

# BITCOIN. AN ECONOMIC APPRAISAL

## 01 INTRODUCTION

Money nowadays is foremostly a system controlled by authorities, which incorporates a triangular transactional relation between two financial agents and a trusted third party (the bank or government). The recently emerged Bitcoin offers a new way of financial interacting. Namely one without a central authority or issuer, without requiring a trusted third-party when making transactions (Reid & Harrigan, 2012, p. 6). The recent 2008 banking crisis has brought to the surface the importance of studying new and revolutionizing economic systems in order to keep on fueling our perspective on the economic system we live in and the possibilities different systems might bring us. As of this, I feel the need to study an alternative monetary systems which is non-reliant on governmental institutes and embraces the possibilities of new technologies.

Situated in the field of Monetary Economics, this paper will examine the potential of the recently emerged digital cryptocurrency Bitcoin as a monetary system. By comparing Bitcoin with two main historical monetary systems, namely the Gold Standard and Fiat Money, and using well known macroeconomic models, I aim to examine this potential. Originated using a scheme outlined by Satoshi Nakamoto in 2008 in a nine page proposal for a peer-to-peer electronic cash system (Nakamoto, 2008, p.1), Bitcoin attempts to overcome the weaknesses of both fiat and gold-based money systems. Where the value of fiat currencies rely on public belief in monetary authorities (Yermack, 2013, p.4), the value of gold backed currencies depends on the opportunity cost of producing an additional unit of gold, thus the intrinsic value of that commodity (Bordo, 1981, p.2). Bitcoin however, functions as a algorithmic currency with a deterministic supply and growth rate tied to the rigor of mathematics, and thus does not has its value determined by central institutions or by its intrinsic value (Yermack, 2013, p.4). Hereby Bitcoin can be seen as a currency system which inherits properties of both a fiat money system, bitcoins being intrinsically useless, and a gold-backed money system, having a fixed money supply. This link between the three systems will be used when comparing them more thoroughly in subsequent sections.

The setup of this paper will be as follows. First, I will outline the three monetary systems - fiat money, gold standard and Bitcoin - each in both historical and economical sense. Next, these systems will be compared with respect to their money supply, money demand, inflation and effect on output and income. In order to do this I will make use of the

quantity theory of money and the IS-LM model. Lastly, I will close this paper down with a short summary of my findings and some concluding remarks.

Throughout this paper, I will use the term Bitcoin to address the system as a whole. To refer to a single unit as a currency of the Bitcoin system, the lowercase variant bitcoin will be used.

## **02 GOLD STANDARD**

### **I. historical outline**

#### **pre gold standard**

The gold standard evolved from earlier commodity money systems and started dominating western monetary systems from 1880 on. Before 1880 there were already commodity money systems, which were mostly bimetallic; silver or copper was used for low-valued transactions and gold for high-valued ones (Bordo, Schwartz, 1997, p. 4). From the 1870's on, the world shifted from bimetalism to gold monometalism (Bordo, Schwartz, 1997, p. 4). Some argue that the motivation for this shift was foremost political - (Friedman, 1990, p. 87) and others argue nations wished to parrot England, the world's leading industrial power at that time. Massive discoveries of silver around that time as well as technical advances in coinage were also pointed out as key determinants for the shift (Redish, 1990, p. 790). After the shift to gold monometalism there generally have been four broad international monetary regimes at play until now. These are: the classical gold standard (1880-1914), the interwar period comprising a short lived restoration of the gold standard, the postwar Bretton Woods international monetary system indirectly linked to gold (1946-1971) and the international fiat money system still currently at play (1971-2016) (Bordo, Schwartz, 1997, p. 2).

#### **classical gold standard**

The gold standard experienced its peak days in the period from 1880 to 1914. It was characterized by rapid economic growth, free flow of labour and capital across political borders, virtually free trade and in general world peace (Bordo, 1981, p.7). This so called classic variant of the gold standard, a pure gold standard, was essentially a commitment by participating countries to fix the prices of their domestic currencies in terms of a specified amount of gold. By being willing to buy or sell gold to anyone at that price, countries maintained these fixed prices. (Bordo, 1981, p.2).

However, such a system entailed high resource costs, because of the physical storing and transaction cost of carrying gold, and therefore in most countries substitutes for

gold emerged. In the private sector, these substitutes took the form of notes and deposits convertible into gold coins, issued by commercial banks, which in turn were held as reserves to meet conversion demands (Bordo, Schwartz, 1997, p. 4). In the public sector, proto-central banks were established in order to help governments finance their fiscal plans (Goodhart, 1994, p. 1426). The gold standard thus diverged from a strict commodity system where the commodity itself was used as currency and as medium of exchange, into a mixed coin and fiduciary system based on a principle of convertibility (Bordo, Schwartz, 1997, p. 5).

Although it operated smoothly for nearly four decades, the classical gold standard experienced periodic financial crises. In most of these cases central banks were faced with both internal and external drains and followed Bagehot's rule of lending freely but at a penalty rate (Bordo, Schwartz, 1997, p. 7). To economize on scarce resources, many countries held convertible foreign exchanges in order to substitute fiduciary national currencies for gold. Because of this, over time the gold standard parallelly evolved into a gold exchange standard. This means that a nation was able to convert its currency into bills of exchange with countries whose currency is convertible into gold at a stable rate of exchange. Due to this exchange mechanism, there was less of a need to maintain as large gold reserves as before and near World War I the system had grown into a massive pyramid of credit, between nations, built upon a relatively small base of gold. The possibility of a confidence crisis, which would trigger a collapse of the system, increased as these gold reserves diminished. Finally, World War I triggered such a collapse when nations in war were eagerly trying to convert their outstanding foreign assets into gold (Bordo, Schwartz, 1997, p. 7).

After WWI, the western world went through a interwar period comprising a short lived restoration of the gold standard. But in the beginning of 1929, nations abandoned the gold standard again in the face of internal and external drains (Redish, 1993, p. 788).

### **bretton woods**

In the period up to 1914, institutional innovations, like the emergence of central banks and the shift to a more fiduciary based gold money system, mostly took place at a national level. After 1914, this changed and innovations shifted predominantly to an international level. After the general abandonment of gold during WWI, two factors dominated attitudes to gold in the 1920's. Namely, the possibility of a lack of gold, which moved the world away from commodity money, and hyper inflation in Eastern Europe, which reminded everyone of the dangers of fiat money (Redish, ,1993, p. 785). The Bretton Woods system in 1944 was an attempt to solve this by returning to a modified gold standard. The US dollar was used as

the world's key reserve currency and in turn the United States pegged its dollar to the gold standard. It had to maintain substantial gold reserves and settled external accounts with gold bullion payments and receipts. However, international and US deficits reduced the US gold reserves and the ratio between currency backed on gold and the actual gold reserve. This resulted in a steady grow of the use of US dollars internationally. Due to this, public confidence in the ultimate ability of the US to redeem its currency in gold diminished. This confidence problem plus many nations' aversion to paying both seigniorage and inflation taxes to the US in the period after 1965, led to the ultimate breakdown of the Bretton Woods system in 1971 when the US decided to stop pegging the price of gold. (Bordo, 1981, p.7).

### **a shift in policy**

After the classical gold standard (pre war), the convertibility principle that dominated both domestic and international aspects of monetary regimes, has since declined in relevance and more emphasis has been placed on stabilizing the real economy. This included the goal of full employment, which was replaced by the goal of low inflation after the Great Inflation of the 70's (Bordo, Schwartz, 1997, p. 3).

## **II. economical outline**

### **II.a Basic properties**

#### **gold as a commitment**

The gold standard essentially was a commitment by countries to fix the prices of their domestic currencies in terms of a specified amount of gold. By being willing to buy or sell gold to anyone at that price, countries maintained these fixed prices. (Bordo, 1981, p.2). Gold was chosen as commodity because it has desirable properties according to early economists. Such as that it is durable, easily recognisable, storable, portable, divisible and easily standardized. And foremost important, changes in its stock are limited (at least in the short run) because of high costs of production, making it costly for governments to manipulate the standard (Bordo, 1981, p.2).

According to Bordo and Schwartz, one of the most important features of the gold standard was that it embodied a monetary rule or commitment mechanism that constrained the actions of the monetary authorities (Bordo, Schwartz, 1997, p. 10). Crucial to this rule was its transparency and simplicity, as it avoided the problems of moral hazard and incomplete information. Moral hazard occurs when one party takes more risk than the other because the other parties bears the cost of those risk. For example this would be the case

when the monetary authority would engage in discretionary policy, like earning revenue from supplying money that has a higher market value than it costs to produce (called seigniorage). The transparency that the gold standard provided concerning its value helped reducing the possibilities for the monetary authorities to deceive agents by discretionary policy (Obstfeld, 1991, p. 6).

### **supply, demand and the price level**

In a monetary regime based on the gold standard, the monetary authority fixes the price of gold in terms of its national currency. Market-clearing results from the interaction of the money market and the commodity market. The price level is determined by the demand for and supply of monetary gold (gold that is used for monetary purposes), and the purchasing power of gold (its real price) is determined by the commodity market (Bordo, Schwartz, 1997, p. 3). The monetary gold stock is the residual between the total world gold stock and the part of the gold stock that is demanded for non monetary purposes (like jewelry for example). In this framework, changes in the monetary gold stock reflect gold production and shifts between monetary and nonmonetary uses of gold (Barro 1997, p. 14).

The supply of gold coins depends on the supply of gold in the economy and by the amount of gold that is used for non-monetary purposes. The supply of gold in the long run is determined by the opportunity cost of producing gold. This opportunity cost is the cost in terms of foregone labor, capital and other factors engaged in producing an additional unit of gold. The demand for gold is determined by the community's wealth, tastes and the opportunity cost of holding money relative to other assets (the interest rate) (Bordo, 1981, p.3).

Permanent shocks to the demand for or supply of monetary gold would change the price level of the gold standard. However these shocks would be reversed as changes in the price level affected the real price of gold. This change in the real price of gold would namely offset the changes in gold production and shifts between monetary and nonmonetary uses of gold. This mechanism resulted in a tendency towards long run price stability because it produced mean reversion in the price level. However, in the shorter run, the shocks to the gold market or to real activity created price level volatility (Bordo, Schwartz, 1997, p. 8).

### **long run stability**

Competition in the gold-producing industry will ensure in the long run, that the purchasing power of monetary gold (in terms of all other goods) equals the opportunity cost of producing an additional unit of gold. This is because when real economic activity rises, the demand for

money rises, and the price level falls. This fall in prices, means more profit for gold producers and will encourage them to increase production. Also at the same time, people will convert their non monetary gold into monetary gold. Gold supply will thus increased and the initial decline in the price level will be reversed (Bordo, 1981, p. 2). The convertibility at that price does ensure that levels will return to some mean value over long periods of time (Bordo & Schwartz, 1997, p. 1).

## II.b Role of the Central Bank

### **lender of last resort**

A key problem of the gold convertibility system is the risk of conversion attacks. This is embodied by internal drains when a distrustful public does attempt to convert commercial bank liabilities into gold with too much at the same time, or external drains when foreign demands on a central bank's gold reserves threaten its ability to maintain convertibility (Bordo, Schwartz, 1997, p. 5). Because of this threat, central banks learned to become lenders of last resort and to use monetary policy tools, like interest rates, to protect their gold reserves to face this tension between substitution of fiduciary money for gold and the stability of the system (Redish, 1993, p. 780).

### **rules of the game**

Central banks did not only play their part in managing domestic tasks, but also an important role in the international gold standard by varying their discount rates and using other tools in monetary policy. Central banks were supposed to speed up adjustment to balance of payment disequilibria, also known as following "the rules of the game" (Bordo, Schwartz, 1997, p. 6). However, central banks violated these rules often by not raising their discount rates (Jeanne, 1995, p. 310) or by using gold devices which artificially altered the price of gold in the face of a payments deficit (Sayers, 1957, p. 16). However, these violations were never sufficient to threaten convertibility (Schwartz, 1984, p. 3) and often even tolerated as market participants viewed them as temporary attempts by central banks to smooth interest rates and economic activity while keeping within the overriding constraint of convertibility (Goodfriend, 1988, p. 91).

### **fractional reserve system**

The same underlying forces which motivated the establishment of central banks were filtered through different political, social, cultural and economic institutions. (Redish, 1993, p. 782).

One of these features was the fractional reserve system. This system stimulated the private banks and the public sector to try to reduce the reserve ratio. The reserve ratio is the ratio between the share of deposits that need to be stored in a reserve account and those that can be borrowed out.

We can write the money supply as  $M = k \times pg \times G$ , where  $M$  is the money stock,  $k$  is the inverse of the reserve ratio,  $pg$  is pounds sterling per ounce and  $G$  is the gold stock (Redish, 1993, p. 782). Among the private sector banks this would encourage centralisation of reserves and increase the profitability of commercial banks over note issue and consequently of rent-seeking activities by being able to provide more loans. Governments were motivated directly or indirectly to share these profits from providing loans, and to provide legislation that permitted more profits, for example, by enabling the banks to reduce the reserve ratio without increasing the potential for fraud or eliminating the gold anchor (Redish, 1993, p. 783).

## II.c Role of the Government

### **a contingent rule**

The gold standard served as a commitment mechanism to prevent governments from setting policies that would be time inconsistent. This means policies that, for example, would be optimal only in the short term (raising seigniorage revenue), but not in the long term. Adhering to the gold standard kept governments away from creating surprise fiduciary money issues in order to capture seigniorage revenue, or from defaulting or outstanding debt (Giovannini, 1993, p. 56). However, the gold standard rule could be interpreted as a rule with escape clauses, in other words, as a contingent rule (Flood & Isard, 1989, p. 11). For example, monetary authorities kept the prices of gold fixed except in the event of emergencies, like in time of war, wherein a nation could decide to suspend gold convertibility and issue paper money to finance its expenditures. Public understanding that the suspension would last only for the duration of the emergency plus some period of adjustment, made the rule a contingent one (Bordo, Schwartz, 1997, p. 10). The gold standard was thus only a strict rule for as long as governments choose to adhere to it, as there were times that a nation could be better off in deviating of the gold standard for a short period.

## II.d International

### **international gold standard**

By fixing the price of gold, each monetary authority also fixed its exchange rate with other countries which ran on the gold standard. This fixed price of domestic currency in terms of gold provided a nominal anchor to the international monetary system and countries hereby became part of an international gold standard (Bordo, Schwartz, 1997, p. 5). The world's monetary gold stock was distributed according to the member nations' demands for money and use of substitutes for gold. Disturbances to the balance of payments were automatically equilibrated by the Humean price-specie-flow mechanism. This meant gold would flow from nations with balance of payments deficits to those with surpluses. The amount of money that would flow into the country equals the amount that the value of exports exceeds the value of imports from the country with the balance of payments surplus. If the central bank would not take any action to offset this money flow, the money supply would rise in the country where the money inflows, and thereby also its price level. However internationally this would keep overall price levels in line (Bordo, Schwartz, 1997, p. 5).

### **centrism**

Although debate continues on the specifics of the adjustment mechanism of the international balances, there is however conformity that the adjustment mechanism worked smoothly for the core countries (like France, England, Germany who dominated international trade), but not necessarily for the more smaller, left out countries (Ford, 1962, p. 16). Adherence to the gold standard was seen as good behaviour internationally and rewarded with lower interest rates on loans and easier access to capital obtainable from the core countries. Because hereof, the gold standard converged the world economic system to a centred one. Means that most of the economic activity took place within the core countries that adhered to the gold standard. Countries that did not do so, were less incorporated of international trade (Bordo & Rockoff, 1996, p. 388).



### **03 FIAT MONEY**

#### **I. historical outline**

##### **development pattern**

According to Redish, monetary systems based on fiat currency have in general followed a same pattern in their development. In most cases, they all started off as a monetary system based on a precious-metal commodity, then started to develop banknotes convertible into that commodity (a fiduciary system), and finally saw their government or monetary authority sanction suspension of convertibility (Redish, 1993, p. 779). Selgin confirm this by stating that fiat regimes always have emerged from prior commodity money regimes, especially from regimes where redeemable banknotes had already largely supplanted actual commodity money holdings (Selgin, 2003, p. 162). Granting legal tender status to paper money paved the way to possible fiat money standard because it lengthened the link between the money stock and the commodity and the idea of attaching use value to intrinsically useless assets was introduced gradually (Redish, 1993, p.785).

##### **early forms of fiat money**

Although fiat money generally has been a relatively late development in monetary history, it has experienced short moments of existence in early history. For example in the 12th century in China where, during the Song dynasty, paper money first convertible into coin, morphed into fiat money when convertibility was suspended. This intrinsically useless paper currency kept on being used without being backed, and thus could be named fiat money. Also here the world experienced its first hyperinflation, when under the pressure of wars against the Tartars and the Mongols, the government overly expanded the quantity of fiat money (Selgin, 2003, p. 163).

Furthermore, early fiat currencies have been noticed in medieval England where due to gold shortage tally sticks were employed as currency, in Spain where paper money, served as an emergency currency in a siege during the Conquest of Granada (1482-1492) (Foster, 2010, p. 60). And also in the 17th century in New France, where playing cards were distributed as currency after a military expedition against the Iroquois had gone badly and tax revenues were down (Powell, 2010, p.6). Also, fiat money got introduced in 1683 by the Bank of Amsterdam (Quinn & Roberds, 2010, p.11)

### **interbellum**

After the general abandonment of gold during WWI, governments and banks generally tried to return to gold-convertibility of notes and coins. However, as the cost of returning to stability after the war was too high and economic growth based on government borrowing was non-doable, governments either suspended this convertibility or weren't able to maintain their convertibility as several countries were running on different convertibility-rates (Bordo et al., 2003, p. 6). In the interwar period hereafter several countries experienced hyperinflation as a consequence of paying debts with newly printed cash which was not backed by a commodity (Bordo & Schwartz 1997, p. 1).

According to Bernholz, nearly all hyperinflations have been caused by governments financing budget deficits through creating new fiat money. In an analysis of 29 hyperinflations Bernholz concludes that more than 25 of them have been caused this way. (Bernholz, 2003, p. 70). The most of these occurred after the breakdown of the gold standard during World War I, like for example the hyperinflation seen in the Weimar Republic (Bernholz, 2003, p. 72).

### **after bretton woods**

The Bretton Woods (1944-1971) system had been an attempt to return to a modified gold standard with the US dollar used as the world's key reserve currency which in turn was pegged to the gold standard (Bordo, 1981, p.7). Since the Bretton Woods system collapsed in 1971, a system based on national fiat money has been the norm worldwide. Although many central banks continued to hold gold assets, no country has had a monetary standard with a link to gold since the 1970's (Bordo & Schwartz 1997, p. 1).

Today's economies using fiat money base their nominal anchor on policy rules such as inflation targeting. It took some time following the collapse of Bretton Woods for central banks to learn how to maintain low inflation and relative price stability. The two most successful countries herein (between 1971 and 2003) were Germany and Switzerland, which had 3.8 percent average annual inflation rates. About a percentage point higher than the highest inflation rates observed during the gold standard era. The worst performance was in Italy where the price level rose by a factor 18 (8.2 percent average annual inflation) (Bordo et al., 2003, p.6).

### **monetary policy**

After the Bretton Woods collapse, abandoning the gold standard could be done at a relatively small cost because of the benefits from seignorage and the freedom to use monetary policy for stabilization purposes. However when the inconsistency between

discretionary monetary policy and anchoring the money stock became apparent, monetary authorities have tried to fill the gap that emerged once the anchoring function of the gold standard left. Governments have invested in a reputation for low inflation, determining the optimal degree of independence for a central bank and choosing to form a currency union (like for example the European Monetary Union) (Redish, 1993, p.791). Therefore, when in 1980 high and variable inflation was the number one economic problem faced by the major economies, monetary policy emerged that adopted implicit or explicit inflation targets (Bordo & Dittmar & Gavin, 2003, p. 2).

## II. economical outline

### II.a Basic properties

#### **definitions**

According to Kiyotaki and Wright, a fiat currency is an unbacked and intrinsically useless asset, circulating as a medium of exchange. Fiat money is accepted in trade because agents expect others to do the same (Kiyotaki & Wright, 1991, p. 216). Money in a fiat system can thus be seen as a social construct; it has value, only because it is valued by a group of agents (Kiyotaki & Wright, 1991, p. 216).

#### **coincidence of wants**

In an economy based on pure barter, trade does only occur when two possess a product that the other wants to consume. Jevons famously called this the **double coincidence of wants problem**. Fiat money solves this problem by providing a medium of exchange that can store value, so trade can occur even when two agents meet without having a coincidence of wants (Kiyotaki & Wright, 1991, p. 219). According to Kiyotaki and Wright agents attach more value to holding fiat money than they do to holding a commodity (in terms of trading) because agents believe others are always willing to trade goods for money (Kiyotaki & Wright, 1991, p. 227). This belief relies partly on the public belief that a nation's government or central bank will not overly, volatile, increase the supply of new banknotes (Yermack, 2013, p. 4). So for fiat money to be an acceptable medium of exchange, the supply of paper money needs to be limited, making its value in terms of goods, predictable (Ritter, 1995, p. 135). Also, when the acceptance probability of money is higher, the liquidity of money will be higher and also the amount its used as a medium of exchange (Kiyotaki & Wright, 1991, p. 228).

### **rate of return dominance**

Hicks questions whether it's possible to have equilibria where rational agents use money as a medium of exchange even when real commodities have a greater interest rate or yield. He labeled this the **rate of return dominance** phenomenon, and states that it is the central issue in the pure theory of money (Hicks, 1935, p. 5). Kiyotaki and Wright argue that the someone's expected discounted utility of holding currency cannot fall short of that on real commodities. Agents use one thing for a medium of exchange, simply because it is universally acceptable, even when it objectively appears to be intrinsically inefficient (Kiyotaki & Wright, 1991, p. 229). So even if fiat money inherently has properties which makes it a less than ideal asset, hinting at the relatively low rate of return, or a less than ideal medium of exchange, pointing to relatively high transaction cost, it can continue to circulate and play a role in facilitating trade and improving welfare (Kiyotaki & Wright, 1991, p. 233).

### **market equilibrium**

In a fiat money system, the price level is determined by the goods market, the central bank's interest rate rule and the quantity supplied (Bordo & Dittmar & Gavin, 2003, p. 10). According to Keynes liquidity preference theory the demand for money, in real terms  $M_d/P$ , depends on the level of income  $Y$  and the interest rate  $i$ . Here income is positively related to demand, because a rise in income raises transaction levels in the economy, and thus more money is demanded to perform these transactions. The interest rate, however, is negatively related to the demand for money. This is because as the interest rate rises, the opportunity cost of holding money (the interest rates not earned by not holding other assets) rises, and therefore demand for money falls (Mishkin, p. 555). Lastly, the demand for money also is positively related to the level of confidence in that money. This confidence depends on the overall expectations of agents that the money will maintain value in the future, which in turn depends on the predictability of the rate of price changes and the confidence in that the authority will keep on backing the currency (Klein, 1974, p. 433).

The supply of money is controlled by the central bank and will be explained in a subsequent section titled "money creation".

The price level is determined by equilibrium in the money market between the supply and demand of money. If there is an excess supply of money in the economy agents are holding more money than they actually want to. This means they will buy assets (bonds, valuable goods, etc) to get rid of some of this money and thereby drive up prices in the

economy. When there is an excess demand of money, the inverse will happen. This equilibrium mechanism controls prices in the fiat money system (Mishkin, 2004, p. 556).

## II.b Role of the Central Bank

### **monetary regulation**

In the gold standard system, backing the value of currency to gold served as a credible commitment mechanism. However, a fiat money system lacks this backing mechanism and in order to be regulated, need to be based on rules. But this will only work for as long authorities are able to credibly commit to them. For example, at the domestic level, these rules are setting growth rates of monetary aggregates or rules targeting the price level. At the international level, fixed exchange rates are based on a set of intervention principles and the dedication of countries in maintaining a certain nominal anchor (Bordo, Schwartz, 1997, p. 2).

Several have stated arguments for why monetary authorities need to regulate the money supply in a fiat economy. The most important one of these is that according to Friedman unregulated competitive production of money will lead to an infinite price level (Klein, 1974, p. 424). This is because in a fiat money system marginal cost of producing money are zero, competition in the money industry would be self-defeating. Money would become so abundant, sell for a price of almost zero, and become a free good. Money then would lose its value as free money is worthless money and is not able to facilitate exchanges of goods among agents (Klein, 1974, p. 428).

According to Bordo, Dittmar and Gavin, a fiat system that is based on a credible nominal anchor does lack the the resource cost and the short-run variability associated with the gold standard but still provides the price stability benefits of the gold standard (Bordo & Dittmar & Gavin, 2003, p. 27)

### **monetary policy**

In a fiat money system, central banks have more policy tools available than in a gold backed monetary system because there is the additional control over the money supply (and so over the value of money). Policy goals often adhered to are influencing outcomes like economic growth, inflation, exchange rates with other countries and unemployment. In order to do this central banks often use one of the following policy tools: increasing interest rates, reducing the monetary base and increasing reserve requirements. With the monetary base is meant the sum of the portion of the commercial bank's reserves that are maintained in their central

bank's accounts and the total currency circulating in the public. All of these contract the money supply (Mishkin, 2004, p. 359).

The primary activity of central banks in a fiat money system are open market operations (OMO). Hereby a central bank manages the quantity of money in circulation by buying and selling various financial assets, such as treasury bills, foreign currencies and company bonds. OMO's affect the level of base currency entering or leaving market circulation (Mishkin, 2004, p. 398).

### **money creation**

In a fiat money system money is issued by the Central Bank. But because of the fractional reserve system used in fiat money systems, the money supply is expanded beyond this initially issued amount by the central bank. In this framework, two types of money can be defined. One is *central bank money*, which is all money created by the central bank, regardless of its form. The other is *commercial bank money*, which is money created by the act of borrowing and lending (Mishkin, 2004, p. 360). There are four different players in this money creation process: the Central Bank, the commercial banks - depository institutions that accept deposits from individuals and institutions and make loans - the depositors and the borrowers (Mishkin, 2004, p. 357). These latter two interact with commercial banks, and these banks in turn interact with the Central Bank by being required in storing monetary reserves at them (Mishkin, 2004, p. 359).

Central bank money is created by exercising control over the monetary base through open market operations, that is buying or selling government securities in the open market, and through extension of discount loans to banks (Mishkin, 2004, p. 359). The **monetary base** is the sum of currency in circulation **C** and the total reserves in the banking system **R**. Here an open market purchase will result in an increase of the monetary base by an amount equal to the price of the purchased bond, no matter whether the seller of this bond keeps the proceeds in deposits or in currency. Because of the possibility of the seller to not store these proceeds in a bank, the impact of an open market operation on reserves is much more uncertain than its impact on the monetary base (Mishkin, 2004, p. 362).

Another way of creating money in a fiat system, is by providing discount loans to commercial banks. This simply means that a central bank loans a sum of money to a commercial bank and hereby expands the money in circulation and the monetary base (Mishkin, 2004, p. 364).

However, for every unit of central bank money initially created, several more are created in the economy, the *commercial bank money*, because of the **deposit creation**

**mechanism.** This works as follows. The money created by a central bank will end up in the hands of agents and will be stored as a deposit on a commercial bank. These banks are subject to a required reserve ratio  $r$  for every deposit they hold. The share of deposits that not needs to be stored in a reserve account, can be borrowed out. This money in turn will end up as a deposit at some other bank and again can be borrowed out by this other bank. Hereby multiple banks extend the initial money creation process issued by the central bank. The amount that can be borrowed out every time by a bank gets smaller because of the reserve requirement this bank is subject to. The amount of money creation  $\Delta D$  now can be formulated as the initial amount of reserves created  $\Delta R$  divided by the required reserve ratio  $r$ .  $\Delta D = \Delta R / r$  (Mishkin, 2004, p. 369).

### **brand name**

Agents may distinguish between multiple monies supplied by either directly examining the technical characteristics of the product or via its brand name. In general agents rely on both of these methods when attempting to determine quality (Klein, 1974, p. 431). However, as fiduciary money is assumed to be independent of any technical characteristics, agents in a fiat money system must solely rely on the brand-name method of obtaining information about quality of the currency (Klein, 1974, p. 431).

The gold standard (or commodity money in general) ensured consumer confidence by placing a physical constraint on the money supply and by that made possible unanticipated depreciations, a more anticipated thing (Klein, 1974, p. 434). In a fiat money system consumer confidence is ensured by the brand-name of the issuer. A main method by which firms are able to invest in brand-name capital, is by successful performance. This can be done by keeping the actual supply rate of money close to the anticipated rate. Because if the actual rate is bigger than the anticipated rate, the firm is supplying a product of which the quality is less than that buyers expected it to be and therefore paid for. How further these actual and anticipated rates lay from each other, the more deceiving does take place and the lower consumer confidence will be (Klein, 1974, p. 436).

## **II.c Government**

### **coordination failure**

The average agent in the economy would be better off with a positive amount of money in circulation. However this outcome is not supported by individual rationality as individuals do not consider the aggregate externality they impose by issuing money. The consequence of this kind of a coordination failure is that there is no monetary equilibrium in which agents

issue money individually (Ritter, 1995, p. 139). According to Ritter this structure imposed thus suggests that it is size (credibility) which allows the government to overcome the coordination failure which otherwise prevents the establishment of a fiat money system (Ritter, 1995, p. 141). Other reasons why governments have a monopoly on the supply of dominant money, rather than regulated private production is that because of its credibility and steady performance over the years, it has an advantage in supplying confidence (Klein, 1974, p. 447).

Also stated as a possible reason for why the government has this monopoly is the government's ability to declare its money "legal tender". Meaning that debtors cannot legally refuse the money as payment and amounts to the assertion by the governments that individuals may use the government law system to force acceptance of its money in discharge of debts (Klein, 1974, p. 448).

Lastly, the production of monetary confidence is highly complementary with the production of other goods that the government generally supplies, like for example the production of national defense. This is another possible advantage for the government in supplying money (Klein, 1974, p. 449).

### **election cycles**

One of the main reasons most fiat money systems have externalized money supply control to a separate, independent, institute, like a central bank, is because of the danger of election cycles. Politicians have an incentive to not undertake the current costs of the long term investment that the creation of stable price expectations is considered. Particularly those whose positions are not secure, will rather consume inherited brand-name capital. In these external institutes, semi independent official control the money supply and are subject to less immediate political pressure. They therefore have less short-run incentives to inflate and consume monetary confidence capital than do elected officials (Klein, 1974, p. 449).

### **seignorage**

On requirement for fiat money to be an acceptable medium of exchange is that the supply of the currency is limited. The government's credibility herein is challenged by the conflicting motive of seigniorage (Ritter, 1995, p. 135). Seigniorage is the revenue generated from money creation. Monetary seigniorage  $s_m$  is defined as the net change in base money outstanding  $\Delta B$ , deflated by the consumer price level  $p$ : ( $s_m = \Delta B / p$ ). Herein seigniorage measures the transaction value of non-monetary assets that money holders trade in to the monetary authority to obtain the desired increase in their base money balances (Neumann, 1992, p. 30). In this context credibility must mean that there is widespread believe that the



government will not attempt to exploit this source of seigniorage to the point where money becomes worthless (Ritter, 1995, p. 135).

### **regulation**

The before stated seigniorage and election cycle problems the government faces is one of the reasons why governments often have regulated a private dominant money supplier, like for example a central bank, to control the money supply. However in doing so most of the advantages a government has in supplying money vanish. If the government does not permit the issuer to set a profit-maximizing rental price for the currency, this issuer will have an incentive to overissue. So if the government aims to prevent the issuer from setting such a high price and also from over-issuing, regulation must include price and quantity targets, so the situation is closer to public ownership (Klein, 1974, p. 450).

## **II.d International**

### **fixed versus float**

We saw that in a monetary system based on the gold standard there naturally existed an international monetary anchor which fixed prices and therefore ensured fixed exchange rates between all the countries adhering to this standard (Bordo, Schwartz, 1997, p. 5). However in a fiat money system there is no such anchor to adhere to. As different countries often use different fiat currencies, exchange rates are either floating, fixed or floating within a fixed band (Mishkin, 2004, p. 435). According to Klein a fixed exchange rate always needs to be constrained by international rules, as otherwise competition would lead each firm to attempt to inflate at a higher rate than all other firms. That is, as each firm would want to run a deficit in its trade clearing account with all other firm which in turn is financed by the increased holdings by the other firms of its costlessly produced money (Klein, 1974, p. 432).

However, if flexible exchange rates are the case, changes in the supply of any country's money relative to other countries money would alter the exchange rate between them. If these changes are anticipated and the two currencies are distinguishable enough, this would be sufficient to guarantee that deficits between firms would not arise. This eliminates the incentive for each country to inflate at a higher rate than competing countries (Klein, 1974, p. 432).

### **optimum currency area**

The existence of fixed exchange rate arrangements is related to the information and transaction costs that comes with having multiple competitive independent currencies. How

bigger the number of currencies internationally, and thus the more sets of prices there are, how more the unit of account and medium of exchange functions of money are hampered. This is because of the computational-conversion and valuation costs that are present due to the variance in prices between all the different currencies (Klein, 1974, p. 443). These costs even remain present when a fixed exchange regime is the case. Again here it is the case that the magnitude of these transaction costs depends on the specific fixed exchange rate arrangement and, again, are lower when the number of fixed exchange rate is smaller (Klein, 1974, p. 443).

According to Klein, due to the before described information and transaction costs of multiple competitive independent monies, floating exchange rates are not viable. The reason herefor relates to the theory of optimal currency areas (Klein, 1974, p. 443). An optimum currency area is a concept by Mundell and is defined by him as a geographical region in which a single shared currency is preferable because of higher economic efficiency (Mundell, 1961, p. 657). These optimum currency areas would be better for the store of value function of money and the costs of future price level uncertainty by providing a fixed exchange rate mechanism without the computational costs of converting currencies (Mundell, 1961, p. 659). McKinnon assumes that maintaining stability of a money's real value reduces these costs and facilitates efficient resource allocation (McKinnon, 1963, p. 720).

## 04 BITCOIN

### I. historical outline

#### **developments in e-cash**

Several developments in payment technologies and alternative currencies have emerged in recent years. Most of these innovations are either functioning as a new payment system (mobile money), or as a new currency (credits and local currencies). Robleh Ali of the Bank of England classified digital currencies as being both a new payment system and being a new currency (Ali, 2014, p.3). Of all the several digital currencies, such as for example e-gold, Ethereum and LiteCoin, that emerged since early 2009, Bitcoin was the first and remains the largest (Ali, 2014, p.5). It was revolutionizing in offering a solution to the double-spending problem (explained later) without relying on a trusted third party, such as a bank (Nakamoto, 2008, p. 1).

#### **bitcoin**

Bitcoin was launched in January 2009 as a privately developed, internet-based currency and payment system and is commonly referred to as a cryptocurrency, as it makes use of cryptographic techniques to ensure the secure validation of transactions (Ali, 2014, p.5). Bitcoins can be used for several transactions, ranging from webhosting to buying a pizza, at any time and between any two users worldwide. One can acquire bitcoins either by offering goods or services in exchange for bitcoins, as a reward for verifying earlier transactions (called mining) or by purchasing bitcoins from other users in exchange for traditional currencies (Ali, 2014, p.5). Currently a single bitcoin trades for around 535 US dollars (according to coinbase.com). According to Robleh Ali, the adoption of, and interest in, digital currencies has risen because of three key-factors: *ideology, financial return and the pursuit of lower transaction fees* (Ali, 2014, p.6).

#### **ideology**

Ideology has always been a strong driver in the security and cryptographic community. As early as 1982, Chaum has outlined a blueprint of an anonymous e-cash scheme (Chaum, 1982, p. 1) and in 1998 Weidai already described a protocol on how to provide a medium of exchange and a way to enforce contracts to and by untraceable entities (Dai, 1998, p. 1). Bitcoin was designed with the intention to avoid any centralised control (from either the money supply or the payment system) and has a minimized degree of trust users need to

place towards any third party (Ali, 2014, p. 6). This ideology also was apparent in the text that was included in the first block, also called the genesis block, that was created in Bitcoin's blockchain:

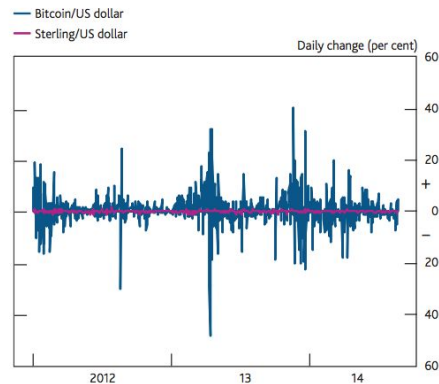
The Times 03/Jan/2009 Chancellor on brink  
of second bailout for banks

This text was a reference to a news article from that day to highlight the conceptual distinction between Bitcoin and the current monetary economic structure at that time. Namely that Bitcoin doesn't rely on the fractional-reserve banking system that had caused great instability around then (Ali, 2014, p. 6). Also this ideology can be found in the adoption of Bitcoin by anti-governmental organizations, such as Wikileaks:



### financial return

Because it has a constant money growth rate, movements in the price of bitcoins essentially reflect only changes in demand (Ali, 2014, p. 6). This, plus the great volatility bitcoins have shown, has attracted many investors to Bitcoin as an asset class for financial investment. Although bitcoins can be obtained via multiple ways, currently most users obtain them by directly exchanging them for other, more traditional, currencies (Ali, 2014, p. 279). For example, the great price-volatility inherent to Bitcoin becomes apparent when comparing the daily price changes of both the sterling and bitcoin with the dollar from 2012 to 2014. This shows that the standard deviation for daily moves of bitcoins is roughly 17 times greater than that for the sterling, see figure below (Ali, 2014, p. 279).



Also the low transaction fees Bitcoin is able to offer because of the absence of third monetary parties, and its transaction irreversibility and divisibility have been strong motivators for Bitcoin adopters (Barber et al., 2012, p. 3).

### **crashes**

Bitcoin has had a few crashes over its yet short existence. The biggest was the crash of the 2013, when its price per bitcoin more than halved from \$1200 to \$600 in less than a day. After this Bitcoin has shown greater volatility and lost in popularity by investors (Hiltzik, 2013, p. 1).

## **II. economical outline**

### **II.a Basic properties**

#### **a mix of gold and fiat**

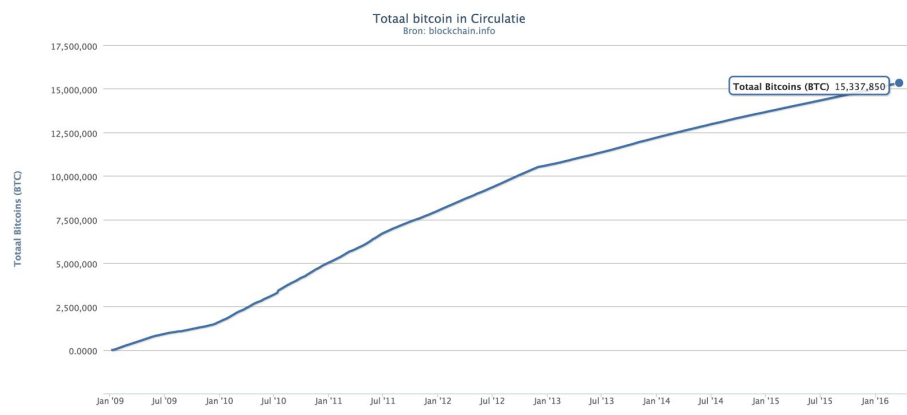
In a commodity money system, the quantity of money is given (often at some remove) by the amount of it present in nature and money has an intrinsic value (the value of the underlying commodity). In a fiat money system a currency's value is strictly determined by factors non intrinsic to the currency and the quantity of money is a matter of policy (how much money the central bank supplies) (Redish, 1993, p. 778). Bitcoin can be seen as being positioned in the theoretical gap between a gold backed money system and a fiat money system as that both its quantity of money is fixed by the nature of the system (at some remove), like is the case with a gold backed system, and it is intrinsically useless, like fiat money is.

#### **constant money growth and a fixed money stock**

In contrast to our traditional monetary system, in Bitcoin the money supply has a constant growth rate and a fixed end quantity. Both these features are realized via the block creation, or mining, process, which ensures, next to the creation of new coins, for the continuous flow

of new transactions. The coinbase of Bitcoin started with 50 bitcoins, mined by Satoshi Nakamoto when he started the blockchain by creating the *genesis* block (the first block in the blockchain) (Barber et al., 2012, p. 5).

Mining is the process of providing CPU power to the Bitcoin system in order to confirm transaction. In return here for miners get rewarded with new bitcoins created by the system. The amount of bitcoins rewarded for mining a consecutive block on the chain decreases over time, halving every 210.000 blocks (that is, roughly, every 4 years), ensuring a constant growth rate in the total amount of bitcoins in circulating (Ali, 2014, p. 5). There are currently somewhat more than 15 million bitcoins in circulation (see figure below) and in 2040 the latest bitcoin is expected to be mined resulting in the fixed maximal end quantity of 21 million bitcoins.



One can acquire bitcoins either by offering goods or services in exchange for bitcoins, as a reward for verifying earlier transactions (this is called mining), or by purchasing bitcoins from other users in exchange for traditional currencies (Ali, 2014, p. 5). Currently, bitcoins mostly trade for the Chinese Yen (95%), but also is exchangeable for US dollars (4%) and Euro's (1%). People holding other currencies, will first need to exchange for either one of these three currencies in order to get hold of bitcoins via purchasing (Ali, 2014, p. 279).

### low transaction fees

A significant feature of Bitcoin which has attracted many users, including retailers, to the system are its low transaction fees. Currently these transaction fees have typically shown to be lower than other retail electronic payments, such as paying by credit card, and international transfers using traditional currencies (Ali, 2014, p. 281). Marginal cost of verifying transactions by miners are generally higher than for traditional payment systems, due to the increasing returns to scale in the operating of computer servers. However, miners are willing to accept lower transaction fees, because of the amount of new coins that are paid to the them as a reward for verifying transactions (Ali, 2014, p. 281).

However, because mining faces scalability problems (explained later), these lower transaction fees might not be able to be maintained (Ali, 2014, p. 281).

### **theft and loss of bitcoins**

According to Barber et al. the money stock in a Bitcoin system is prone to theft of bitcoins. Possession of someone's private key gives the possibility to steal someone's bitcoins or to have his wallet vanish from the internet and thereby get bitcoins out of circulation. This private key can be obtained by hacking someone's wallet, which, although Bitcoin has stated to have a great security system, happened in a cyber attack in 2013 when \$1.3 million worth of bitcoins vanished from the system (Barber et al., 2012, p. 10). Also if a user loses his private key, he has no access anymore to his wallet, which practically means his bitcoin are not able to circulate in the system anymore (Barber et al., 2012, p. 10).

### **privacy**

One of the prominent features of Bitcoin is its approach regarding user privacy. In the traditional banking model a user's identity is known to a trusted third party who handles the transactions with the counterparty. In Bitcoin all transactions are publicly visible, which precludes this method of guaranteeing user anonymity. Bitcoin solves this anonymity-problem by setting up users with both a private key and a public key. One's private key is only known to themselves and used for signing a transaction. One's public key is used for validating transactions. A different public key is generated for each transaction a user takes on (Nakamoto, 2008, p. 6). In the figure below the differences between the traditional and new privacy model is represented graphically.

Traditional Privacy Model



New Privacy Model



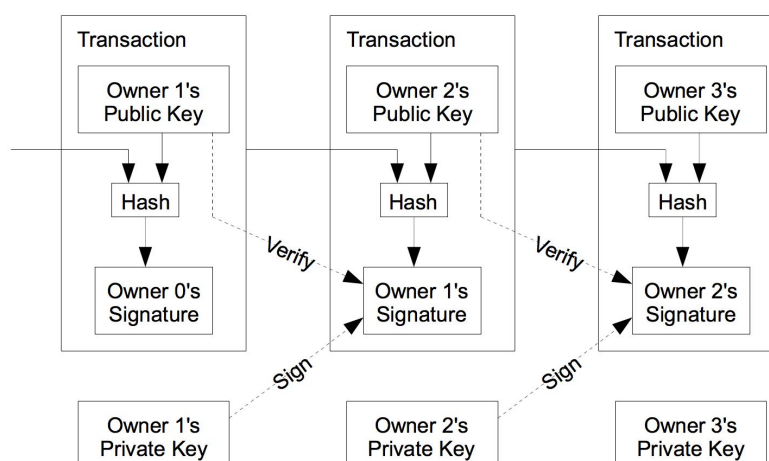
In the new privacy model created by Bitcoin, the public can see all the transactions taking place, but without information linking the transaction to anyone (Nakamoto, 2008, p. 6). For users that adhere a great ideological value to privacy, this feature of Bitcoin makes using it as main currency be more valuable (Ali, 2014, p. 280).

## II.b The Role of the Blockchain

### how the blockchain works

Each digital payment system needs a reliable method of recording transactions so that all participants can agree on the accuracy of it. According to Robleh Ali this raises two challenges for a decentralised system like Bitcoin. The first is devising a secure and reliable method for updating a public ledger (an overview of all monetary transaction that have been done), which has several copies distributed throughout the world. The second is to provide or coordinate resources in the absence of a central authority, creating the necessary incentives for users to contribute resources in order to verify transactions (Ali, 2014, p. 7). Explaining the working of the blockchain will show how Bitcoin aims to overcome these two problems.

Satoshi Nakamoto defines an electronic coin as a chain of digital signatures, with every block in that chain having to be 'signed' by the two parties making the transaction and the miner(s). The miners are the ones validating that specific transaction, who in return get rewarded therefor by the Bitcoin system. Each owner of a bitcoin wallet holds a private key, and generates a separate public key for every transaction he or she does. These keys are mathematically interrelated in such a way that user identities are secured. Each owner transfers the coin to the next by digitally signing a hash (a digital signature) of the previous transaction and the public key of the next owner and adding these to the end of the coin (Nakamoto, 2008, p. 2).



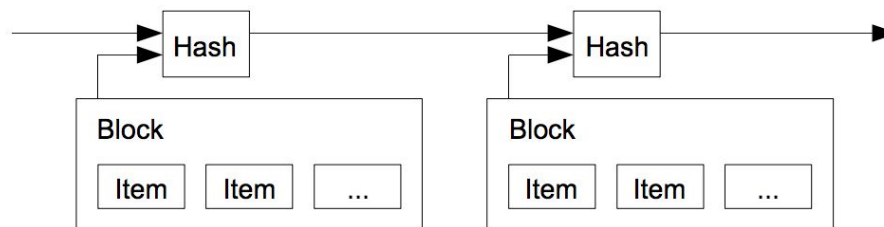
### solving the double spend problem

In this transaction process the problem of **double-spending** shows up. Which means that with lack of a trusted central authority, or mint, that checks every transaction with his ledger,



Bitcoin needs a way a payee can verify that one of the owners does not double-spend the coin he is currently spending (Ali, 2014, p. 8). Bitcoin takes care of this this by sharing copies of the ledger between all participants; publicly announcing all transactions and establishing a system for participants to agree on a single history of these transactions (Nakamoto, 2008, p. 2). Since anybody can check any proposed transactions against the ledger, this approach removes the need for a central authority (Ali, 2014, p. 9).

More specific, Nakamoto's proposed solution to the double-spend problem begins with the idea of a **timestamp server**. This server works by taking a hash of a block of items to be timestamped and widely publishing the hash. Each timestamp includes the previous timestamp in its hash, forming a chain. This timestamp proves that the data must have existed at the time in order to get into the hash (Nakamoto, 2008, p. 2).



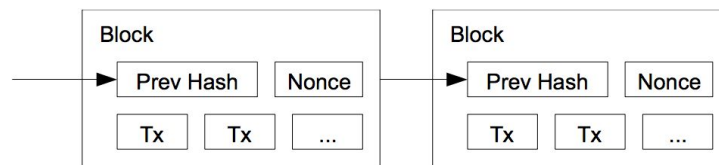
A transaction is confirmed when its various element have been validated and checked against double-spending (Barber et al., 2012, p. 4).

Validating a block of transactions includes checking the correctness of the digital signatures, and thus going through the whole history of transactions to verify the amounts owned by each party. This validation process takes a relatively short amount of time (Ali, 2014, p. 8). In order to achieve consensus on the non-occurrence of double-spending, miners (users trading CPU for newly created bitcoins) check all the transactions done on the chain and need to demonstrate the investment of computing resources known as a **proof of work** (Nakamoto, 2008, p. 3). The Bitcoin protocol requires that miners combine three inputs and feed them into a SHA-256 hash function (a hard to break crypto algorithm) (Ali, 2014, p. 12):

- A reference to the previous block
- Details of their candidate block of transactions
- A special number called a 'nonce'

Proof-of-work schemes need to be difficult to establish but easy to check, so it is easy to spot fraudulent transactions (Ali, 2014, p. 8) This proof-of-work is designed to require great amounts of computational effort and involves the repeated computation of the cryptographic

hash function, along with the arbitrary nonce, resulting in each transaction having a specific form (Harrigan, 2012, p. 7). After this work has been put into chaining a new block on the blockchain, this block cannot be changed without redoing the work of all the subsequent blocks chained after it (Nakamoto, 2008, p. 3).



If two miners create two blocks with the same preceding block, the blockchain is forked into two branches. Since miners have to maintain a totally ordered set of transactions where they globally agree on, the protocol prescribes miners to adopt and mine on the longest chain in order to resolve forks (Eyal & Sirer, 2014, p. 4).

### **the scalability of mining**

In the Bitcoin system the mining mechanism serves as an incentive for users to support the system. That is, users get rewarded with newly generated bitcoins if they successfully verify a transaction block. In order to do this they need to provide their computers' CPU power to the system. This then is used to solve complex algorithms to show their proof-work as explained earlier (Nakamoto, 2008, p. 3).

According to Ali, the marginal cost of verifying a transaction may be expected to increase over time. Bitcoin is designed to maintain a roughly constant time, around ten minutes, between transaction blocks. This means that if more agents start using Bitcoin, the number of transactions per block increases, and therefore the CPU power miners need to provide in order to verify a transaction, does so too. Thus, miners' cost will increase over time as more agents start using the system (Ali, 2014, p. 282).

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