2 CBDC Implementation: academic discussion

A fundamental work in understanding the implementation of CBDC is the paper written by Kumhof and Noone (2018), which look at CBDC design principles to guarantee financial stability despite (or through) CBDC issuance. Given that "[CBDC] systems can in principle have very different scope, in terms of the sectors that are allowed to access CBDC" Kumhof and Noone analyse three possible scenarios.

The first one is the "Financial Institution" (FI) model, where CBDC access is limited to banks and NBFIs, what Bech and Garratt defined as "wholesale CBDC".

The second one is a subtle case of deposited currency, called "Economy Wide" (EW). Looking at its implementation, Kumhof and Noone (2018) increase the level of details of the money flower. Indeed, where Bech and Garratt (2017) exclude any FI involvement in the "deposited account" version, Kumhof and Noone add financial intermediaries (i.e. banks, as per the original definition and functioning) to manage CBDC accounts for an efficient and stable financial system, but "only banks and NBFIs can interact directly with the central bank to buy/sell CBDC, while households and firms must use a *CBDC Exchange* (it uses the deposits it receives to purchase gilts, and then uses the gilts to obtain CBDC at the central bank) to buy/sell CBDC in exchange for deposits". That said, an option of deposited currency account without an Exchange house is also feasible (Kumhof and Noone 2018). This scenario was previously DSGE-modelled by Barrdear and Kumhof (2016).

The last model is called FI+. This is a hybrid and complicated version of the previous two, in which at least one FI/NBFIs has direct access to CBDC and provide a financial asset to households and firms which is backed by CBDC. A big difference in its operativity is that "[it] does not extend credit", meaning that it is an extension of CB account and it has CB's risk profile instead of the borrower's. They call it *indirect CBDC* (iCBDC). In the EW model households don't have direct access to CB balance sheet, but they do have access to CBDC. In the FI+, they don't have either access to CBDC, but a synthetic ("backed") financial instrument based on CBDC (and the same risk profile nonetheless).

Fundamentally, Kumhof and Noone find four core principles in order for any CBDC model to be sound: "(i) CBDC pays an adjustable interest rate. (ii) CBDC and reserves are distinct, and not convertible into each other [to address the risk of a run by the back door]. (iii) No guaranteed, on-demand convertibility of bank deposits into CBDC. (iv) The central bank issues CBDC only against eligible securities".

Important is the issuance of "eligible securities", which is indeed a similar solution identified by Meaning et al. (2018), according to whom the supply of CBDC will depend on the "purchasing [of] financial assets from the non-bank private sector (or the bank sector), paying in CBDC". The financial asset would be bonds – and only other assets might be considered during crisis (e.g. repos) because of higher demand of the bonds, depending on risk tolerance and on the objectives of the monetary expansions themselves, as suggested by Bordo and Levin.

On-demand convertibility (i.e. "issuance against bank deposits, which would amount to a guarantee of automatic unsecured lending to banks" (Kumhof and Noone 2018)) is not guaranteed and banks are not obligated to provide CBDC on demand for deposits. Non-banks can freely obtain CBDC against bank deposits from other non-banks and most importantly does not imply "that households or firms cannot exchange deposits against CBDC in a private market" or cannot obtain additional CBDC from the central bank if they hold eligible assets. This is mostly conceived to avoid *digital* bank runs, but it also has positive consequences, since the CBDC infrastructure could make easier and faster to resolve an individual troubled institution and avoid the danger of contagion effects to other parts of the financial system. That would be at the central bank's discretion rather than automatic, to avoid a raise in moral hazard. Fung and Halaburda (2017) also notice that "to the extent that the presence of widely accessible CBDC increases the credibility of the run threat, banks may respond ex ante by reducing their risk taking or holding higher capital buffer stocks", but that does not hold if banks are not obliged to convert deposits.

Whereas Kumhof and Noone (2018) argue that on-demand convertibility is not necessary to "maintain a 1:1 exchange rate (parity)" as long the central bank adjusts the quantity of CBDC (under a CBDC price rule), there is a functioning and liquid market for CBDC eligible securities, and there is at least one private sector agent acting as arbitrageur, Meaning et al. (2018) directly face Agarwal and Kimball (2015)'s idea of a flexible exchange rate between CBDC and other central bank liabilities. Meaning et al. criticize Agarwal and Kimball's idea because it is implausible in practice, it would create chaos in understanding which one is the unit of account to use in everyday purchases and would add administrative costs to sellers in the pricing process.

Lastly, Kumhof and Noone explore a price rule for CBDC, "a scenario where the central bank fixes the interest rate on CBDC and allows households and firms to obtain the quantity of CBDC that they

desire at that interest rate". In the coming chapters, I will talk about the *interest rate* (Kumhof and Noone's core principle) more comprehensively.

2.1.3 Monetary policy via CBDC

The most distinctive and common argument in favour of CBDC is the possibility of having the interest rate on the cash-substitute as a new monetary policy instrument, de facto breaking the ZLB and allowing larger flexibility (especially in this period, a crisis would find ECB very limited in manoeuvring the interest rate, given that the policy rate is close to zero[1]) and monetary policy can undertake fiscal policy potentials (Barrdear and Kumhof 2016).

Yet, it depends very much on its implementation. In fact, first CBDC needs to be account-based to bear an interest, and second it is still debated whether to provide such CBDC with interest rate at all and what kind (Bordo and Levin 2017) (Sveriges Riksbank 2017). Moreover, in the case it would subject to an interest rate, it is likely that "a deep negative interest rate would then encounter political discussion before any application" (Kumhof and Noone 2018).

Bordo and Levin (2017) made a fundamental analysis of CBDC with the framework of the three properties of money (mean of exchange, store of value, unit of account). They provided the basic "design characteristics" and identified the ideal CBDC configuration: interest bearing (as a main tool of monetary policy to keep it as a "stable store of value"), account-based (to have an "almost costless medium of exchange"), it can function as a fiscal tool if necessary, and it is universally accessible (valid as legal tender for all public and private transactions).

The most interesting arguments in their paper regard the possibilities of the interest rate. They discard the option of a constant nominal value (the same banknotes have now), because it wouldn't bring any monetary policy tool novelty and monetary policies will face the same ZLB constraint that have today.

A second option (their winning one) is to have CBDC bearing an interest rate (for a stable store of value function). Bordo and Levin keep the implementation straight, stating that "[the] interest all funds held at the central bank would bear the *same nominal interest rate*, regardless of whether those funds belonged to an individual, firm, or financial institution", adding that the same policy adopted as with reserves would enhance the competitiveness of the banking system. It is also likely that *with no cash, there would also be no ZLB and thus no need of maintaining 2% buffer of inflation*, even if it would be recommended to keep a 2% target for a smooth change of customs (Bordo and Levin

[1] It can go lower, it is not a technical difficulty, but its efficiency is quite limited because cash is still "king". Last month some of the controversial cases in which, in Germany and Switzerland, negative interest rates have been applied to bank deposits (Bloomberg 2018).

2017). There would not be need for CE and QE, CBDC interest rate becoming the main tool beside reserve interest rate (which will be the same).

Lastly, worth to be mentioned given the fairly technical easiness with CBDC, there is the alternative to index CBDC funds to past changes in the general price level, compelling need during the gold standard but solved differently nowadays. That would be a factual *zero real interest rate*. But they notice that a CBDC index would be problematic whenever aggregate demand is depressed, and hence real interest rates drop below zero (Bordo and Levin 2017), becoming a burden more than a flexible instrument.

They conclude their argument that a single interest rate on CBDC and reserves might simplify monetary policy for the public, vouching for a stable nominal anchor rather than an inflation target ("a constant price level target that would be a natural focal point for expectations").

An extra important element of the paper (Bordo and Levin 2017) is that CBDC could function as a fiscal tool under extreme circumstances. In the event of a severe economic downturn, CBDC technically would facilitate the provision of money-financed fiscal stimulus – see Dyson and Hodgson (2016) for the helicopter money, or as called by Meaning et al. (2018) "a more effective QE" because would be more targeted.

The use of interest rate as a flexible tool beyond the price rule is also considered in Meaning et al. (2018), another interesting paper on monetary policy via CBDC. They expand considerations on interest rate, talking of using it for many goals (not simultaneously): it could be used to stabilise inflation and output, as the primary instrument of monetary policy, or it could be used to "regulate demand for CBDC".

But the core of their research (Meaning, et al. 2018) is to look at a CBDC version of reserve accounts (narrow money, CB liabilities) available to a broader array of actors and its impact on the monetary transmission mechanism (MTM) and the three stages of the MTM. The broad conclusion is that a universally accessible, interest-bearing, account-based CBDC could be used for monetary policy purposes in much the same way that central bank reserves are now.

Kumhof (Head of research at the Bank of England, somehow the supervisor of Meaning et al.' job), is very critical of this work. As mentioned beforehand, one of his core principles is to keep reserves separated from CBDC. Kumhof himself is limited in criticizing given the abstract condition of CBDC – but it seems that "broader access to reserves could change the transmission mechanism of monetary policy in unknown ways, while at least the transmission mechanism of conventional monetary policy via the policy rate could look very similar to today when reserves and CBDC remain separate" (Kumhof and Noone 2018).

Indeed, Meaning et al. (2018) first they conceive CBDC to substitute completely reserves and then to make those CBDC-reserves available to everybody. Using the flower of money (Bech and Garratt 2017), CBDC reserves and CBDC as deposited currency become the same. They try to argue and to study how different interest rates depending on the CBDC-holders might work, but this seems a vicious complication to correct the lack of differentiation between narrow banks and economy-wide actors. Kumhof and Noone (2018) highlight that CBDC and reserves will not be completely fungible and they will provide different functions, so it doesn't even make sense to merge the two entities (this no-fungibility also clear the critique advanced by others that would lead to the disappearance of the second monetary policy tool due to "arbitrage which will bring about convergence between the rates on reserves [i.e. CBDC-reserves] and CBDC" (Bordo and Levin 2017) (Fung and Halaburda 2017).

Despite that disputed important point in Meaning et al. (2018), their approach is noteworthy, especially in the structure of the analysis of the MTM, as I am going to summarize.

The first stage of the MTM is the overnight rate set on Central bank money, which will function as policy instrument (following either a price or quantity rule) in the interbank market. Operationally there are a number of ways in which this can be achieved. In a nutshell, the consequence for the CBDC introduction is a demand of reserves shift.

The second stage consists of the transmission to financial markets, i.e. the pass-through of changes in the interest rate on CBDC to the interest rates and prices of other assets in the economy.

The last stage is the transmission of the interest to the real economy. The pass-through from these financial market movements to the real economy, which can be subdivided in real interest rate channel, the bank lending channel and the expectations/signalling channel, among others. Additional competition in credit provision may make pass-through to lending rates more complete.

Taken all together, Meaning et al. (2018) analysis suggests that a universally accessible CBDC would most likely strengthen the impact of changes in the policy rate on the real economy.

As mentioned earlier, they also propose a scenario in which different CBDC account holders are paid different interest rates and show how this is largely analogous to reserves existing alongside a second CBDC, called *differentiated rates*. The most logical way to differentiate CBDC holdings would be between those held by banks and those held by non-banks. That would make sense to compensate the disappearance of normal reserves in their model, but it might be subject to arbitrage that will nullify the effect of second monetary policy instrument if they function as "expanded reserves".

In the end, Meaning et al.'s research is along the further understanding of the second round effects of introducing CBDC, even though it might fall a bit short. A good understanding of the possible effects is fundamental in "developing specific operational designs for implementing the core principles – for example, the design of an efficient mechanism to allow the rate on, or the quantity of, CBDC to adjust in response to supply-demand imbalances" (Kumhof and Noone 2018).

An important contribution despite having been published two years earlier, is Barrdear and Kumhof (2016)'s experiment with a DSGE model – after a theoretical introduction of benefits and issues faced by CBDC implementation – in which CBDC is issued similarly to what later has been called an EW scenario (Kumhof and Noone 2018). The study shows that if CBDC follows a price rule there are more beneficial effects compared to a quantity rule for CBDC. In the price rule scenario central bank sets the interest rate on CBDC and allows the private sector to determine its quantity by offering to buy and sell CBDC in exchange for well-defined asset classes and the DSGE modelling suggests a steady GDP increase of 3% due to reductions in real interest rates, in distortionary tax rates, and in monetary transaction costs. That CBDC regime will be able to contribute to the stabilisation of the business cycle, by giving policymakers access to a second policy instrument that controls the price of CBDC in a countercyclical fashion.

In the end, CBDC doesn't need to be aimed at monopolizing the payments system but could instead be complementary to the payment services provided by private entities. It is also relevant to highlight how CBDC issuance might be important considering risks that an inertial and passive approach to CBDC could lead to (Bordo and Levin 2017). For example, macroeconomic instability in case paper currency becomes obsolete and the economy might be subject to indeterminacy (i.e. there is no equilibrium that exhibits stable prices) (Fernàndez-Villaverde and Sanches 2017); there might be a loss of monetary control (if paper currency becomes obsolete); systemic risk arising from lack of competition in payments; susceptibility to severe downturns, given that rates nowadays are still very low (except for US monetary policy), thus they are already very limited by ZLB (Riksbank is at negative) and the risk to leave central banks "out of ammunition".

2.2 Theories of money

During the introduction to the CBDC literature, I mentioned how Bech and Garrett first tried to define CBDC using four properties – issuer, form, transfer mechanism and accessibility. That is the most advanced attempt in defining CBDC, but as they call them, those are *properties*. Bordo and Levin (2017) also show how CBDC strengthen the measure of value (unit of account), medium of exchange and store of value being, the famous functions performed by money (there is also a fourth

one, means of unilateral payment). Before starting my argument, I am providing a bird's eye view on theories of money. They can be split into two large groups, namely *orthodox* and *heterodox* theories (Ingham 2004).

2.2.1 Orthodox theories

This group of theories are those that are mostly explained and taught in traditional macroeconomics textbooks. They all are rooted in the *commodity theory*, that recognises money essentially as commodity. It is composed of two slightly different versions. The first one sees money as an actual commodity (i.e. metal, that's why it is often referred to as *metallist theory of money*), whereas the second one sees money as *symbol of representative commodity* (as in Walrasian general equilibrium theory, where the *numéraire* acts as a "symbolic representation of existing commodity value" and money "is not, properly speaking, one of the objects of commerce, but only an instrument" (Hume 1752).

Other approaches that can be considered intrinsically orthodox are Fisher's *quantity theory of money* (and its Friedman's revival *monetarism*) and the more recent *optimum currency area theory* (Mundell 1961), which uses commodity theory to justify the diversification of currencies.

Their theoretical foundations lie on *object-object relations* (exchange ratio between commodities) and *individual agent-object relations* (Ingham 2004), but those orthodox theories encountered limitations from their pure logical description of money ("commodity that can be traded for all other commodities") given that were incompatible with the creation of credit-money as a "social relation of debt (*agent-agent relations*)" (Ingham 2004). Moreover, the focus on money's role as a medium of exchange failed to fully recognise its "moneyness" – money as unit of account – and that is where the heterodox theories stem.

2.2.2 Heterodox theories

There are several heterodox theories, but the most relevant are two, the *credit theory* (claim), which moves from realising that credit (as deferred payment, IOU) started circulating as means of payment. The other, in some way opposing theory, is the *state theory of money*.

The aporia between commodity and credit theories of money sparked more post-Keynesian discussion, such as the endogenous versus the exogenous money discussion, where the causality of money supply is debated ("are central banks or commercial banks driving the supply of money?"). That will bear an important role in my theoretical framework based on Kantian categories, to which I will provide an interesting interpretation. Another worth mentioning theory related to the endogenous debate is the *monetary circuit theory*, which argues that money moves in two phases, the efflux – when "debts are issued by bank credit", and the reflux phase – "debts are extinguished when firms

reimburse the banks with the *circulating* debt that they have acquired" (i.e. money is created and destroyed).

Older state theory in the nineteenth century tried to explain money as an expression of communal trust and culminated in Knapp's State Theory of Money, who recognised the centrality of money as a means for "accounting and settling debts, the most important of which are tax debts" (Ingham 2004). He distinguishes between the value of debts (expressed in *money of account*) and the actual means of payment (the money-stuff), which is of secondary importance. Accordingly, credit notes issued by banks become money when they are accepted as payment of taxes and reissued to the state's creditors (Ingham 2004). Given that all money is a "token that bears […] the units of abstract value", this theory is also called *Chartalism*, from the Latin word *charta*, token.

From the definitions of money briefly presented it appears that those approaches are mutually exclusive, that they encapsulate a degree of truth in a way that they all seem right (or most at least), but none of them is exhaustive. It follows that in understanding CBDC, are utterly inadequate. Another theoretical framework is needed and that passes through Kantian categories, which can account for different settings of the same entity, *money* – and for one of its possible implementations, CBDC.

2.3 Kant: categories and schemata

In this section, I am going to introduce *categories* and *schemata* which are the backbone of the classification of money-entities that I am going to develop in Chapter 4. I am not going to explain in depth how Kant deduced them, but just what they are.

2.3.1 Categories

Category according to Kant, is "the condition of the possibility of objects in general, that is, objects as such, any and all objects, not specific objects in particular" (Kant 1998). In other words, it is not what we generally mean it as a classificatory division. They "contain the grounds of the possibility of all experience in general from the side of the understanding" (Kant 1998) and are derived directly from the *judgments*. Kant derives twelve categories from the faculty for judging, which are "pure concepts of the understanding that apply a priori to objects of intuition as there were logical functions of all possible judgments" (Kant 1998).

The table of categories can be split into two large parts, one concerned with objects of intuition (pure as well as empirical) called "mathematical" categories, the other with the existence of these objects (in relation either to each other or to the understanding) called "dynamical", which are dichotomies (Kant 1998).

A further distinction is represented by the columns, which are four *classes* of *categories,* namely *quantity*, *quality*, *relation*, and *modality*. Each of those four classes of categories has precisely three moments, where the third member of each trio arises from the combination of the first two members and "a further and different act is required for the combination of those two to produce the third" (Kant 1998). Thus:

- Totality (allness) is just plurality considered as a unity,
- limitation is just reality combined with negation,
- community (reciprocity) is the causal situation of substances that mutually interact, and
- necessity is nothing but the existence that is given by possibility itself.

Mathematical		**Dynamical**	
Quantity	**Quality**	**Relation**	**Modality**
Unity	Reality	Substance and attribute	Possibility/impossibility
Magnitude (number)	Negation	Causality and dependance	Existence/non-existence
Totality (unit+number)	Limitation	Reciprocity	Necessity/contingency

Table 1. Categories according to Kant.

Yet those categories, "they themselves cannot […] be defined" (Kant 1998):

> "[…] the categories require, beyond the pure concept of the understanding, determinations of their application to sensibility in general (schema), and without these are not concepts through which an object can be cognized and distinguished from others, but only so many ways of thinking of an object for possible intuitions and of giving it its significance in accordance with some function of the understanding (under the requisite conditions)" (Kant 1998).

For this reason, I am now talking about *schemata*.

2.3.2 Schemata

According to Kant, *schemata* "stand in homogeneity with the category on the one hand and the appearance on the other, and makes possible the application of the former to the latter" (Kant 1998). That is to say that the "the schematism of the pure understanding" is originated only when the judgment deals with *sensible* condition under which alone pure concepts of the understanding can be employed. What he calls transcendental schema is thus a *mediating representation* which is *pure* (without anything empirical) on the one hand and yet *sensible* on the other.

An application of the category to appearances becomes possible by means of the transcendental time-determination which, as the schema of the concept of the understanding, mediates the subsumption of the latter under the former.

The schema is in itself always only a product of the imagination, which has to be distinguished from an image. For the synthesis of the schema has as its aim the unity in the determination of sensibility, not the individual intuition (the case of the image). The pure image of all magnitudes (quantorum) for outer sense is *space*; for all objects of the senses in general, it is *time*.

Schemata structure follows the same of categories' (four groups, three moments per each group, the last as a combination of the previous two). Hence the *schema is only the phenomenon, or the sensible concept of an object, in agreement with the category*. Without schemata, therefore, the categories "are only functions of the understanding for concepts, but do not represent any object. This significance comes to them from sensibility, which realizes the understanding at the same time as it restricts it."

In chapter 4, I am going to analyse the "media of exchange" through categories, thus having *media of exchange schemata*.

2.4 Macroeconomic and monetary policy background

To better grasp the following discussion on money and on the CBDC fractal trilemma, is essential to be clear on some macroeconomic definitions and concepts.

2.4.1 Legal tender

One of the first instinctive question on CBDC regards the function as legal tender. According to the Sveriges Riksbank (Sveriges Riksbank 2017) legal tender means that everyone is obliged to accept a specific financial instrument as mean to extinguish debt, in that case cash.

Same in the United Kingdom, but what is classed as legal tender varies (Bank of England 2017). In England and Wales, legal tender is Royal Mint coins and Bank of England notes, in Scotland and Northern Ireland only Royal Mint coins are legal tender and there are also some restrictions when using the lower value coins as legal tender (e.g. 1p and 2p coins only count as legal tender for any amount up to 20p). Then there are many acceptable payment methods which aren't technically legal tender (debit-credit card, cheques, contactless, MobilePay, Apple Pay, etc.), that most shops accept as safe and convenient ways to pay (Bank of England n.d.).

2.4.2 Monetary policy and exchange rates

To better understand the possibilities of monetary policy faced by any Central Bank, we can look at the *Annual report on exchange arrangements* by the International Monetary Fund (International Monetary Fund 2016), which exhaustively represents in a table all the regimes of the member States.

Succinctly I can say that a *monetary policy* can be committed to a:

1) Exchange rate anchor (i.e. US dollar, EU, Composite);
2) inflation-targeting framework (price rule, e.g. the Taylor rule);
3) monetary aggregate target (quantity rule; e.g. Friedman's k-percent rule, in which the interest is let to float due to supply/demand processes, or the McCallum rule, more recent);
4) other, e.g. managed regime whose Central bank look at various indicators (such as in the case of EU and USA). Other tools are reserves requirement and unconventional monetary policies (such as Quantitative Easing).

Important to notice is that even for a price rule regime the Central Bank adjusts the quantity of money in money market, but the level at which it adjusts that amount is set by looking at the price (interest rate) and the quantity follows consequently, through the so-called Open Market Operations.

Regarding the *exchange rate arrangement*, a currency can be (elements A and B are defined "anchored" in the monetary policy framework):

A) hard peg (also called fixed): a central bank is committed to buy/sell its currency at a fixed price in order to maintain its pegged ratio through Open Market Operations, keeping stable the value of its currency in relation to the reference to which it is pegged (either there is no separate legal tender, or there is a currency board);
B) soft peg (conventional peg, stabilized arrangement, crawling peg - within band, pegged exchange rate within horizontal bands);
C) floating (managed or free floating).

One last note regarding the exchange rate arrangement is an important distinction between a *de jure* regime and a *de facto* one (International Monetary Fund 2016), highlighting that not always Central Banks operate as they declare to do and engage.

2.4.3 Capital movements

Free markets are defined as having free mobility among countries and capitals are free to flow, unless control measures are employed. Forms of capital controls generally (International Monetary Fund 2016) are: on money market instruments, derivatives and other instruments, credit operations, direct investment (threshold amount on what transaction to validate if coming from foreign entity), real estate transactions, on personal transactions, on Banks and institutional investors, on repatriation and surrender requirements. In reality, control measures are finely balanced and there is much of politics involved.

For an explanation of monetary policy and pass-throughs of the transmission mechanism, exchange rate dynamics and the effects of capital control on the quantity-price with supply-demand curves I suggest (Krugman 2013) and (Krugman, Obstfeld and Melitz 2012).

2.4.4 Monetary policy trilemma according Obstfeld

The above mentioned independent monetary policy, exchange rate regime and capital movements are the elements of the famous monetary policy trilemma, according to which only two items out of three contemporarily are achievable (Krugman, Obstfeld and Melitz 2012). This is both a formal model based on the uncovered interest rate parity condition, and a finding from empirical studies where governments that have tried to simultaneously pursue all three goals have failed (Obstfeld, Shambaugh and Taylor 2004) (Krugman, Obstfeld and Melitz 2012). The first option is to have (1) a stable exchange rate and free cross-border capital mobility (but not an independent monetary policy), the second (2) is to be able to pursue an independent monetary policy while allowing free capital flows (but that entails having a floating exchange rate). Lastly, (3) a stable exchange rate and an independent monetary policy requires that there are controls over the cross-border capital flows.

2.5 Conclusion of literature review

CBDC encompasses a vast set of possibilities, that are so different from each other that using one single wording (*CBDC*) can result to be confusing and misleading.

Despite a large part of the CBDC literature proposes advantages and problems of issuing CBDC, definitions of CBDC itself were pivoting around four properties – issuer, form, transfer mechanism and accessibility, and monetary policy *scenarios* are mostly based on *accessibility*. That is a very narrow approach, compared to the existing traditional monetary policy practices and goals.

A new definition that can account for the orthodox and heterodox theories of money, and at the same time can properly define CBDC, is needed and that is what I am going to provide.

The final problem regards what monetary policy rules apply to CBDC. Thus, I am using the logic behind to the traditional monetary policy to derive those for CBDC, especially in reciprocal influence with the current domestic broad money aggregates.

That leads the argument to evaluate what is the best CBDC policy settings, for regulating inflation and steering economic growth rate for a small open economy. In this thesis, there is no final judgment regarding them, because the choice will also depend on the specific setting of the financial system that adopts CBDC (i.e. different countries have different settings and priorities).

3. Methodology: Philosophy and Economics

At the Copenhagen Business School, the distinguished cand.merc.fil.'s approach intertwines philosophy with economic issues, "using" philosophical concepts to interpret business and economics problems.

That brings an evident clash of methodologies, one self-reflecting and the other (i.e. economics') being at the intersection of a positivistic and normative paradigm (Hausman 2018). My dissertation is within Monetary Economics, a special branch of Economics, and I can fairly separate my thesis into two parts according the methodology I used, Chapter 4 and 5 respectively. I followed the main CBS' input in Chapter 4 (with relevant differences) and in Chapter 5 I especially focused on *monetary policy* (Arestis and Mihailov 2009).

One of the most important branches in philosophy is *ontology*, the study of being and concepts directly related to it, what Aristotle called categories and in everyday language we call generally definition. As it was clear since the literature review, money is lacking a sheer definition and in Chapter 4 I am going to provide a different money definition and a new interpretation of those money theories – where appropriate.

First, a brief introduction to definitions according Kant, fundamental in his transcendental idealism. A definition is *analytic* if it is of a given concept (makes a concept distinct), a concept that can be given *a priori* (independent of experience) or a given *a posteriori* (dependent on experience) (Beck 1956). A definition is *synthetic* if it is of a concept made or synthetized by the definition itself (makes a distinct concept) and can be similarly, a priori or posteriori. Another distinction of definitions can be done looking at the content of the *definiens*, between nominal and real: "a real definition is one from which other properties can be derived, while a nominal definition suffices only for comparisons and not for derivations" (Beck 1956).

Generally, according to Kant, to define "means to present the complete concept of a thing within its limits and in its primary character [and] if a definition does incorrectly contain derivative predicates (i.e. properties) it is lacking in precision" (Beck 1956). Even though in "empirical knowledge, definition is only loose and informal", Kant describes "the way logical certainty is gained […] analysing concepts, expressing the analyses in analytical judgments, and only then organize these analytic judgments into definitions" (Beck 1956). Thus, I based my method for defining the object of economics – money – on Kantian methodology, namely categories and schemata, but as just quoted, that is an analytical process that starts from already stated contents – which I found in the Economics literature (Monetary Economics), ortho- and heterodox theories of money.

Kant (Bennett 2006) says regarding his tools used for defining (i.e. categories and schemata):

> "This table of categories suggests some nice points that could be made, ones that might have an important bearing on the scientific form of all items of knowledge through reason. This table contains all the elementary concepts of the understanding, and even provides the form - though not the content - of a system of them in the human understanding. Offering the complete over-all plan for a science based on a priori concepts, and dividing it systematically on the basis of definite principles."

A spontaneous question is why I chose Kant and not more recent (ontological) philosophies. I am not excluding that a similar definition would be possible with other philosophers' methodologies, but his approach, despite the fact that schemata are not at the forefront of the philosophical discussion nowadays, has been effective, neat in defining and the results seem at least plausible (especially in relaxing the differences between state theory of money, credit money and endogenous/exogenous money creation).

Lastly, I haven't followed my research towards philosophical critiques and alternative philosophical perspectives to the Kantian reading of money mostly because the public of this thesis is intended to be generally economists and policy makers in the process of deciding upon CBDC existence and implementation. So, it has been a conscious choice to incept the discussion towards fruitful applications, even though I don't exclude that it might be interesting to pursue this approach in a more systematic way, or to expand the philosophical methods used. This thesis has the scope to clear important distinctions that are often blurred in the public discourse by exponents with an agenda.

After the exposition of a new money theory in Chapter 4, I explain another concept of monetary policy through the Kantian schemata narrative, when I codify the logic framework of the traditional trilemma of monetary policy and unveil the links with the relational class identified in my definition of money, being on the verge of discourse analysis.

In Chapter 5 I speculated on monetary policy, that provides "rationale and microfoundations to the supply of money and the unique role of the central bank in affecting it", namely rules and practices in pursuing an active role in the Economy (focusing on the inflation-targeting framework) (Arestis and Mihailov 2009). Thus, I deducted my argumentation from both the money theory and the logical codification of the traditional monetary policy trilemma that I explained in the previous Chapter 4, synthetizing the concept of *fractal monetary policy trilemma*. Its abstractness though, comes with an inherent weakness that Kant himself identifies pertaining to *synthetic nominal definitions* (which my CBDC and fractal trilemma definitions are): "Such a definition is a stipulation or a "declaration" of an intended usage, the concept being created by the definition [and] they are not determined by experience or by analysis of a given concept" (Beck 1956).

Despite that intrinsic weakness, my proceeding in defining the fractal trilemma has been to show all the nine logical combinations available, and even though real environments will make a selection of

which one out of the nine is the case of a specific small open economy (see § 5.2), that is a good overview to start understanding the CBDC phenomenon, and the monetary policy trilemma has been the most encompassing concept I could find. At this point, worth to be mentioned is the rationale behind my choice of calling it *fractal*: that is because the nine cases originated by the combinations of a domestic trilemma with an international trilemma, figuratively recalls the Sierpinski triangle and its mathematical fractal structure.

Using Kantian arguments made my reasoning tending to transcendental idealism, but even though I sympathise for Kantian philosophy, I am not endorsing the overall Kantian philosophy as it is clear from other passages (e.g. § 4.1.3) where influences emerge from social studies.

In fact, in my endeavour of defining money (especially during the writing process) I am rooted in a verification process that recalls Mill's method a priori:

> "Scientists first determine the laws governing individual causal factors in domains in which […] methods of induction are applicable. Having then determined the laws of the individual causes, they investigate their combined consequences deductively. Finally, there is a role for "verification" of the combined consequences, but owing to the causal complications, this testing has comparatively little weight. The testing of the conclusions serves only as a check on the scientist's deductions and as an indicator of whether there are significant disturbing causes that scientists have not yet accounted for" (Hausman 2018).

Finally, I can also justify my choice of methodology due to the fact that CBDC issuance stands in an unknown territory, and my methodological choices are a good way to obtain a (simplified) conceptual model that theorists and policy makers can work on. In fact, as transpires in many passages throughout my thesis, that approach is also mixed with a broad underlying Lakatos' theoretically progressive approach (Hausman 2018), recognising the theoretical limitation and calling for more empirical research and additional testable implications.

4. Money theory: Definition of media of exchange and mathematical conversion

From the reading of § 2.2 regarding theories of money, it is clear how a good definition of money is still missing, resulting more in a collection of functions, properties and the feeling that they point at not mutually exclusive perspectives. One thing for certain, ortho- and heterodox theories are limited in trying to grasp the nature of central bank digital currency and that is the main reason why I start this analysis.

In this chapter, I am going to define money (and in general, media of exchange) according to the twelve Kantian categories and schemata, those that I introduced in the literature review and are the logical structure necessary in defining any object, according to Kant. For a discussion of "definition" according to Kant and philosophy in universal terms, I refer to the methodology chapter.

Suffice to highlight here is that a "definition is a late stage in the progress of knowledge, being preceded by the analysis of given concepts, expressed in analytic judgments" (Beck, 1956). Accordingly, relying on consolidated Economics literature, I will use Kant schemata to define money, also with the help of an enlarged concept of *mathematical conversion,* which is fundamental for the completeness for understanding money.

Discussion around the difference between commodity and money (or, money as commodity) has always been crucial. Before solving that with my framework, I present the schemata for any media of exchange, exemplifying the concept into two cases, namely one general (you can think of it in terms of general commodity) and money. That differentiation is arbitrary, but it helps to understand the nuances between the two and likely to solve the confusion arisen around money. Subsequently, in § 4.2.2, I discuss that distinction. I will also explain why metals and then money as we know it gained the prerogative status of store of value.

The relevance of this discussion relies on the fact that CBDC is the synthesis of a new financial instrument and literature has been struggling in finding a clear-cut approach on it. For example, the money flower in Bech and Garrett (2017) is good to get an intuition of money and CBDC, but the four properties are mostly technical aspects rather than a proper definition of money and are insufficient to widen the discussion on it.

4.1 Schemata of media of exchange

As I previously quoted in § 2.3, "for every empirical concept, there are schemata" (Kant 1998). That also applies to media of exchange. *Media of exchange* is a very broad class of elements though, encompassing anything that can be *exchanged* and *has been* exchanged in history among humans – as Adam Smith has already stated "propensity of human nature [is] to exchange one thing for another" and "every man lives by exchanging […]" (Smith, 1776). Specifically, money has always been recognised as a medium of exchange, but clearly the medium of exchange set is larger than just money and includes any commodity, which originally was meant as raw material, but later assumed a narrower meaning of valuable thing.

Thus, a rigorous logical path to follow in order to understand what makes money and what simply remains commodity, is to look at the definition of media of exchange and at the two separate cases between general commodity and money as commodity and then explain the difference, given that according to orthodox theories money is still considered a commodity.

In both cases, schemata are obviously the same because they belong to the same empirical concept "media of exchange". But given my focus on money, and the importance of it, I am going to properly codify *money schemata* (Table 2), using the orthodox (and partly heterodox) lexicon. In this way, a new interpretation will arise from common agreed concepts for a very intuitive table, as following[2]. It is one of the core contributions of this thesis and I will spend the coming paragraphs explaining it.

Quantity	**Quality**	**Relation both w/ another commodity and w/ itself in deferred time** (*either option 1. or 2.*)	**Modality**
Unit of account	Asset	1. P persistent *and* Q changes 2. Q persistent *and* P changes	Possible[3] *or* impossible (e.g. credit money)
Multitude (number)	Liability	1. P determines Q (s/d driven) 2. Q determines P (s/d driven)	Existent *or* not existent (e.g. commodity money)
Number + unit of account	Settlement deferred in time (accounts creation)	Reciprocity (P/Q and s/d reciprocal influence)	Necessary by law *or* not necessary (e.g. fiat money)

Table 2. Money schemata table.

[2] The setting of any financial instrument is defined by the choice of one box (called schema) per each column (called class). Abbreviations used are: P for price, Q for quantity, s for supply, d for demand.
[3] With grades of probabilities.

4.1.1 Quantity

The first class is *quantity.* This encompasses the schemata for which money is usually defined relying on its nominalist view, even though the name "quantity" in economics is what is meant by Kant as *totality*, exclusively the last schema of the *quantity* class.

Unit

It is the unit of measurement of the medium equivalent in time and space and the actual unit of account of the totality (Kant 1998).

In the case of a *general commodity*, this *unit* can be anything (also candies for children). So, any fairly equivalent objects (like cigarettes) can be considered *unit*. Noteworthy to say is that for example the Chicago Mercantile Exchange (CME Group) labels corn in three varieties to account for physical differences. Each of them would be defined a different unit, as I will discuss better in § 4.2.2.

In the case of *financial instruments*, *unities* are all the unit of measurement in which the amount of the financial instrument is expressed, the bare "currency", such as dollar, euro, pesos, what is also called "money of account" (Ingham, 2004).

There is no need for further considerations on unit, given that monetary theories spent much of their efforts on it and it is quite self-evident. The difference between commodity and money as unit though is very interesting, and it will be subject to discussion in § 4.2.2.

Plurality – magnitude

As Kant explained, the pure schema of *magnitude* (quantitatis), as a concept of the understanding, is *number*, which is a representation that summarizes the successive addition of one to another, basically just the number without being accompanied by the unit of account.

Thus, in both cases – *general commodity* and *financial instrument* – magnitude is the number which accompanies the unit of measure. This is the mathematical ground of any media of exchange, which relies heavily on quantities as numbers.

Totality

This is "plurality considered as unit" (Kant 1998) and the last schema of the *quantity* class. In other words, all those equivalent and homogenous *units* are summed, and totality is "nothing other than the unity of the synthesis of the manifold of a homogeneous intuition in general" (Kant 1998). It generally is a number accompanied by the unit of measure: "A specific amount of …".

In the case of *general commodity*, this is simply a quantity of something, e.g. "15 cigarettes" to follow the example above mentioned. Nonetheless, from a real standpoint, general commodities are too much variegated to be considered a unity. That has been resolved in having different grades

describing their properties ("standardised and counted", Ingham 2004), such as carats for gold. This also will be discussed and made sense of in § 4.2.2.

In the case of *financial instruments* (money-entity), *totalities* are all those amounts expressed as a number accompanied by the respective unit of account. In Economics, *totality* is also called "money aggregate" in the case of the overall totality of a specific unit of account[4]. For example, there was approximately $1.67 trillion in circulation as of June 27, 2018, of which $1.62 trillion was in Federal Reserve notes (Federal Reserve 2018), which defines the *entire totality* of US dollars. Worth to be noted, any part of that totality, it is still a *totality* in schemata terms as long as it is expressed as an amount accompanied by the respective unit.

Anticipating what will be better explained in the *relation* class (§ 4.1.3), when a financial instrument totality is referred to any entity, that amount of money-totality originates the *price* (see § 4.1.4).

4.1.2 Quality

The *quality* class is one of the two *mathematical categories* and it can be "fill-empty".

In the pure concept of the understanding, the *reality* schema is that to which a sensation in general corresponds, therefore is a "concept of which in itself indicates a being" (Kant 1998).

In the case of *general commodity*, it is the positive being of an asset in general, i.e. a property.

In the case of *financial instrument*, this is the positive account, the mathematical plus "+", asset considered as credit. No negativity is necessary for this positive schema to exist in reality.

The *negation* schema is the "concept of which represents a non-being" (Kant 1998).
In the case of *general commodity*, this is the schema of being *liability*, the negative stage of the asset that has to be given back, the counterpart of an asset which can be literally anything (e.g. a service).

In the case of financial instrument, this is the so-called debt, mathematical minus "–". It always come with a potential asset.

Limit – maturity date
"Every sensation has a degree or magnitude, through which it can more or less fill the same time" (Kant 1998), that means there is a transition from reality to negation, "that makes every reality representable as a quantum, and the schema of a reality, as the quantity of something insofar as it fills time, is just this *continuous and uniform generation of that quantity in time*, as one descends in time

[4] Please note the difference between *totality*, i.e. a specified amount, and the overall totality of a currency (i.e. overall amount of a currency), such as M4.

from the sensation that has a certain degree to its disappearance or gradually ascends from negation to its *magnitude*" (Kant 1998) [italics mine].

That coexistence of negation and reality at the same time, in Economics terms, is the case of an open position of a trade, until credit-debt dichotomy ceases to exist: this means that until then (the settlement day) there is an open transaction between two parties, and one has a credit and the other has a debt position. That time in the future is called *maturity date***,** and – as the original limit schema – that time of settlement has different grades, generally from one day to infinite. In normal life situation, "infinite" is not declared, but in essence demand deposits or stakeholders' equity "[are] assumed to have infinite life" (Gitman and Zutter 2012), implicitly arguing that it is infinite until somebody decides to quit the position. That coexistence of reality and negation, any time that two trading parts are involved in which each has an opposite position toward the other until the deferred settlement is actually settled, constitutes then the structure of *account* creation.

In the case of a *general commodity*, it is said that a commodity is still waiting to be paid and the maturity day means that the payment is due in a predetermined number of days.

In the case of *financial instrument*, it is said that there is an open position between two accounts. At the maturity date agreed, credit and debt clear and each agent has its own asset (again, here is irrelevant to consider the commodity exchanged). This is the origin of *account*, where a future settlement of debt-credit is set: an authority creates a credit and a debit, whose sum is zero (interests included), in an account (that can be both electronic or paper) and postpone the settlement in time. That operation creates a time-series and delays credit and debt settlement.

This is the necessary condition to the origin of the interest rate, that I am going to define in § 4.1.3 as originating from the relation of a financial instrument with itself on a postponed date in the future – the settlement date.

4.1.3 Relation

This class of schemata defines the relation between media of exchange and give *origin to markets*.

Here, given that relation entails two entities taken into considerations, I will analyse a *general case* where money is related to a commodity[5], and a *specific case* where money is related to money (another totality though, which is considered as a commodity, see FOREX rates). There would be another very general case of commodity-commodity, which – if we exclude money as commodity as we have already considered in the other two cases – is plain barter. But, given the limited resources in this thesis, it is less relevant, and I am not analysing this last case.

[5] The "commodity" can be anything, like a job done (which is time and energy). See Smith 1776.

Trades in general happened to rely on quantities. Relations are mainly relations of quantities: a quantity of commodity and a quantity of money (*which is totality in Kantian terms*, see § 4.1.1) – whether nominal or as pounds of gold – is called price. As Bordo and Levin (2017) quote Julius Paulus Prudentissimus perfectly summarising: "That material, struck in due form by the mint, demonstrates its utility and title not by its substance as such *but by its quantity*, so that no longer are the things exchanged both called wares but *one of them is termed the price*." [italics mine].

I will then talk about a special case of money, which is the relation with itself in the future, originating the *interest rate*.

As always, only one schema (i.e. one single box of the table) of the three can define a relation between two media. Moreover, in *relation* and in *modality* classes, every schema is dichotomic, so one medium is defined by one term and the other medium (object) by the remaining one.

In a relation between media of exchange, not only there are entities to be exchanged, but there are also two agents involved, which are called *supply* and *demand* in Economics literature. Overall, the elements in the supply-demand model – and essential in being analytical regarding relations between media – are: the price demanded by the supplier, the price offered by the demander, the quantity offered by the supplier and the quantity demanded by the demander, for a total of two media of exchange (usually is money and commodity).

Substance or attribute

According to the first schema of this class, an object can be either substance or attribute to the other which is in relation with. Kant explains that *substance* is the persistence of the real in time, i.e., the representation of the real as a substratum of empirical time-determination in general, which therefore endures while everything else (i.e. *attribute*) changes (Kant 1998).

In the *general relation between commodity-money*, the cases are two, with two sub-cases looking at supplier/demander.

First, we can look at when the preference of supplier is fixed and the preference of the demander changes (*price* is defined as quantity of money and *quantity* as quantity of commodity). That means that either:

- The price demanded by the supplier is constant at any quantity demanded by the demander; or
- The quantity offered by the supplier is constant at any price named by the demander.

Alternatively, the preference of the demander is persistent and the preference of the supplier changes. It means that either

- The price offered by the demander is constant at any quantity offered by the supplier; or
- The quantity demanded by the demander is constant at any price demanded by the supplier.

I show what happens to price-quantity demanded-offered when a shift happens, using the model of asset market equilibrium (to notice that X and Y coordinates are alternatively parallel or perpendicular, thus they are constant, i.e. *persistent*):

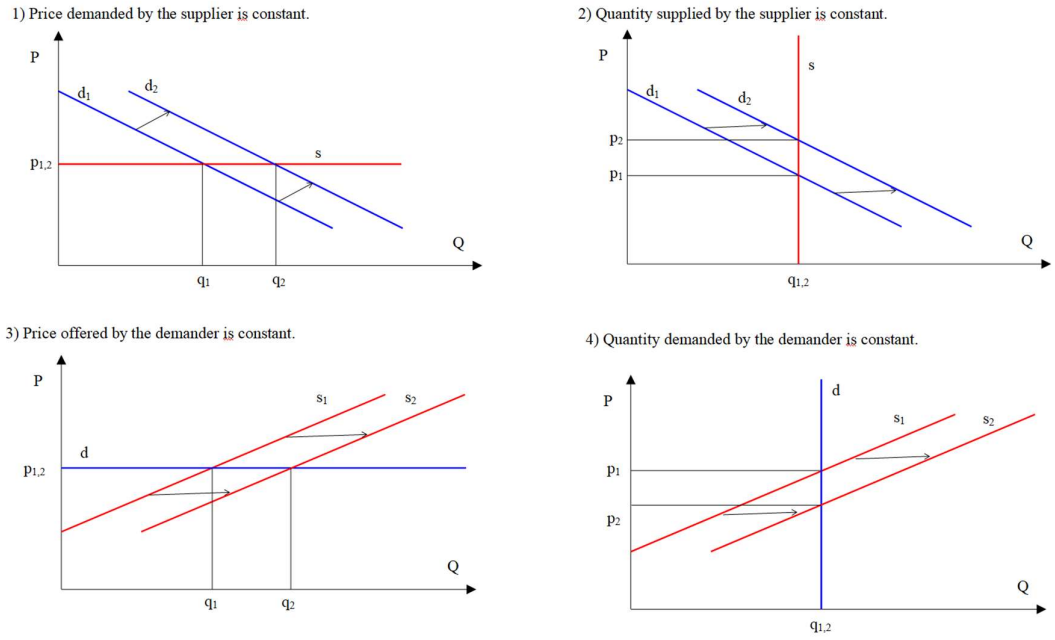

Figure 1. Substance-attribute relation settings of supplier/demander preference.

In the specific case, *money is traded against money*. In fact, it is part of the more general one commodity-money, where one currency is considered persistent and the other just a commodity-like. In economics, exchanging currencies in different unit of account (like dollars against sterlings), one of those currencies is considered the *base currency* (can also be a functional currency of a business), the other the counter (or quote) currency. So, which one to put first might seem an issue regarding convention of quoting. This schema is important to be distinguished by that notation, because we are trying to define their relation, not just describing their quantitative ratio (that ratio is part of the Forex exchange rate discussion and respective conversion in § 4.2).

This schema of attribute-substance though, it doesn't seem to have much confirmation in reality, but that's because we are talking of extreme bounds. In everyday terms, that would be a situation in which the demander (or the supplier) doesn't want to negotiate any amount of money offered nor

the quantity of product demanded (or the quantities of money demanded nor of the product offered, if it is the supplier), which are the elastic and inelastic cases in Economics literature (Krugman 2013). Clearly, it is hard to imagine an exchange at all between two such actors, in which one is *persistent* and the other *changes,* but the important thing to remember is that if the persistent preference doesn't shift, that is the origin of demand or supply surpluses (in the case the actors close the deal without achieving the equilibrium point of preferences (Krugman 2013)).

Causality or contingent

Causality of a thing in general is the real upon which, whenever it is posited, something else – the *contingent* – always follows (Kant 1998).

In the media of exchange narrative, this dichotomy regards how the price (quantity of money agreed to be exchanged for the asset) changes under the effect of its quantity and the other way around, following what in economics are called *shifts* or *movements* in order to reach the price equilibrium at which the market clears. In order to be able to change under the other's influence (causality), neither curves have to be elastic or inelastic (vertical or horizontal). In fact, when one curve shifts and neither is elastic/inelastic, that also affects the quantity of the other entity (see Figure 2).

Following the same method used with the first relational schema, for both the general commodity and the special money case, two more sub-cases can be observed looking at both supply and demand. Causality means that when demand or supply shifts, supply or demand respectively has to change in order for the market to clear (or, if the actors are only two, that equilibrium is simply called an agreement of intents). Before starting, it is worth to be noted that an endogenous variable is a factor whose value is determined by the states of other variables in the system; an exogenous variable, a factor whose value is determined by factors outside the causal system and that in turn affects the system.

Once again, I am going to rely on supply-demand equilibrium graphs. They entail much more than what their minimalism might suggest. One curve that moves, implies that is acting and the other that stays fixed, is passively re-acting accordingly the decision made by the other actor. In reality though, might be a case of reciprocity – whose purest dynamics are rooted in causation.

Before starting, I specify that when I say "determines alone", it can be said to "be the only cause", or that "drives" – I consider them synonyms.

The first *general case* of commodity – money relation, has two main subcases, each of which has two more subcases. Either:

1) the *supplier preference is causal*, and the demander preference is determined; that further means that either:

- The price of commodity demanded by the supplier drives the quantity of commodity demanded by the demander. Imagine when Krugman calls it "shift of the supply curve" (Krugman, 2013) – and it is supply driven (exogenous). This is the case in which a change in price decided by the supplier determines also the price and quantity at which the demand curve clears; or
- The quantity of commodity offered by the supplier determines alone the price offered in the market by the demander. Krugman calls it a shift of the supply curve, which is exogenous and this is the case in which a change in quantity decided by the supplier determines also the price and quantity at which the demand curve clears.

2) Or the *demander's preference is causal*, and the supplier's preference is determined; that further means that either:

- The price (for the commodity) offered by the demander determines alone the quantity of commodity offered by the supplier. Krugman calls it a shift of the demand curve (endogenous, demand driven). This is the case in which a change in price preference of the demander determines also the price and quantity at which the supply curve clears; or
- The quantity of commodity demanded by the demander determines alone the price of that commodity offered by the supplier in the market. Krugman calls it a shift of the demand curve (Krugman, 2013), which is endogenous and that is the case in which a change (a shift) determines also the price and quantity at which the supply curve clears.

In the specific case of money-money relation, the dynamics are the same as those in the general case. That is the case of trading USD against Euro for example (two distinguished totalities), but also selling/buying securities denominated in the same currency to adjust the money supply. Interest rates are consequently indirectly affected.

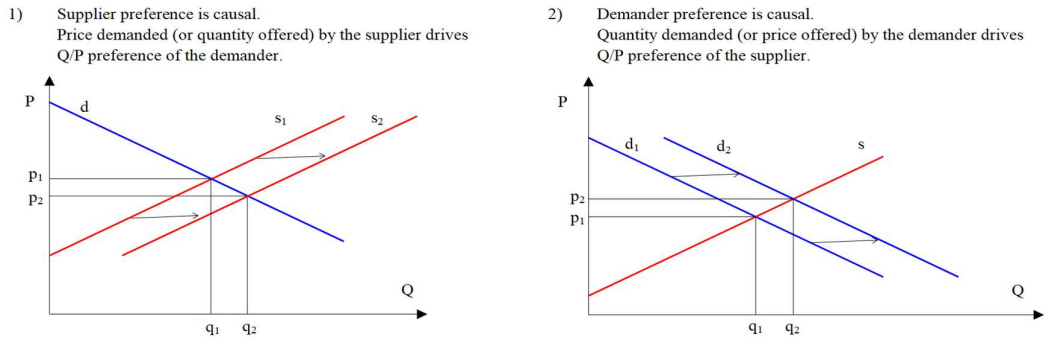

Figure 2. Causality-contingency relation settings of supplier/demander preference.

Reciprocity

Kant defines the schema of *community*, "[…] or of the *reciprocal* causality of substances with regard to their accidents, [as] the simultaneity of the determinations of the one with those of the other […]" (Kant 1998). And the same applies when there are several objects that are in community with one another, and "each of them acts on and is acted on by the others, so that again there is *no primacy or seniority*".

In the money world, this defines the schema in which the price demanded (or supplied) affects the quantity and the quantity demanded (or supplied) affects price too. The first two relational schemata are pure forces of how market operates. I say "pure forces" because, in reality, rarely they can be seen working singularly in that way: supplier and demander preferences combine together and the mechanism of supply/demand curves in the market is *reciprocal*, sometimes one prevails over the other. Coherent with the previous interpretation, reciprocity in the market means that both curves of supply and demand are not persistent (i.e. they are both inclined) and shift.

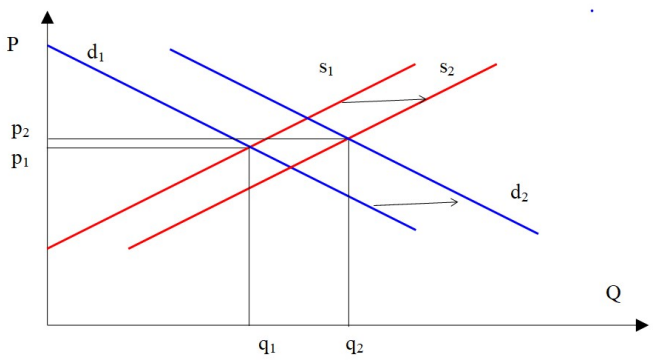

Figure 3. Reciprocity relation settings. Supplier and demander preferences are both determinant, causal to each other.

That means that there are fluctuating situations looking for an equilibrium, when the market clears – exactly at the price agreed that the demander pays, and the supplier receives. Price, as mentioned, is usually expressed in money (even if theoretically can be any metric/totality, but money is that the one having the famous superiority of store of value, see § 4.2.2). More details on reciprocity regarding money will be analysed in § 4.3.

4.1.4 Modality

This class of schemata regards the modes of the medium's being: may – is – must be. Reading the *Critique of Pure Reasons*, this class defines "whether and how an object belongs to time". For a more recent explanation of the mutual exclusiveness of necessity and possibility, interesting is the *theory of possibility*, an extension of fuzzy logic (Zadeh 1978).

Possibility or impossibility

The schema of *possibility* is the agreement of the synthesis of various representations with the conditions of time in general (e.g., since opposites cannot exist in one thing at the same time, they can only exist one after another), thus the determination of the representation of a thing to some time (Kant 1998).

In the economic setting, this dichotomic schema split the mode of the medium *can be or not*, has a pending existence, and different grades of probability are also conceivable[6].

In the *general case of a possible asset*, possibility regards the forecast of its yields or production and it is a less relevant case for my analysis, the same as its *impossibility*.

In the *specific case of financial instruments*, possibility identifies the essence of *credit money* – because the fact of receiving it in return is only a possibility. Credit money and the majority of financial instruments, such as options, but also bank deposits, certificate of deposits, debit card, and so on have this status of *possibility*, thus the lack of absolute certainty (enforceable by law) to be received back. It is evident that there is a legal contract, or a medium that can be guaranteed, but its existence is not enforceable, here is still the possibility that the actor holding the debt might not able to repay it back. From here, stems the need of a deposit fund guarantee for example, which covers an *impossibility*, like in the case of a defaulting bank or of a debt holder. Financial trading literature supports this interpretation, who defines the "*credit risk*" as "[…] stem[ming] from the issuer's possible inability to finance the issued debt" (Siddhartha 2011).

Interestingly enough, other monetary alternative can be *possible*, such as Hawala system, which is based on honour but it relies on possibilities and it is not enforceable.

Existence or non-existence

The schema of actuality is described by Kant as the "existence at some definite time" (Kant 1998). The *general case* is easily defined as being an existing asset, such as a bushel.

Regarding the *specific case of financial instrument*, we encounter the characteristic schema of *commodity* money, that *existed/exists* on a par with the commodity chosen as money (Ingham, 2004), such as gold or silver, material and tangible.

Necessity or not

The schema of necessity is the "existence of an object at all times" (Kant 1998), its necessity of being.

[6] Probability, in mathematics, is a ratio which expresses the grade of possibility.

In the monetary economics landscape, this pertains the modality of an asset to be the only accepted by law, necessary is what is considered legally binding (a social construction-necessity) and whose claim is enforceable.

For the *generic case of the asset*, an example of necessary asset is the ancient tithe, which was a compulsory tax to a government or a noble originally in the form of one tenth of annual produce.

For the *specific case of money*, that brings us to the definition of fiat money, that is a currency without intrinsic value that has been established as money, often by government regulation (but it could otherwise) within an economic system. In fact, the legal tender is a medium which is obliged to be accepted as a medium for debt repayment within a jurisdiction, "the law does not relieve the debt obligation until payment is tendered". In other words, specific transactions need to be settled by necessity via a specific medium, that *in almost all cases is fiat money.* Worth to be mentioned is that one of the most important proposal for CBDC is to be used as legal tender for taxes (Sveriges Riksbank 2017).

It is common use among advanced CB to back fiat money with government bonds. That is because it offers more credibility to a fiat edict, and as praxis central banks accompany money issuance with bond acquisition. But could be anything or nothing else.

The opposite, a *contingent medium of exchange*, is not recognized as legal tender (duty to accept it as a quantity of repayment) but can still function as a mean of exchange – the only issue is that can *also not be accepted* indeed (like for example local currencies).

Now that I distinguished possible and necessary money, an interesting question arises from Knapp's Chartalism explained by Ingham (2004): how does happen that *possible* money (e.g. bank deposits) are accepted as payment of tax debts and again *possible* money is reissued in payment to the state's creditor? That is because, first, both entities (tax debts and deposit banks) are the same totality, and secondly, the authority agrees on the *convertibility* of modality between fiat and credit money. Hence, I am going to define that *mathematical conversion* in the following paragraph.

4.2 Money according to Kantian schemata and the mathematical conversion

4.2.1 Convertibility and Conversion of money schemata

Exchange is the foundation of social activities and those media subject to exchanges "make for the efficient operation of the division of labour and exchange of products […]. This indirect multilateral exchange is a means of 'translating the work of the farmer into the work of the barber … Money is action at distance" (Ingham, 2004). This quotation highlights two fundamental factors**:** the socially

agreed importance of money as being medium of exchange, and a certain kind of conversion between work and money. In other words, media of exchange are all relatable per definition, thanks to their being totality and convertible, in the sense that are able to be exchanged one for each other.

Moreover, looking at the broad financial world, anybody can easily realise that financial instruments are more or less easily converted into other financial instruments, and sometimes are converted so smoothly that one simply doesn't realise there is any difference at all. Money itself acquires many "forms". Think of withdrawing cash with a debit card: doubts regarding the perfect substitutivity of the "number in the bank account" with cash at hand arises only when banks are in trouble and the nexus between "converters" breaks down.

From the reading of media of exchange schemata above, I said that each financial instrument has different "settings" (i.e. a specific combination of schemata) but – as media of exchange – they share the peculiarity of being – in *schemata* terms – qualitatively, quantitively or modally easily convertible into each other. Also, the financial instrument convertibility arises from the exchangers as social agreement stated in written laws, that agree on making those instruments convertible into each other, that is, acceptable in exchange for the other one respectively. A counterexample is the Venezuelan Petro, which has been declared the new unit of account by President Maduro, but the USA has declared it illegal (Vyas 2018), thus not recognising the legitimacy of converting it into US dollars.

Being more precise, along with the nominalist trend, connection is granted by the *quantity class* whose importance I first introduced in § 4.1.3. So, it turns out that when we – more or less consciously – convert two money-entities, we synthetically change one or more schemata of the original entity according to an exchange parameter (a ratio of numbers) and thus there is a quantity conversion, a quality conversion, and/or a modality conversion: I am going to call this active process (synthesis) ***mathematical conversion***, given that it is already called in many sub-cases "conversion" and it relies on numbers as parameter. The following is a table with some examples of conversions of schemata (everything else being equal).

Quantity	Quality	Relation	Modality (vertical conversion)
-	Somebody's else debt is accounted as credit	-	E.g. Cash is deposited into a deposit account at a commercial bank
-	Somebody's else credit is accounted as debt	-	E.g. Pure gold nominal coin out of a debt.
FX ratios	A bank account is transferred to another bank, same person holder	-	E.g. Money in a deposit (at a commercial bank) is converted into cash; Central Bank converts bonds into reserves.

Table 3. Examples of mathematical conversions.

In the case of a *quantity conversion*, if everything else equal, the financial instrument changes amount, and that is possible only when it changes *totality*, in financial words, when we transform a currency into another one[7]. In those cases, we need an exchange rate, the exchange ratio between commodities as *object-object relation* that I introduced in § 2.2 (Ingham 2004) and now I define as a relation between two *totalities*. That corresponds to a numerical ratio, in the case of two currencies is called FOREX exchange rate, whereas an example of a currency-commodity is a conversion of gold into euro, using the ratio of units kg/€. Depending on the final totality desired, the conversion is in one way or in the other. When that ratio is 1:1, that's often the case when we don't realise that there has been a conversion at all (that might be the case of CBDC if traded at par). A curious case is Cuba, where there are two legal tenders, the pesos and the convertible pesos, the latter of which is pegged 1:1 to the USD, so a replica synthetized on the USD thanks to mathematical conversion.

In the case of *quality conversion*, (everything else constant, e.g. same currency) the conversion happens vertically among different schemata of the class and the entitled authority transforms a debt into a credit in somebody's else account or a maturity into credit/debit. This is mostly a technical conversion and veiled, but nonetheless fundamental to the good functioning of the financial system.

There is then a *modality conversion* (vertical among schemata[8]), everything else equal, for example when a possibility is settled (in commodity) or cash is withdrawn (e.g. converting a deposit at a commercial bank into fiat currency); when existent commodity is transformed into possibility, but it is not possible to transform it into fiat currency; when, depositing cash, fiat necessary money becomes credit/debt (possibility) and similarly when Central bank provides reserves in exchange for bonds.

Lastly, *relations* don't really convert into each other, because more than one entity is involved. Nonetheless, a change is possible vertically when, by authority, policy makers decide to change the type of relation money has with the rest of the currencies, but practically not all of them are possible (and if it is not possible to transform a relation from being dependent to be causal, but they can try to make it less dependent). In reality, depending on all the sum of the markets forces, there are different grades of relations and they will be clearer after reading the first paragraphs of Chapter 5.

[7] In the money schemata above I showed that there is no standing alone multitude, but just totality indeed.
[8] Horizontal would entail a conversion in impossible and not-existent, they are just bankruptcy cases.

4.2.2 Store of Value and unit of account: difference between money and commodities (and commodification)

Now that the theoretical framework has been introduced, I can explain the difference between money and commodities when talking of the two most prominent functions of money that have been debated ever since, the *store of value* and the *stable unit of account* being. This is not an attempt to revolutionize anything, but a necessary explanation to validate the above presented media of exchange schemata.

There is *store of value as physical property* and *store of value as social construct*.

To make sense of the *store of value as physical property* it is essential to remember what I showed earlier. Surprisingly, the starting point is to think at the *unit*: strictly speaking, anything is a *unit of account*, like cigarettes, candies, etc, because totality is a multitude of the same units (§ 4.1.1). But, compared to money, commodities in general are different because there is a tricky part – hidden in plain sight: they differentiate, i.e. perish, as soon as time passes and (except for metals) they happen to increase the number of totalities (thus they become more units of account), losing physical value at the same time. I explain this with more details.

Generally speaking, a store of value is defined as pertaining to something that is expected to be stored and retrieved equally, after a certain period of time (that can be either one day or 100 years), or an adjustment is needed to account for the change undergone. As the grade of maturities is expressed in time, time from a human-anthropocentric perspective is also the key element to understand these dynamics.

I can take as example a *real* commodity, like corn. It is subject to time, in other words time passing their qualities are altered and there is an Aristotelian "corruption of the elements" of a perishable commodity. Looking analytically at that corn, one might be lean towards considering the same "corn" those of the same genetic type and at the same stage of "corruption". From the market perspective, CME Group lists three types of quality according time, maturity, the period in which that corn is considered eatable, in other words, not-perished. Moreover, looking at different harvestings of corn, assuming the storage conditions are equal, at present they are differentiated from one to the other. Imagine taking a picture of the same type of corn bushels, harvested in different periods: those cropped at the same moment, will be at the same stage of "corruptness".

It is finally important to note, that the change that affected the corn bushel is negative, in other words it perished and lost value right after harvesting. Whereas, if we look at other agricultural product-derivatives such as good wines (a Petrus for example), we can easily recognise that its change starts as positive and the good wine acquires value over time (at a certain point, it starts degrading and

losing any taste-quality – in the case of Petrus can happen after decades). Good wines are used indeed as a store of value.

So, it turns out that those assets which are affected by differentiation of unities over time (e.g. vintages or different dated harvestings), don't have a great store of value functionality. That is at most clear with agricultural products – that's why that choice. Either way, it has been assumed that everything else being equal (that especially means that no demand and supply drivers are involved). Those commodities with low store of value as physical functionality, have also many unities that become many totalities in Kantian terms. Thus, there is a continuous differentiation of the same "product" over time.

Regarding *store of value as social construct*, that falls into the dynamics described in the *relation* class above, subject to demand-supply forces and quantities of commodities exchanged (today, the quantity taken usually as reference is money). As Adam Smith noted (1776), "in the rude ages of society […] things were frequently valued according to the number of cattle [and store of value] is said to be the common instrument of commerce and exchanges […] a species of shells in some parts of the coast of India; dried cod at Newfoundland; tobacco in Virginia […]". Those cases highlight more the marketable property as social necessity of cattle and dried cod, rather than their physical store of value property.

Those two aspects of store of value are very tight together and part of the same concept, that are similar to what Adam Smith identified in being the difference between "value in use" and "value in exchange" (Smith, 1776). What is more in my interpretation, is that this distinction makes possible to understand the difference between cigarettes and gold as unit of account, given that I showed in media of exchange schemata that all things are units (thus totalities) and that more perishable objects generate more totalities, making their units less practical to be used as reference with other objects (i.e., stable unit of account).

Historically, gold and other precious metals have been humanly considered "valuable" – preference has been given to metals. Adam Smith (1776) notices that "[they are] kept with little loss […] anything being less *perishable* than they are" [italics mine] (for example iron used by Spartans, copper by Romans, gold and silver by all rich and commercial nations). Metals can be divided without loss and reunited, so resulted to be more practical than any other commodity (Smith, 1776). It is likely that the property of being less-perishable among all other materials had driven them to become a constant in social exchanges. Worth to be noticed, time affected gold and silver measures because people were *debasing* golden coins (inflationary debasement), not per intrinsic or natural perishability of gold. Durability of gold and silver is also one propriety Ingham (2004) mentions in regard

to the small amount of yearly supply of gold and silver compared to the total stock circulating in coins.

Nowadays, money in the digital version and accounted as the western world is used to – nominally, relying on the pure mathematical aspect, regardless of the *money-stuff* (Ingham 2004). Theoretically, a USD 5 banknote can last infinitely, because *nominal* (in schemata terms) means that it relies on the abstracted *quantity* class.

Money is not affected by time passing, not at the same way as normal commodities do. Nominal money is affected by inflation (even though expected inflation is counterbalanced by the discounted value) that erodes its purchasing power – that is, the quantity needed to exchange it with another object in the market. In the case of high inflation, like in Venezuela in the current period, is hard to define its currency as store of value. Money is thus not perishable in the physical sense (because Central Banks guarantee to substitute – convert – the spoiled banknotes), but is affected by inflation, whose adjustability is in turn the goal of Central Banks.

The so-called commodification acquires now a definition. Looking at how corn is processed by CME Group, commodification means considering anything according to specific parameters of empirical quality and time, in order to be able to make it comparable to the totality of money. That is a process of "standardization" followed by counting of the units stemmed out of the process of standardization, the same as Ingham (2004) describes when golden coins have been made out of golden bar.

In the end, it turns out that the *store of value as social construct* is a function of the physical store of value and the time span the exchangers *expect* to store that value (i.e. cigarettes few months, candies few days, gold as long as possible, nominal money theoretically infinite – and in this sense reputation[9] of Government and Central Bank is fundamental): this in turn generates *unit of account as social construct*, and history shows us that the one that lasts longer, wins over the other.

4.2.3 Private cryptocurrencies in schemata terms

As I said since the beginning of the Chapter, there are various financial instruments which also differentiate from each other in some (but not all) aspects. Now those aspects have names, which I called *schemata* along Kant's definitions and conversions from each to any other are possible, thanks to social agreements and to mathematical conversions.

What links all financial instruments, which can be reconducted to moneyness (deposit, coin, debt, etc. decided by law), are the following schemata: totality over time, accountable (up-to-infinite-

[9] "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" (European Central Bank 2012).

maturity), marketable (relatable, endogenously or exogenously driven), necessary/possible. When full metals were used, money was existent too.

Hence, it is noteworthy to briefly look at schemata of the cryptocurrencies privately issued. Regarding cryptocurrencies many questions have arisen, and many arisen in terms of money schemata: is that money? It is just asset, there are no maturities. And is it possible or necessary? Is it existent? Is that up to debate?

As I have introduced in Chapter 2, cryptocurrencies can be distinguished between token and coin.

Common to both versions, in the cryptocurrency environment there is no debt and settlement date postponed in the future. Yet a debt could hypothetically be denominated in "bitcoin", but the inability to create debt/maturities is the raison d'être of private cryptocurrencies, sponsored as "instantaneous settlement" of transfers. I argue that it is not a coincidence that cryptocurrencies' "accounts" are called *wallets*, you cannot have debts in a wallet but just assets-credit. It has a similar status to gold, but the asset schema of crypto-coins is constituted by registries made of bits.

Recalling the description of *crypto coins* above, coins are those blockchain that are mined by computing power, resulting from solving computer problems. The mining corresponds to the original supply (which is decentralised) and that reacts to the desire of the miners looking for more quantities, anybody with sufficient computing power can be the endogenous cause. Once in the market, price and quantity of coins follow the same rule of causality described above. In which way they behave in the open market, what are the driving factors, it is still unclear. Their status is set in *possible modality*, without anything or anybody backing it.

On the other hand, *tokens* too are totality. Given that they are backed by a specific asset, any asset that the initiator decides it to be, they are *necessary* within their only system and they act as a store of value as long as the mathematical conversion between the nominal token and the asset (existent) backed by is guaranteed. Within the broader traditional monetary system, tokens (not all are equal) are still in *possible*-mode, as long as authorities hesitate in recognising them (private cryptocurrencies won't be accepted to repay taxes anytime soon). So, for now, they are not trustworthy store of value as social construct and people hesitate in investing in them too (maybe mostly for speculation purposes).

My position is that private cryptocurrencies are not close to be eligible as necessary-money at all, and CBDC is a better answer. Petro (CBDC) is allegedly existent because a mathematical conversion by law is backed by real commodity, oil reserves. But Petro's structure is unclear and markets for now are sceptical. CBDCs are the core of the thesis and I will talk about them in the next Chapter.

4.3 Closing remarks on central banks, money creation and policy rules

From a practical point of view, it is worth to be noted that original suppliers of money are Central Banks operating in the interbank lending market where the participants are few selected financial institutions, and then Central Banks operate in the money markets which namely are the FOREX market and the interbank lending market (the most common being the overnight rate) for Open Market Operations fine-tuning. And in that environment, every time an agent sells money it becomes then the supplier, and the buyer is the demander, that means also that when Central Banks operate OMO and buys assumes a demander position (buyer).

Most interestingly – as mentioned in *maturity* date – there is a further special case of relation when a quantity of money is in relation with *its own quantity postponed at another time*. In this way we can look at the *interest rate* as price of money itself, which is a time phenomenon[10], and pertaining to the realm of monetary policy. In *quantity* class terms borrowed by money schemata, money is the same totality, but in different times. Globally, one of the most relevant is the fed funds rate(s), but every economy has its own which have a time span between one day (called the overnight rate, "which in turn affects market rates at longer maturities"), or one week – which is the main target REPO in Sweden (Sveriges Riksbank 2005).

I focus on the even more specific case in which money in relation with itself in a postponed time is object of *monetary policy*. In economics literature (Krugman 2013), this case is graphed as if money supply is vertical and it might shift, becoming a case of *causality* schema. So, as long as the *CB is committed to meet any price (or quantity, depending on the rule it is following)*, the supply curve of the CB stays horizontal (or vertical – inelastic or elastic). That means that the central bank doesn't act arbitrarily (in that case, is said it manipulates the currency market for other goals than those declared). When the central bank shifts the supply curve, it becomes active part in the market and those are the cases I am analysing now.

The supplier is determinant and hence the demander is determined:

- The price of money demanded (percentage-rate) by the supplier drives the quantity of money demanded by the demander. This is the case in which a change in price decided by the supplier determines also the price and quantity at which the demand curve clears. In this case, the central bank decides first the price of money and it is said to be supply driven, exogenous.

[10] The formula for the interest rate on a amount of money is given by: $(Q_2 – Q_1)/Q_1$, where Q_1 is the quantity at present and Q_2 is the quantity in the future.

- The quantity of money offered by the supplier (CB) determines *alone* the price offered in the market by the demander. This is the case in which a change in quantity decided by the supplier determines also the price and quantity at which the demand curve clears. In this case, the central bank decides first the quantity of money and it is said to be exogenous, supply driven.

The demander is determinant (and the supplier determined):

- The price offered by the demander determines alone the quantity of money offered by the supplier. This is the case in which a change in price preference of the demander determines also the price and quantity at which the supply curve clears. This is demand driven and it is said to be endogenous.
- The quantity of money demanded by the demander determines alone the price offered by the supplier in the market. It is endogenous and that is the case in which a change (a shift) determines also the price and quantity at which the supply curve clears. Endogenous, demand driven.

The above listed schema are extreme bounds, and only the elements of the final definition. In fact, I identify any monetary policy rule as *reciprocal*.

In the case of a price rule it sounds like: the *interest rate set by the central bank is persistent* because the Central Bank is committed to meet any endogenous demand at a predetermined price set by the central bank. When the central bank change the interest, i.e. supply curve shifts, at that moment the central bank is acting exogenously. In converse, the *quantity of money offered by CB is dependent* upon the quantity demanded by banks-market to meet that price (interest rate).

Whereas a quantity rule sounds like: the quantity set by CB is persistent (even though it can change) and the price of money offered by CB is dependent upon the quantity demanded by banks-market.

And in fact, sustaining this new interpretation, Krugman (2013) represents CB supply as horizontal or vertical: that means that either Y or the X coordinate is fixed, like in the substance schema. And to recall Kant, *reciprocity* is defined as the "reciprocal causality [i.e. final settlement determination] of substances [i.e. persistent interest rate] with regard to their accidents [i.e. change in the quantity of money demanded by demanders and of the interest rate, when applicated], is the simultaneity of the determinations of the one with those of the other, in accordance with a general rule" (Kant 1998).

Yet, in the literature the driver of money existence is debated between an endogenous/demand or exogenous/supply money creation. Ingham (2004) provides a good overview of it and it seems that there is no final saying. Well, this framework shows how they (Central Banks and commercial banks) operate in *reciprocity*, and that could explain why somebody focuses on the exogenous aspect

and somebody else on the endogenous one: they look at two different sides of the same medal, that is right – but partial. So, according to my definition, price is exogenously driven by CB and quantity is endogenously driven by banks and consumers (in most of the advanced free floating regime economies), and that also fancily recall George Soros' idea (Soros 2008) of reciprocity.

Despite this reciprocity, commercial banks are important intermediaries, and problems can arise when they limit or control arbitrarily the flows between CB and the wide public. For this reason, too, a deposited currency CBDC would be a way to bring a larger market freedom (giving to citizens the opportunities that banks have with reserves), and more responsibilities.

5. Monetary policy: CBDC Scenarios and policies

I have shown in chapter 2, how starting from Bech and Garratt (2017) CBDC has been defined according four parameters. One of those, namely access, has also been the main parameter to generate CBDC scenarios in successive papers, such as Kumhof and Noone (2018) who generated three scenarios on that parameter.

This thesis presents a different framework, that projects CBDC scenarios onto the international stage and taking into considerations monetary policy consequences (which are – at this stage – theoretical but only data will tell whether it is also the empirical case), and most importantly taking into considerations domestic setting of CBDC implementation. Nonetheless, *access* is considered, but that is not the main parameter anymore and I will show in § 5.2.1 that access is an issue of capital control measures, that means is just one out of the three elements of domestic policy.

I will proceed as follows.

First, starting from a general CBDC schemata definition, I will split possible CBDC settings into two main cases, namely CBDC envisioned either as *e-cash* or as *deposited currency account* and pointing at available options for each version.

Secondly, I will explain briefly the e-cash version and then dig into the complexity of the deposited currency account version, until the end of the chapter (§§ 5.2 – 5.3).

Thirdly, I will analyse the domestic relation between CBDC as *deposited currency account* and the current broad money aggregate (BM) in the form of an internal domestic monetary policy trilemma. Once I have done that, I can further split the *deposited currency account* version into two cases, regarding its relation of the new agglomerate (constituted by CBDC and broad money, whose relation has previously analysed) with the international stage (constituted by foreign currencies, countries, funds). I then analyse that domestic-international relation in schemata terms, that can be either considered as substance-attribute, causal-contingent, or as reciprocal (§ 4.1.3). In economics terms, they are the cases of a *small closed economy*, *small open economy*, and the latter is a *large open economy* (USA, EU, UK, China), but I will only focus on the small open economy due to limited space in the thesis.

Analysing this international relation, I will introduce the so-called *fractal trilemma*, which is an adapted theoretical version of the traditional monetary policy trilemma introduced in Chapter 2. In doing so, the domestic trilemma (which is the one between CBDC and the current broad money) is encompassed by the classical outsider trilemma.

In the case of a small open economy, there are nine possible combinations and I will draw the attention to the CBDC scenarios and prominent issues that the CBDC literature has discussed from a narrower approach.

I will conclude with a discussion of the results and clearer exposure of the specific case in which CBDC is traded at parity with BM to address independently both inflation and economic growth rate (as credit contraction/expansion), that is the CBDC fractal trilemma applied. I will also include some implementation issues that are necessary to be addressed in order to proceed in the execution of a CBDC issuance.

5.1 CBDC Design according to money schemata: e-cash or deposited currency account?

The overall approach in this thesis has been quite theoretical, starting from abstract concepts regarding money. In this paragraph, I will continue deductively from the theoretical framework of money schemata (which proved to be consistent with the most relevant issues in monetary Economics) to reflect upon the design of the new entity-money: Central Bank Digitally issued Currency.

Considering all the combinations that can be originated by the schemata-money table, would require quite a lot of space, thus I am restricting my focus on those that are more relevant.

The element that CB are considering and that makes the largest difference in designing CBDC, is whether envision CBDC as the same unit of the current broad money or not, in other words, whether policy makers are conceiving CBDC as e-cash, or as reserves-deposited currency account (register-based). In the former case, CBDC would be just what cash is today in electronic form[11]. In the latter, CBDC would be a new monetary entity, what might be seen (as an example mentioned with the only purpose to understand it, not as descriptive definition) as a "foreign" currency within the same domestic system – and an exchange ratio would be needed, even only as a 1:1 ratio[12].

5.1.1 First CBDC version: e-cash

The first version to be considered is CBDC as having the same unit (thus, being part of the same totality) of the current broad money. That has been called in the literature as *e-cash*, which basically

[11] Remember from conversion: cash and deposit usually have the same unit-totality, just different quality and modality. If CBDC is the same unit as the current broad money, they can be counted also in the same totality (i.e. same M aggregate comparable to cash, otherwise an extra one is needed, even though they have been very inconsistent as definitions, and it doesn't make sense to use that).

[12] If we conceive a 1:1 exchange ratio that assumes there is a difference in unit. As later will turn out, e-cash version can be seen as CBDC (deposited currency account) which has been "*controlled*" by legal act and fixed its value to be 1:1. In that case, clearly, literature has provided a new signifier – but schemata and the overall purpose of the thesis is aimed at going beyond different signifiers and looking at their intrinsic structure.

entails a new name for cash and a new plain technical (mathematical) conversion of a fixed 1:1 because granted by law. If it is also coexisting with cash, that could be conceived as a new money aggregate comparable to cash in digital form (which is not accounted, and the public can exchange it peer-to-peer, without a third-party account) and can be added directly to the existing broad money, because it has the same unit. In some papers, that has been referred to as electronic cash of the *money user scenario* (Bjerg 2017) and *value-based e-cash* (Sveriges Riksbank 2017).

The following table is an overview of e-cash schemata possibilities.

Quantity	**Quality** for: 1. CB; 2. Public	**1. Relation w/ BM** **2. Relation w/ itself over time**	**Modality**
n.a.	1. - (money destruction); 2. Asset.	1. Fixed quantity & fixed nominal value; 2. Fixed 0% interest (e-cash version).	n.a.
n.a.	1. Liability (money creation); 2. -	1. P determines Q or Q determines P (s/d driven); 2. n.a.	n.a.
Same totality of the current Broad Money	1. Account (only as liability); 2. -	1. (very limited reciprocity); 2. No independent monetary policy.	Necessity (by law)

Table 4. CBDC schemata, e-cash version.

As it is clear from Chapter 2, this e-cash version does not bear any interest rate. The access will be granted to consumers and to special intermediaries (e.g. some banks) to handle it, like cash is structured nowadays. Thus, e-cash will constitute an asset in consumers' hands accounted at the central banks' balance sheets and at any intermediary's involved. The Sveriges Riksbank assessed concisely its impact on its balance sheets (Sveriges Riksbank 2017).

Like its physical variant, e-cash modality will be *necessity*, and it has been further suggested that to strengthen its position should be ensured that it functions as legal tender for tax repayments (currently cash cannot be used, it is only used to settle debts), even if it is likely that it will be used generally for small payments (Sveriges Riksbank 2017).

5.1.2 Second CBDC version: deposited currency account

The second option is to conceive and implement CBDC as a *different unit*. Since in that case CBDC would also be a different totality (see § 4.1.1), the conversion between CBDC and the current broad money is more than plainly technical and needs to pass through an exchange rate, the domestic analogous of the forex exchange rate in which two currencies are traded and that I call *domestic exchange rate*, or from now on, DOMEX[13].

[13] Credit money and cash for now are different, but they are considered the same by law. If CBs are going to do the same with CBDC, that would fall in the e-cash scenario, as just explained in §5.1.1.

That legal difference between the two currencies opens a larger number of options in how to design CBDC, because CBDC is not bounded to have the same schemata settings of the current broad money.

Quantity	**Quality** For: 1. CB; 2. Public	**1. Relation w/ BM** **2. Relation w/ itself over time**	**Modality**
n.a.	1. - (money destruction); 2. Asset.	1. Fixed quantity & fixed nominal value; 2. Fixed interest 0% (e-cash version)	n.a.
n.a.	1. Liability (money creation); 2. Liability.	1. P determines Q or Q determines P (s/d driven); 2. P determines Q or Q determines P (s/d driven).	n.a.
Different from current Broad Money	1. Account; 2. Account.	1. DOMEX rate dynamics; 2. Price/quantity rule for independent CBDC monetary policy.	Necessity (by law)

Table 5. Possible CBDC schemata, deposited currency account version.

One interesting class to analyse is *modality*. According to the schemata discussed in Chapter 4, CBDC (which, again, is not the electronic version of cash from this paragraph until the end of the Chapter 5) can be either necessary, or not. In the former case, CBDC would coexist with the current broad money unit of account as a double legal tender. There might not to be any hurdle in this implementation, even though more controlled solutions might be enacted, but "bearing in mind that the value is stored on the card or in the app" makes likely that this kind of e-krona will only be used for smaller payments due to security fears (Sveriges Riksbank 2017). If it wouldn't be legal tender, that doesn't make sense to talk about because it is issued by CB and a *possible* status would spoil central bank's reputation. The same goes with an *existing* status, even though – theoretically – CBDC might have a stronger relation with existing commodities, such as the Petro has[14].

Regarding the class of *quality*, CBDC will be clearly account-based, whereas it is still discussed whether its settlement date on the central bank's balance sheet is set at infinite (i.e. deposit account, whose deposits can be withdrawn at demand), or is time-limited (Sveriges Riksbank 2017). According the Riksbank's report, CBDC could be allowed to be kept only for a limited amount of years, but that is a discussion to pursue in concert with other considerations (see § 5.2.1). For now, suffice to say that modality and quality classes decisions will influence market *expectations*, whose dynamics depend much on the markets and users' feeling and further surveys aimed at answering those questions might be useful.

The most difficult class to grasp, richer in options, and my focus from now on, is what kind of *relation* to envision for CBDC both with the current broad money and the international stage. This

[14] Petro seems to not be a successful example of implementation, because of weak political situation. That shouldn't obscure all the opportunities entailed in a CBDC-existing-schema solution, that might have a better implementation phase.

is much more complicated and slippery than the others, and for sure will have great repercussions (known and unknown) on the economy as it is. I call this as *domestic relation* (which I will talk about in § 5.2.1), to differentiate it from the *international relation* (§§ 5.2.2 and 5.2.3). Many researchers have already analysed some aspects of that *domestic relation*, what I am doing is providing an organic structure to those discussions, calling it *fractal monetary policy trilemma (and its elements)*.

5.2 Fractal Trilemma of deposited currency account

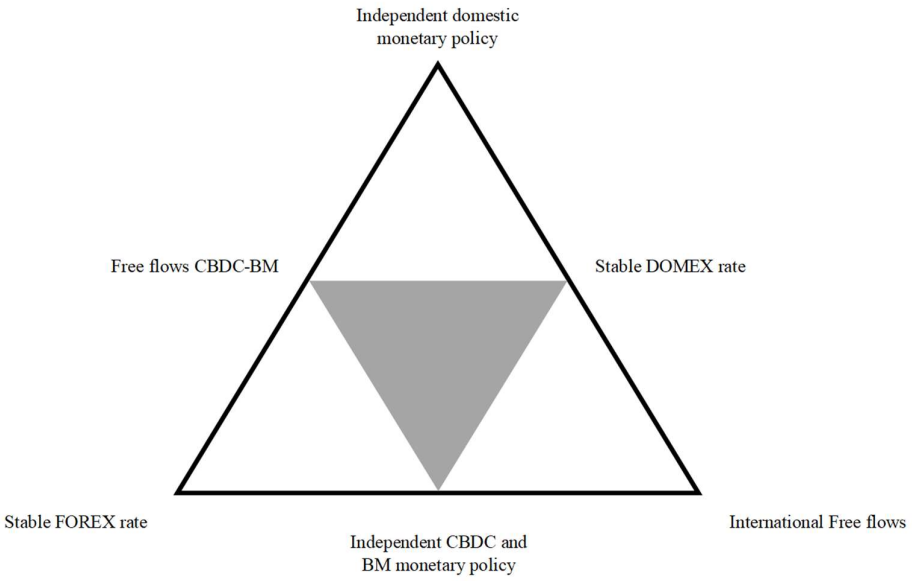

Figure 4. Monetary policy fractal trilemma.

Paragraphs 5.2 and 5.3 are the core of the whole thesis, in which everything that has been introduced beforehand concentrates. At first glance it will look convoluted, but that is because of the nature of this problem, which as I am describing has a *fractal* shape (see Chapter 3). Nonetheless, I reflect the fractal frame and use the Kantian *classes* order, to make it more familiar.

As I specified, from now on the analysis is focused on CBDC conceived as *deposited currency account* (as an expansion of § 5.1.2 and opposed to the e-cash version) and the modality conversion

is guaranteed by law, but not the 1:1 ratio (issue belonging to the *quantity* class and to the markets' actors, including the Central Bank).

The so-called *fractal trilemma* (see Figure 4) is composed of an internal trilemma – shaped out of the logical structure of the classical trilemma and which I explain in § 5.2.1 using also the money schemata – and an external trilemma, that projects the economy on the international scene, in § 5.2.2. Depending then on the relation between CBDC, BM and the international stage, there will be three main bound cases. I say "main bound" because in reality things are more complicated and nuanced, but those can identify the extreme cases according to which reality can be simplified.

In § 5.3 I will narrate how a small open economy might behave targeting both inflation and economic growth rate with two distinct monetary policy tools, while pursuing a stable DOMEX rate. Credit contraction and expansion and CBDC literature are also taken into considerations.

5.2.1 Internal Triangle: domestic Trilemma with CBDC and Broad money

The new element of that Fractal Trilemma is the *internal triangle*, that it is subsumed to the traditional monetary policy trilemma. The difficulty stems out of the coexistence of the current broad money (credit and monetary base) and CBDC.

The starting point is once again the existent literature.

Kumhof and Noone (2018) proposed three scenarios and for each looked at three exhaustive options, focused on the impacts on balance sheets. Briefly, in most short-term cases balance sheets of Banks on the liability side decreases (exception in EW, option 2). But they notice that even if balance sheets are affected, balance sheet extension is a less relevant measure because they don't show profits, only assets and liabilities. They also argue that the important measure to look at is total credit aggregate and they show how the "total credit [is] not affected directly" but it might "[…] impact regulatory ratios and so affect the quantity or price of credit" (Kumhof and Noone 2018). That is because reserves requirements are a percentage of the amount of deposit liabilities and reducing deposits will also reduce reserve requirements (where present) and the leverage of the banks in issuing loans. So, in those scenarios in which liabilities of banks are affected by any incremental conversion in CBDC from deposits (passing through bonds conversions in their case) would reduce households' or NBFI's liabilities detained by banks, but not the amount of loans. Thus – ceteris paribus, *like reserve requirements* – the ability to issue loans (and create credit money) will be reduced. And that means that loans in the short-term will be constant from an accounting perspective, but if the amount of CBDC is persistently higher than BM, in the long run the economy will slow (as reciprocal interaction of monetary policies, § 5.2.1.3). Yet, as far the public (firms and households) will continue to want loans and mortgages, they have to convert CBDC into credit-money to get them.

In the following arguments, I will say "CBDC bought by BM (Broad Money)" or the other way around. That is a contracted form for logic sake. Current broad money encompasses reserves, deposits, bonds denominated in the current domestic currency unit of account and are convertible into each other (see the parameters of their convertibility in § 4.2) with specific but changing haircuts when passing through the monetary transmission mechanisms, due to financial frictions and capital flows control.

At this point, that we know how CBDC and BM might interact in the long-run *ceteris paribus*, as far as literature suggests, CBDC issuance will impact banks' ability to create credit and is a phenomenon that has similar effects to modifications in the reserves' interest rate. That is a counter-effect that any monetary policy maker must take into consideration in the decision process, and policy makers need to decide how to regulate (as synthetic rule creation) the relation between CBDC and BM. Here is when Kantian schemata and my following money schemata can help to solve the riddle.

In the previous chapter 4, it emerged that a financial instrument can have three dichotomic relations with another financial instrument, namely *attribute-substance*, *causal-contingent*, *reciprocal*. CBDC and the current broad money are two distinct financial instruments (totalities) and, consistently, given that this is an attempt to synthetize CBDC and its relationship with broad money, theoretically that relation can be as follows:

- *Attribute-substance*: price demanded/offered of CBDC and BM don't influence each other. They would be merely juxtaposed, while one changes the other persist (two cases, alternatively considered substance and attribute). This is the extreme bound where price or quantity of supply or demand are fixed (X and Y coordinates are alternatively fixed) and the other is a curve, that shifts; similar reasoning for the relation of CBDC with itself in postponed time.
- *Causal-contingent*: price or quantity of demanded/offered for CBDC or BM (depending whether supply-demand driven) drives quantity and price respectively; similar reasoning for the relation of CBDC with itself in postponed time.
- *Reciprocal*. In this case, both price and quantity demanded/offered influence and react to each other.

In § 4.1.3, I demonstrated that there are two types of relations for most of the financial instruments. In particular for a currency, the special case when is in relation with itself in a postponed time, which is called *interest rate* and it is normally traded in the money market, the operational field of monetary policies; the case in which the currency is traded against other currencies (the FOREX market, and again operational field of monetary policies).

Similarly, CBDC monetary policy exchange operations would act in both markets: monetary policy operations aiming at adjusting the future expectations of price supplied and quantity demanded of CBDC, and at adjusting the exchange ratio with other currencies. In the case of a domestic exchange market there are only two currency-units (CBDC and BM) and the rate is what I called DOMEX, the price (units of CBDC) that someone is willing pay for one unit of BM. This process will affect bonds price too, reverberating all over the economy.

In the coming sub-paragraphs, I will dig deeper on those schemata. Before moving to the core of the arguments, I just remind that – as according to the original Kantian categories – attribute-substance and causality-contingency might seem intuitively incomplete and uncomfortable taken as a complete option, but they are the extreme bounds of the third schema, *reciprocity.* In any economy issuing CBDC beside having the current broad money, it is very likely that they will tend to reciprocally influence each other – though it is an issue that will acquire full definition and sense in an implementation phase, considering results, amount of currencies traded, liquidity, perceptions of the public, and many other measures.

5.2.1.1 Domestic relation: attribute-substance

In explaining monetary policy in schemata terms (see § 4.3), there were two relations for the currency, one with itself in postponed time and the second with another currency. In this case, CBDC is in relation with itself and with the current domestic broad money aggregate. First, I consider whether a relation of the type attribute-substance can define those relations.

In the case of i*nterest rate*, either:

- The supply curve is constant (elastic/inelastic), thus the price demanded (at the end of the period) and the quantity offered (at present) by the supplier are constant at any quantity demanded by the demander. That means that for example the Central Bank just provides a fixed amount/price of money, no matter what the demand for it. Or,
- The demand curve is constant, thus the price offered (at the end of the period) and the quantity demanded (at present) by the demander is constant at any quantity offered by the supplier. That means for example that the public asks a fixed amount/interest, no matter what the supply by the Central bank.

These cases might happen as an unwanted case of distortion of the market, where policy makers cannot control money price-quantity anymore. I anticipate that they will become useful in understanding reciprocal monetary policies (similarly to §§ 4.1.3 and 4.3).

In the case of the *DOMEX market*, either:

- Price CBDC demanded changes, quantity BM offered persists; or

- Price CBDC demanded persists, quantity BM offered changes; or
- Price BM demanded changes, quantity CBDC offered persists; or
- Price BM demanded persists, quantity CBDC offered changes.

That means that whenever the CB changes the CBDC interest rate the quantity of BM demanded isn't affected at all, and the other way around.

5.2.1.2 Domestic relation: cause-contingent

According to the theoretical framework of money schemata, the second case is that CBDC-BM relation can be planned to be causal-dependent. I use again supply-demand dynamics to explain this relation.

CBDC with itself - Interest rate (this is one element of monetary policy independency):

- The quantity of CBDC offered (at the end of the period considered as a change in quantity) by the supplier (CB) determines alone the price offered in the market by the demander. This is the case in which a change in quantity decided by the supplier determines also the price and quantity at which the demand curve clears.
- The quantity of CBDC demanded at the end of the period by the demander determines alone the price demanded in the market by the supplier. This is the case in which a change in quantity decided by the demander determines also the price and quantity at which the supply curve clears.

DOMEX market (Exchange house)

In the following analysis, for simplicity CBDC and BM start from parity (DOMEX ratio is 1:1) and equal starting point of interest rate set by CB. Movements from different starting point (but in equilibrium) follow the same reasoning, per interest rate parity.

This is the case in which there are two totalities of money, CBDC and the current BM.

- The price (expressed in BM) demanded by the supplier drives the quantity of CBDC demanded by the demander.
- The price (expressed in BM) offered by the demander determines alone the quantity of CBDC offered by the supplier.
- The quantity of CBDC offered by the supplier determines alone the price (denominated in CBDC) offered in the market by the demander.
- The quantity of CBDC demanded by the demander determines alone the price of CBDC offered by the supplier in the market.

5.2.1.3 Domestic relation: reciprocity

Consistently, there are two cases also for a reciprocal relation. Following the price rule defined in § 4.3, monetary policy rule translates into a price and quantity rule for CBDC:

- Price rule: the central bank set first the interest rate of CBDC as persistent and offers consequently the quantity of CBDC money demanded by the market;
- Quantity rule: the central bank decides just the quantity of money to supply, thus the interest rate follows market demand.

When CBDC is considered in relation to BM, they generate the DOMEX rate and it is likely that CBDC and BM will influence each other through the mechanism of *banks' deposit destruction and CBDC-creation* (or the opposite CBDC-destruction and deposit banks creation) according the bound dynamics explained at the beginning of § 5.2.1.

At the same time, traditionally an independent monetary policy is defined independent if it is able to follow a rule independently from international influences and to target domestic measures. The question is what happens when there are two domestic monetary policies, and both want to be independent. That independency and stableness of exchange rates are both elements of the classical monetary policy trilemma, and to explain how they interact I have to consider the missing elements of that trilemma, capital flows. Thus, that brings directly into interpreting the new CBDC-instrument in the domestic economy as a *fractal monetary policy trilemma*, as in the following §§ 5.2.1.4 and 5.2.3.1.

5.2.1.4 Internal Trilemma: elements

In § 2.4 I introduced the classical monetary policy trilemma. What I am going to do now is to convert the classical trilemma into a monetary policy trilemma between CBDC and BM, which is a domestic version of the trilemma.

From a pure logical standpoint, the classical trilemma consists in choosing only two elements out of three – or in a passive way, that only two elements can happen at the same time and it is based on: the two currencies (i.e. domestic and international) are two different units (totalities) that can be mathematically related and generate a ratio; their respective monetary policies can be independent or not; that capitals can be converted into each other (and an authority can control the rules of the transfers or conversions between the two). Given that I am studying the case in which CBDC is considered as deposited currency account and coexisting with BM, I argue that the same logical trilemma can holds for CBDC.

Thus, the following domestic trilemma elements reflects the same structural logic of the original trilemma read through CBDC-schemata.

A. *Monetary policy*

As long as CBDC is a new totality beside BM within the same economy and under the control of the same monetary authority, there will be two coexisting monetary policies, which can be both, either, or neither independent.

In the case of BM, an independent monetary policy would mostly mean what it means nowadays, in the sense that it will follow a price rule[15]. There will be one more possible case in which *BM is not independent monetary policy* because it is subsumed to a CBDC monetary policy. More will be explained in § 5.2.3.1.

In the case of CBDC, mimicking the logic of conventional practices of monetary policy, the central bank would follow either a price or a quantity rule, and that's what opens more possibilities to CBDC in terms of monetary policy.

So, for an *independent CBDC* monetary policy following a price rule the options already proposed are:

- indexed to the general price level (Bordo and Levin 2017), CPI;
- interest rates different for each agent holding CBDC (Meaning, et al. 2018), which also depends whether normal reserves are still existing according to Meaning's explanation.
- An arbitrarily adjusted CBDC interest rate.

In the case in which CBDC monetary policy would *not be independent* in a price rule setting, the CBDC interest rate would be the same as the current main interest rate instrument, even if it might be likely that it would have a constant spread against repo rate, as Riksbank is currently thinking of (Sveriges Riksbank 2017).

I discussed price and quantity rules of CBDC monetary policy in schemata terms in § 5.2.1.3, as the reciprocity relation of CBDC with itself in a postponed time.

B. *Exchange rate*[16]

I explained in Chapter 4 that the exchange rate is a ratio from a mathematical standpoint. From a monetary policy perspective, the exchange rate is the objective of open market operations, that "manage" the exchange rate (market is liquid and active (Kumhof and Noone 2018)) – the implementation step of the schemata *totality* in relation with another one. What was a foreign exchange rate, in a domestic case is simply a *domestic exchange rate* between CBDC with "domestic broad money", what somebody is willing to pay in unit of CBDC for one unit of BM and vice versa (as

[15] Reciprocity between CBDC and BM excluded, here I am analysing static momenta.

[16] Note that the absence of a rate – which results in maintained parity either way, but by legal act (conversion is only of quality or modality, not of totality) – is just the case of e-cash.

mentioned, any eligible asset can be expressed in BM even though it makes more sense to use bonds; worth to note, bonds functions as in-between financial instrument, whereas the demand originates from the conversion of, and finishes to, deposits). Given that this would be a new case of international economics and both units (CBDC and BM) are controlled by the same Central Bank in a special way (unique in the world).

Following the logic of classic monetary policy regimes, the DOMEX rate will be either floating, hard peg, soft peg, which is the mathematical ratio CBDC:BM.
A safe choice to begin with, and the one that makes sense to talk about (because of everyday practicality) is clearly to be committed to have a stable (hard or soft pegged) rate and the Central bank, committed to it, will act accordingly in its open market operations to ensure a stable DOMEX rate 1:1.
When the current base money changes and the CB wants to keep the parity actively, CB has to react to changes of the foreigner via OMO (its dynamics follow the relation of causality/reciprocity previously analysed).
In the case of a *domestic floating regime*, the DOMEX rate will vary freely according market actors' demand, and the CB is not committed to maintain the exchange rate stable.
I discussed price and quantity rules of the DOMEX schemata terms in § 5.2.1.3, as the reciprocal relation between CBDC with BM-money.

C. Domestic Flows conversions

To understand better domestic flows and possible forms of control, it is useful to look at the logic behind the current ones.
Parameters for restrictions on flows generally fall in the following categories (International Monetary Fund 2016): amount of the transaction allowed (either setting a maximum or a threshold of transfers), length of time, actors/holders of financial instruments, relations (both between holders and between financial instruments that want to be *mathematically converted* into each other).
Similarly, conversions between broad money quantities (reserves, bonds, bank deposits, any eligible assets) and CBDC (as another totality) in both ways could be subjected to some of those convertibility parameters restricted by law, if requested. Here I am only considering the conversion flows within the same country, the case of domestic capital flows between CBDC and general BM. For international influence see both §§ 5.2.2 and 5.3.3.

In money schemata terms, the utter absence of convertibility controls entails determines free *mathematical conversion* among financial instruments. In real environments, any small regulation is likely to limit perfectly free conversions, and the proposed versions of CBDC scenarios until now

can be considered a kind of control measures (holders of financial instruments). The same apply to the capital flows between CBDC and BM, that can also be controlled in many ways (Sveriges Riksbank 2017).

My starting position, which partly reverse the current approach, is that a perfectly "liberalised" scenario is one in which CBDC is so-called Economy Wide (Kumhof and Noone 2018). As in the classical scenario, determining by law who is entitled to hold a special financial instrument is a form of capital controls, and the same goes when policy makers decide who is allowed to hold CBDC, or in other words who to allow to be the *demand* (i.e. the market participants). In this case of control, I can finally show how the accessibility parameter used widely by other researchers is part of *free flows* issue:

- Economy Wide access (EW) (Kumhof and Noone 2018): demand for CBDC is depending upon everybody. They also make a further distinction (which constitutes one of the four core principles), stating that CBDC has to be different from reserves: that is indeed a form of control (limitation), whereas Meaning, et al. (2018) argue that everybody can have access to CBDC and convert money freely.
- Financial Institution (FI) and FI+ (Kumhof and Noone 2018) (Monetary Authority of Singapore, Accenture 2017) (Monetary Authority of Singapore, Deloitte 2017): CBDC functions as an alternative *e-reserves* and demand is depending only upon commercial banks, investment banks, FI, NBFI, et similia.
    - E-cash for households: demand driven only by consumers (electronic version of cash).

Other examples of forms of control are:

- Block an outflow that exceeds a certain amount;
- Haircuts on conversion (e.g. converting CBDC will be capped or taxed);
- limiting the number of transactions (it is also possible to do it selectively per actor or per amount beyond a threshold);
- limiting the length of time of CBDC deposited;
- Relation between CBDC and the eligible asset (this is a control on the convertibility allowed), as for now they are generally bonds (Petro has oil reserves);
- General checks on the relation between transferrer and receiver.

5.2.1.5 Internal Trilemma: options available

Now that I have introduced the elements of the trilemma, concluding the same reasoning, it would be likely that are possible *three choices* (i.e. three pairs to choose among):

1. The first option available is the case in which the DOMEX (*domestic exchange rate between CBDC and broad credit money*, reserves and/or bank deposits) is stable and the public can

freely exchange CBDC for bank deposits or reserves and vice versa, but CBDC and BM monetary policies are not independent – that means that CB will have to operate in the market (following either a quantity or price rule) to adjust the DOMEX rate and not pursuing any specific goals. It is worth to be highlighted again, a DOMEX rate 1-to-1 is a specific case of conversion, the trilemma only tells us that the DOMEX rate (whichever it is) will be fairly stable, despite the possibility of having different CBDC and BM interest rates.

2. The second option is to have free flows between CBDC and current broad money (Meaning, et al. 2018) and two independent monetary policies, respectively for CBDC and BM (following either a quantity or price rule). Nonetheless, the DOMEX rate will be floating (and it will be even less likely to have a 1-to-1 conversion, with more difficulties faced by sellers and pricing in general).

3. The third option is to have a stable DOMEX rate (between CBDC and current broad credit money) with two independent monetary policies, respectively for CBDC and BM-credit. The downside is that there won't be free flows between CBDC and domestic broad money and restrictions are needed to control the market, among (and beyond) those listed right above under *Domestic flows conversions*.

In depths details, dynamics and consequences will be discussed later in § 5.3. As for now, I am considering CBDC and BM as part of the same bulk (even though the outcome results from their reciprocal interaction, discussed above). This leads to talk about the international (or world) stage.

5.2.2 External Triangle: Trilemma between domestic and international stage

In § 5.2.1, I considered two money-entities (and related trilemma) within the same domestic economy. As promised since the beginning, I am going now to take into considerations the international stage. This constitutes the *external triangle* of the fractal triangle trilemma, the classical trilemma that is still valid after the CBDC introduction. It would be mostly unaltered from the original form when in relation to the domestic economy. What must be added, is the fact that the classical domestic currency is now an aggregate of CBDC and BM and that there are also CBDC capital flows.

According to the classical monetary policy trilemma logic, the *domestic independent monetary policy* is a combination of CBDC and BM monetary policies (interest rates – relation with themselves in postponed time). I will finalise this argument in the next paragraph.

The *foreign exchange rate* is both in relation to the CBDC and BM aggregate, how much of a foreign amount is willing to give for one unit of CBDC or one unit of BM. Again, when the domestic money aggregate is put in relation to a foreign the exchange ratio can be hard-soft pegged, or it can just be floating.

A *conversions of capital flows* between domestic and international financial instruments might be subjected to capital flow management and macroprudential measures, such as control on amount transferred, length of time, actors operating, relation between holders and with other financial instruments traded (both in- and out-flow movements). They are the same as usual but in this case, there are few differences that will be cleared in the next paragraph.

Once again, the available options of the external trilemma are[17]:

1) Central bank is committed in maintaining the FOREX rate with a foreign currency set as a standard stable; international and current broad money freely converted into each other, but the independency of the domestic Central Bank is lost;
2) Independency of the domestic Central Bank, international and current broad money freely converted into each other, but a stable exchange rate with a foreign currency set as a standard is lost;
3) Current broad money price changes in relation to a foreign set as a standard, independency of the domestic Central Bank, but international and current broad money are unable to be freely converted into each other and control measures are needed.

What is most interesting to consider in this *external triangle*, is that similarly as done before (§§ 5.2.1.1 – 5.2.1.3) to better grasp the problem, I consider the new domestic aggregated currencies (CBDC and BM) in relation to the international aggregates according to the *relation class*, thus the relation can be conceived as substance-attribute, contingent-causal, reciprocal.

Since an economy defined as *attribute* would mean that changes while the international persists, this can fairly be said to be the case of a *small closed economy* compared to the aggregates of the rest of the world (in which there is no mutual influence whatsoever). In the case an economy is *determined* by an external one, that is the case of a *small open economy*. In the case world currencies are considered as determinant, the domestic price is determined. For example, when the international changes and the domestic CB wants to keep the exchange rate stable, CB has to react to changes of the foreigner via OMO. An economy that *determines* alone the remaining rates of the world has no representation in reality. But in case an economy can affect the world in large measure and being less affected in converse – in *reciprocal* exchange, that is exactly the definition of large open economies, such as USA and Europe. In reality, there are graded cases in between (between being completely dependent on the international scene and a full reciprocity – not even US can reciprocally interact with the entire globe). Extraordinarily prophetical what Kant says (1998), "when several objects [economies] are in community with one another, each of them acts on and is acted on by the

[17] short version also used for combinations later.

others, so that again there is no primacy or seniority". Clearly there are not such perfectly power-balanced economies, some are more powerful than others and no one is equal.

So, the two relevant cases are *small open economy* (determined by international stage) and *large open economy* (in reciprocal causality with the rest of the market). In the remaining paragraphs of the chapter, given the irrelevance of a domestic close economy, given the limited number of large economies in the world, and given the relevance of the small economy as Sweden is seriously considering of implementing the CBDC project[18], I will analyse and discuss only the small open economy case with the framework of the *fractal trilemma* in its entirety, both the internal domestic trilemma-triangle (reciprocity between CBDC and BM) and the external international trilemma-triangle (fairly classical, considering the international stage both as causal and as in reciprocal activity with the domestic economy), and I will lean towards the conclusion of my paper then.

5.2.3 Fractal Triangle: broad money and CBDC are affected by the international stage (i.e. small open economy)

This is the case of a small economy, one whose currency (per price and quantity) is dependent to the international stage or to a specific currency (e.g. in the case of Sweden is EU even though Sveriges Riksbank is pursuing an independent monetary policy). I am going to present the results of the *schemata relation* between CBDC, broad money (base and credit) and the international stage in general.

Recalling the new fractal triangle, I am going to talk about the *fractal trilemma* where the internal triangle is related to the external as *dependent*, which is an adapted (theoretical) version of the traditional monetary policy trilemma introduced in Chapter 2, where another triangle appears inside the outsider.

5.2.3.1 Fractal Trilemma: elements

This is the case of a small open economy, thus its currency prices and capital flows are strongly influenced by the international stage, unless the country enacts forms of capital control (this is part of the trilemma indeed).

The new trilemma so generated, I call it *fractal trilemma*, because as the fractal structure of a Sierpinski triangle, the traditional trilemma will continue to exist, but a new trilemma within that will appear (mirror of each other but with different terms and different seizes). The fractal trilemma triangle becomes "choose two out of three of the outsider triangle (BM together with CBDC vs. the international stage), choose two out of three inside triangle (CBDC vs. BM), which will be dependent from the outside. Here I am going to present the single elements faced by policy makers and in the next paragraph, I will present the whole table of combinations generated.

[18] And the limited resources in this thesis.

Mostly has been said previously about the structure of those two triangles. This is the specific case in which the international stage is affecting the domestic currency (economy). At a quick reading it might seem that the international stage can create apparent contradiction, when the internal elements are reciprocal to each other but together are dependent on the external international stage. I will explain how that is not the case in fact.

A. Independent Monetary policies

There will be two monetary policies. One will be within the domestic economy between CBDC and BM, the other is the whole bulk of CBDC and BM versus the international influences. Central Bank can decide which one of the two to keep independent, or if relevant neither. That flexibility is possible and not contradictory, because if the Central Bank decides to keep just the domestic policy independent, the Central bank will set one rate as the reference level and the remaining rate will move around the dominating rate.

B. Exchange rates

The Central Bank will have to decide which rules to follow and in relation to the international stage (which can be hard-soft pegged or floating) and how to manage the domestic exchange rate accordingly.

In that case, there will be three exchange rates, one domestic (DOMEX) and two FOREX exchanges (CBDC-foreign BM, domestic BM-foreign BM)[19]. Usually a small open economy, if pegged, anchors its FOREX to one foreign currency.

Similarly discourse to the monetary policy independency, one of the two (CBDC or BM) can be pegged to the international and the other not, it is not theoretically impossible. One question that might arise is which ratio to consider to be the most relevant on the international stage, the one to use as reference point and that one to be subsumed. That will depend on future dynamics of the markets (other countries issuing CBDC, which currency is more reliable and demanded- traded in higher volume, etc.). As for now, a BM hard peg might result to be the most trustworthy.

C. Capital flows

Once again, in this *Fractal trilemma* capital can be split between domestic capital (which I discussed about in the previous internal triangle, see § 5.2.1.4) that concerns access control and other measures; and international capital. Nobody has ever discussed it, and it is understandable because it is a further

[19] Once more CBDCs will be issued in other countries, if not controlled, also CBDC FOREX between different countries are possible and between domestic BM-foreign CBDC.

step of complexity and the novelty of my approach is to consider it. Theoretically, international capital is both a) any foreign currency form, b) other foreign CBDCs.

That nexus between CBDC and any international money aggregate is very interesting here, because that is how CBDC would be subject to speculation by other countries.

Regarding a), for example blocking foreign investors into converting CBDC is considered a form of control, that a digital wallet might make it even easier to accomplish. But again, the same parameters of existing forms of control can be applied, adapted in the implementation phase.

Regarding b), the impossibility of converting any CBDC into another not-existing CBDC is another form of limit, which might be overcome with future CBDC international markets. That nexus will mostly depend whether other countries will adopt the same system on CBDC, in that case only there might be a direct link between CBDC and international CBDC. If we consider international current broad money, though, there will be a mediated conversion between CBDC and international BM passing through the domestic broad money infrastructure. Freely conversions between international and current broad money will determine increase or decrease of monetary aggregates.

Worth to be noticed, there is no apparent limitation in having simultaneously international investors' flows controlled and free domestic flows.

5.2.3.2 Fractal Trilemma combinations: options available

Finally, I can show the available options in monetary policy for a small open economy that issues CBDC beside cash as new totality. The combinations of the two trilemmas (insider and outsider) – which I called fractal – generates nine scenarios.

$$\frac{3!}{2!} \cdot \frac{3!}{2!} = 9 \qquad (1)$$

The schematic (schematic in normal language) results are presented in the following table. That looks complicated, but at this point should be straightforward. The combinations are straight addition of the trilemmas elements (one per each triangle is excluded, that is the logical rule induced by the traditional monetary policy trilemma), whereas the relation between CBDC and BM is reciprocal (internal triangle, § 5.2.1.3) and the relation between domestic economy and the international relation is causal (the domestic is mostly determined), note the *causal arrows*.

This describes what might happen with CBDC issuance on the domestic scene with two monetary policy instruments and, using Kantian terms, "in their reciprocities with the international stage".

Options	International →[20] (BM+CBDC) – External triangle			BM ↔ CBDC – Internal triangle (domestic)		
	Stable Exchange	Free flows	Independent domestic Monetary Policy	Stable Exchange CBDC – BM	Free flows CBDC – BM	Independent CBDC and BM Monetary Policies
1.a	YES	YES	NO	YES	YES	NO
1.b	YES	YES	NO	YES	NO	YES
1.c	YES	YES	NO	NO	YES	YES
2.a	YES	NO	YES	YES	YES	NO
2.b	YES	NO	YES	YES	NO	YES
2.c	YES	NO	YES	NO	YES	YES
3.a	NO	YES	YES	YES	YES	NO
3.b	NO	YES	YES	YES	NO	YES
3.c	NO	YES	YES	NO	YES	YES

Table 6. Nine combinations of the monetary policy fractal trilemma - small open economy.

These are the scenarios resulting from the *fractal monetary policy trilemma*:

1.a A stable DOMEX rate CBDC/BM (that means are equally wanted) is pegged (because it is a causal relationship) to an international standard. Domestic flows are not controlled, the same as between domestic-international investments. It goes that the Central Bank loses independent causality on CBDC interest rate and on domestic money base in general, thus neither CBDC nor BM interest rates are independent to each other, nor CB can follow other rules than those to be pegged to the international standard.

1.b The DOMEX rate CBDC/BM is stable, and the domestic bulk (BM plus CBDC) is pegged to an international standard. The Central Bank has independent causality on CBDC-or-BM interest rate, but it has limitations on pursuing an independent general domestic monetary policy. Thus, there is no free conversions between CBDC and current broad money (which means there are measurement of controls, e.g. those mentioned in § 5.2.1.4), whereas there are free flows coming from international investors.

1.c There is free conversion between CBDC and BM, and between domestic and international quantities in general. The Central Bank can pursue independent goal on the CBDC interest rate. It means

[20] Note the one side arrow: international is affecting the domestic economy.

that BM interest rate has to adjust to keep FOREX (BM/international) pegged, but that there is not a stable DOMEX rate CBDC/BM.

2.a There is a stable FOREX rate and the Central bank can pursue a general independent monetary policy. There is stable DOMEX rate (CBDC/BM) and free conversion flows between CBDC and BM, but there are no free in- and out-flows with international investors. Finally, the Central Bank loses internal monetary policy independency of CBDC rate.

2.b There is both a stable FOREX rate and DOMEX rate, and the Central bank can pursue both a general independent monetary policy and an internal independent monetary policy (both CBDC and BM). Yet, it loses free flows with international investors and also free conversions between CBDC and BM denominated assets.

2.c There is a stable FOREX rate and the Central bank can pursue a general independent monetary policy, but it has to give up on free in- and out-flows with international investors. Internally, there are free conversions between CBDC and BM assets and the Central Bank pursues an internal independent monetary policy, but the DOMEX rate is not stable.

3.a The Central Bank can pursue a general independent monetary policy and it allows for flows with international markets, but the FOREX rate is not stable anymore. The DOMEX rate is stable and conversions between CBDC and BM are free, but the Central Bank renounce a domestic independent monetary policy.

3.b The Central Bank can pursue a general independent monetary policy and it allows for flows with international markets, but the FOREX rate is not stable anymore. There is a stable DOMEX rate and the Central Bank pursues a domestic independent monetary policy, but there are controls on the conversions between CBDC and BM.

3.c The Central Bank can pursue both a general and a domestic independent monetary policy and it allows for flows with international markets and within the domestic economy between CBDC and BM, but the FOREX and the DOMEX rates are not stable anymore.

Those options above listed exhaust the choices available and should be sufficient for policy makers. In the following paragraphs, I am going to further discuss specific issues, expand considerations and compare them with the CBDC Literature.

5.2.3.3 Discussion of the results: comparing fractal trilemma with the existing literature

The trilemmas show all the nexuses between CBDC, BM and the international stage assuming being a small open economy (but the difference with a large economy in the table would be pretty much the relation between the economy considered and the rest of the world, which will be reciprocal).

Worth to be noted is that it is true that a small economy is never completely and solely determined by an external one. Nonetheless, by definition, the smaller the economy is the more likely is that it is impacted by world dynamics or by other economies with which it has tight relationships (as I repeatedly said before, this is closer to a real small open economy than a pure reciprocal relation is). Researchers focused the attention on USA and UK mostly, so on large economies. Yet, given the generality of their frameworks and within a general domestic economy without taking into consideration foreign intervention, I am going to discuss their observations in this session, because are mechanisms that are going to function – likely – similarly. Most of all, I will finish comparing them with my results to see how they perform.

In the Internal triangle I talked of *independent monetary policy* as being those that can follow a price or quantity rule without being anchored to the predominant BM rate. But there are other options of non-conventional monetary policies that I mentioned in the literature review. In fact, it is likely that QE (Meaning, et al. 2018) and helicopter money (Turner 2015) would be easier to implement via CBDC accounts, and they belong to the possibility of having a domestic independent monetary policy too.

Another relevant issue is *parity*. There have been a bit different views on parity between CBDC and BM (Kumhof and Noone 2018) (Meaning, et al. 2018), especially how the actors might react when the economy (or the banking sector) is under stress. Meaning, et al. (2018) argue that the ability of depositors to exchange commercial bank money for central bank money is fundamental in maintaining the confidence in bank deposits, especially to remove bank runs risks (a CBDC mass inflow is an extreme case of domestic capital flows; the opposite is a CBDC mass outflow, which would make CBDC useless). So, Meaning et al. depict a scenario in which there is free and guaranteed conversion, independent monetary policy rates for each holder of CBDC and a stable exchange rate between bank deposits and CBDC.

On the other hand, Kumhof and Noone argue that there is no need to intervene or to "guarantee deposits-to-CBDC convertibility" because the exchange rate will be maintained at 1:1 if three conditions are maintained: if the Central Bank is committed in meeting any quantity demanded (under a CBDC price rule), if there is a functioning and liquid market for CBDC eligible securities, if there is at least one private actor that can act as arbitrageur to take advantage of arbitrage opportunities (Kumhof and Noone 2018). Similarly will parity between reserves and CBDC and between cash and CBDC be maintained (Kumhof and Noone 2018). In bank runs too, parity doesn't break down basically because of bank deposit interest rate adjusts.

The Meaning et al. interpretation might look a little too much stretched and the Kumhof explanation let rise a question: if CBDC' and BM's functions are different, and they are not perfectly fungible

(Kumhof and Noone 2018) it is unclear why parity would be maintained. The fractal monetary policy trilemma can give one deeper explanation.

From the fractal trilemma perspective, to have a CBDC-BM parity that holds, Kumhof and Noone (2018) should be assuming that either there are capital controls, or that there is no independent interest rate monetary policy. And indeed, the authors say that CBDC cannot be converted into reserves, as per core principle. It is now clear that the exchange rate and the capital conversions are not standalone elements. They will depend on each other and on the monetary policy enacted.

My model is innovative regarding Kumhof's and Meaning's because it takes into consideration convertibility, monetary policies and parity as part of the same theoretical framework (borrowed from the logic behind the classical monetary policy trilemma) and showing how one choice might exclude the others. Kumhof's explanation results to be aligned with my fractal monetary policy trilemma (no conversion on demand for deposits granted: i.e. conversion is free but reserves cannot be converted), because it is partially controlled (that make EW correspond to scenarios number 1-2-3.b of the fractal trilemma), whereas my model and Kumhof's critique on Meaning are also aligned in highlighting the controversy of Meaning's results.

5.3 Rethinking monetary policy: tackling stagflation

The core purpose of my thesis stemmed from the complications that a CBDC issuance might add to monetary policy processes, related opportunities and the potential arbitrariness of its usability that would be preferable to overcome. What moved my research is the need for rules for the systems and the markets, before let the markets play. Of course, there is space to improvement, but hopefully this framework can guide to more sound rules, which ultimately will make a CBDC adoption more likely and effective. The introduction of a CBDC as deposited currency account, that bears an interest rate beside the traditional monetary policy main interest rate, and that also affects credit creation in the long run, will let policy makers rethink the conventional monetary policy.

As I have just showed, there are nine general settings available, but not all of them are feasible or worth to be pursued.

First, the most attracting elements of the internal triangle, those that most economists would regard as desirable are:

A. Having one more CBDC independent monetary policy instrument;
B. fixed DOMEX rate for smooth payments and easy functioning of the economy (Meaning, et al. 2018);

C. allowing broad access to CBDC to everybody (EW scenario).

Due to the trilemma, a choice is needed and the preferable combination will depend surely on the economy adopting CBDC, but it is likely that parity between CBDC-BM is the most compelling priority, because it is important to give consistency to consumers and sellers, thus it is likely that policy makers will pursue that objective (even though relying on apps and digital devices might simplify a not-perfect exchange rate of 1:1). According to the internal trilemma, it entails that monetary policy makers have to choose either to have free movements or to have independent monetary policy.

Now, I am going to have a closer look at the scenario in which (1) the DOMEX rate is stable, (2.a) the CBDC interest rate targets inflation, and (2.b) the traditional interest rate (e.g. repo rate, overnight rate, etc.) functions to expand/contract credit, given that economic growth and inflation are not empirically always aligned. Hence, there are (2.a and 2.b) two independent monetary policies, and consequently, according to the trilemma, proper (3) capital controls. That is what most of the papers on CBDC have been vouching for, even without explicitly considering the latter one. This can recall the option discarded by Bordo and Levin (2017), of having CBDC interest rate tight to CPI, but it is not. Indeed, it is an overall rethinking of what to target with the old traditional monetary policy main interest rate and what to target with the new CBDC interest rate available.

I briefly remind that the *inflation rate* is measured comparing the price level of one period with the price level of another period (i.e. the *price* level as *relation with itself in postponed time*, whose change is measured in percentage), and the *economic growth rate* is the *quantity* of output in relation *with itself in a postponed time* (whose change is measured in percentage). Also, there are *two agents* that affect inflation and growth: *aggregate suppliers* and *aggregate demanders* who influence the *price offered/demanded* at persistent quantity (inflation), and the *quantity offered/demanded* at persistent price (economic growth rate).

The monetary policy novelty consists precisely in using the *CBDC interest rate* (a time-measure) to affect prices over time (demanded-offered, thus *inflation*) and the *BM interest rate* (a time-measure) to affect quantity (offered-demanded, thus *economic growth rate*).

That doesn't mean that monetary policy makers have to constantly intervene in the economy, but if economy conditions are worrisome, they are committed in changing price and quantity of CBDC and BM. Just to give an indicative esteem, "the threshold level of inflation above which inflation significantly slows growth is estimated at 1-3 percent for industrial countries and 11-12 percent for developing countries" (Khan and Ssnhadji 2001) and a CBDC setting can follow the same precautionary target. Moreover, in the case of stable growth and inflation, there is no need of two domestic

independent monetary policies at all because inflation and economic growth are aligned, thus the CB can allow more free movement of capitals.

The following Table 7 represents the nine general cases that cover the basic possible combinations of inflation and economic growth rate pace, in a domestic economic environment.

	Stagnation	**Stable growth**	**Excessive economic growth**
Low inflation rate	Reduce CBDC rate Reduce BM rate	Reduce CBDC rate -	Reduce CBDC rate Rise BM rate
Stable inflation rate	- Reduce BM rate	- -	- Rise BM rate
High inflation rate	Rise CBDC rate Reduce BM rate	Rise CBDC rate -	Rise CBDC rate Rise BM rate

Table 7. Monetary policy actions at varying of inflation and economic growth rates.

As theoretical example, I narrate only what happens in the case of *stagflation*, splitting it in two simultaneous moments in which only one of the two variables changes.

- Inflation is above the inflation target: according to the new monetary policy setting, CB raises CBDC rate because it is committed. Consequently, more bank deposits are converted into CBDC because they are more attractive, and people tend to spend less (assuming expectations are that CBDC will increase in nominal value and that prices will lower), triggering a demand-pull deflation. In the long run, banks tend to rise the deposit rate for clients and attract funds. In the meanwhile, (as per reciprocal interaction effect § 5.2.1) total credit is stable but loans issuance declines so that in the longer run economic growth tends to hinder.
- Economic growth is hindered: according the new monetary policy setting, CB raises the repo rate (BM rate). That in turns, encourages businesses to borrow cheaper money and financial intermediaries to lend it, thus boosts investments and increase output. Yet public will also tend to buy more CBDC (because deposit rates are lower), and total credit is unchanged. Though, in the long run, if the conversion flow from BM to CBDC is large, both loans issuance declines (thus hindering economic growth) and it tends to increase inflation (demand-pull, because CBDC pays a higher interest rate and the public will be more confident), as per reciprocal interaction effect.

Worth to be noticed, the risk that with a lower BM rate the public might consider buying more CBDC, gives origin to the necessity of controlling flows (listed in § 5.2.1.4), to impede large

conversions of BM into CBDC and to counterbalance the *reciprocal influence* (as per internal trilemma in § 5.2.1).

At the end, once inflation reaches the target, CBDC rate will be lowered to not influence the inflation anymore, while people can gradually switch back to bank deposits. Same goes with the BM rate, it will be raised again once the output reaches the target.

This is a simplistic case of stagflation, because many different factors can cause a situation of low economic growth and higher inflation. Today when the main policy interest rate is low, as it is for firms and consumers who borrow, at the same time also bank deposits have a low interest, and a high inflation causes their real value to diminish. The core idea with CBDC, is that the CBDC and the classic monetary policy rate can be independent and exchanged at parity, if forms of control are enacted. Both rates affect inflation, but CBDC rate is more direct because *affecting the savings hold in (CBDC) deposits of the aggregate demanders*, whereas the BM interest rate can become the main tool to expand and tighten economy (through the classical Monetary Transmission Mechanism), which is more direct in *affecting the investments of the aggregate suppliers*. This should cut the price/wage spiral, by dissolving the wage-earners pressure in increasing salaries to catch up with inflation (because they will have higher CBDC interest rates and savings growing at a faster pace). So, theoretically, these two instruments of monetary policy can notably address stagflation scenarios.

Worth to be noticed, the idea of limiting credit growth during the upturn of the cycle is not something new; monetary economics literature has already started to indagate that procedure, but just with conventional tools (Rey 2015). Further assessment of the indirect effects of CBDC issuance on credit is needed, but as for now it appears that in the short term CBDC and BM don't affect each other, whereas in the long run, CBDC slightly slows the economy growth because of banks' balance sheet shrinking.

That also depends on the quantities of CBDC and BM involved. The initial proportion CBDC/BM will be challenging to decide. For example, that issue was introduced in Barrdear and Kumhof (2016), when they first chose 30% of GDP as initial quantity of CBDC, even though they "do not examine the question of the optimal steady-state stock of CBDC, but […] it ought to be large enough to avoid problems with a "quantity zero lower bound" in the conduct of countercyclical policies". Worth to be noted, the larger the conversions between CBDC-BM, the larger the changes of each other prices and quantities in the market and that lets the Central Bank react to adjust the DOMEX rate via Open domestic market operations, due to the reciprocal long run interactions between CBDC-creation and bank-deposit-destruction (see introduction of § 5.2.1).

Looking at the fractal trilemma in its entirety, hence considering the domestic economy under international influences (§ 5.2), I just remind that two independent monetary policy can coexist, as per *fractal trilemma,* see aboveTable 6.

5.3.1 Final remarks on implementation of CBDC

As I have already mentioned, this fractal trilemma is based on a logical synthesis. But before implementing, it is better to address specific issues and answer specific questions. Answers will depend specifically from the economy issuing CBDC, general topics are (assuming that CBDC markets will be enough liquid and there will be large transfers (Kumhof and Noone 2018)):

- How the reputation of Central Banks would be affected, if they will start to "digitally issue" CBDC. So, how markets will react to the other existing domestic currency. Low confidence might result in a financial shock and currency will depreciate. This is a reason why it is also important – generally in monetary economics – to proceed step by step, control variables and convince actors (and authorities) of the soundness of the decisions taken;
- Discussion of drivers for the value CBDC, what is important to avoid in terms of Gresham's law "bad money drives out good money"?
- Closely studying (with qualitative studies, pilots, surveys, etc.) how banks, NFBI, consumers, retailers, might receive CBDC, what they would use CBDC for and how they will react (e.g. will retailers raise more the prices?). Besides, User Experience studies to improve CBDC usability.
- How large and liquid needs to be the CBDC markets?

6. Further limitations and future research

The present thesis can be divided into two from a very broad perspective, chapter 4 (focused on defining money) and chapter 5 (focused on solving the monetary policy trilemma with CBDC).

Chapter 4 has been discussed in the Methodology section and I add that it might be interesting to assess whether the same framework can be used in describing all financial instruments. But those are bold results and there are no competitive ideas that I am aware of. One theory I haven't directly compared with is the *Financing through Money Creation* (Zoltan and Kumhof 2015), even though I discussed some of their positions.

One clear doubt raises from the role played by time and space in this money-schemata framework, given their importance for the Kantian philosophy. I purposely excluded to discuss it in chapter 4 because it would have complicated the narrative. According to Kant, time and space exist a priori, thus there is no time-space version of media of exchange. Indeed, time is the sine qua non condition of interest rate, when the settlement is postponed in the future. Through imagination (the so-called expectation in business), we are able to value media in the future compared to the entity at present (another or itself).

Regarding the space dimension (i.e. paper, bytes, coins) it turns out that is relatively irrelevant for money, in the sense that money is a social construction in nominal terms and beyond practicality issues, the material of which it consists of is not relevant in defining money, because we are now in a system of nominal values.

The main limitation of the discussion in chapter 5 is that it relies heavily on pure logical forms, as mentioned in the methodology chapter. Normally, this is a huge gap, but I argued that CBDC is not yet issued, thus that was a very demanding effort and limited in resources. The ever-underlying issue in the thesis is whether the trilemma is applicable to CBDC. But that is something that, beyond being tackled with surveys and market reactions, can also be looked at from a pure mathematical perspective. Given the theoretical basis of the monetary policy trilemma on the interest rate parity, it will be interesting to further analyse that framework and demonstrate it mathematically (which is a stronger version of deduction).

Interesting would be to indagate how other quantifiable objectives to pursue with CBDC is possible.

Finally, further field of research could be to look at and discuss macroeconomic theories (surplus of labour, profits generation, etc.) according the proposed framework.

7. Conclusion

Central Bank Digitally issued Currency is not only a means to overcome the problem of the gradual obsolesce of cash, but an opportunity that will allow to steer the economy more efficiently for longer business cycles, a stable inflation and an organic economic growth. That can happen if its dynamics are understood, and stable rules and sound projects are designed properly.

In order to explain this phenomenon, I started from defining the *money-schemata theory* that can solve most of the (apparent) contradictions in the orthodox and heterodox theories of money, and the *fractal monetary policy trilemma* accordingly to the same *money-schemata theory*.

I showed how Central Bank Digital Currency can be the financial instrument to rethink monetary policy. Summarising, CBDC issuance will allow to lessen financial frictions, facilitate helicopter money implementation (as fiscal goal), to have the reserves interest rates below zero, that in turns allows commercial banks to push deposit rates below zero, if needed, breaking the ZLB of cash.

But most of all, CBDC issuance will allow to steer the economy, both economic growth and inflation, with two independent instruments that are also able to address the puzzling case of stagflation. That is possible (1) nudging the economy into credit expansion/contraction (for sluggish or overheating economy, as monetary policy makers currently do even though they aim at inflation) and (2) being able to directly target inflation with another tool, the new CBDC interest rate according to the dynamics I explained. Those instruments will indirectly influence each other and in what measure hasn't been quantified yet, but it is likely that business cycles will be longer (Barrdear and Kumhof 2016). Moreover, in this way, CBDC and BM won't be perfectly substitutable. The public (anybody that will be able to hold CBDC) will differentiate their holdings between CBDC and deposit money (that are still used by banks to finance credit) according to their preferences. and also banks would be interested in investing in some CBDC, as part of their risk management strategies. But how really the markets will consider (and price) CBDC compared to bonds, deposits, reserves and international financial instruments, that is a matter of observation and study once CBDC will be issued.

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