A Bitcoin Standard: Lessons from the Gold Standard*

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Abstract

This paper imagines a world in which countries are on the bitcoin standard, monetary system in which all media of exchange are or are backed by the cryptocurrency bitcoin. It examines the lessons from the "Classical Gold Standard" period, 1880-1914, for the bitcoin standard. The paper describes the "rules of the game" that countries on the gold standard were supposed to follow. It shows how gold points permitted countries to follow interest rate policies, and it argues that monetary authorities could act as lenders of last resort because of their ability to issue fiduciary currencies. It finds that under the gold standard price levels tended to move together and there was little inflation over the period studied. It also finds that exchange rates were relatively stable and that there was good real output growth. The paper argues that because virtually no transactions costs for international transactions, countries could not follow interest rate policies under the bitcoin standard, although they would still have limited ability to act as lenders of last resort. Based on this experience during the Classical Gold Standard period, the paper conjectures that there would be mild deflation, low nominal interest rates, fixed exchange rates, and good output growth under the bitcoin standard.

Keywords: gold standard, cryptocurrency, bitcoin

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I am much more confident that the world of payments will look very different 20 years from now than I am about how it will look.

Larry Summers
Wall Street Journal, interview, 30 April, 2014

1 Introduction

There are a myriad of cryptocurrencies in existence today.[1] The best known of these crypto currencies is bitcoin. Bitcoin has been the subject of numerous articles in the media. It has also been the subject of numerous books and documentaries.

The use of bitcoin has been growing worldwide. According to CoinDesk, as of 14 September 2014, there were slightly approximately 6.56 million bitcoin wallets, 76,000 merchants who accepted bitcoin payments, and 238 bitcoin ATMs. By 15 September 2015, these amounts had increased to 11.05 million bitcoin wallets, 106,000 merchants who accepted bitcoin payments, and 475 bitcoin ATMs. Some merchants that accept bitcoin are Microsoft, which began accepting bitcoin as payment for games, apps, and videos in December 2014, Dell, which started accepted bitcoin as payment in Canada, the U.K., and the U.S. in February 2015, DISH Network, and Overstock.com.

In this paper I extrapolate the growth of bitcoin as a medium of exchange and conduct this thought experiment: Suppose that the use of bitcoin has grown to such an extent that it has replaced existing fiat currency and has become the predominant medium of exchange or at least the backing for the predominant medium of exchange in a large group of countries. I will call this international monetary system in which bitcoin is the common backing for the various countries' payments systems as *the bitcoin standard*. I choose this terminology because such a monetary system will be similar to the gold standard in many respects. The gold standard was a monetary system under which countries' currencies were tied to gold. My imaginary bitcoin standard is a monetary system under which countries' currencies are tied to bitcoin.

There may be some skepticism at this point as to how it could come about that the bitcoin standard could ever be adopted, even by a single country. A major reason for this skepticism is the fluctuations in the price of bitcoin relative to the U.S. dollar since its inception in 2009. The price of bitcoin relative to the dollar from January 2013 is shown in Figure 1. As the figure shows, bitcoin went from about $13 per bitcoin on 1 January 2013 to a high of almost $1,150 per bitcoin on 30 November of that year. Thus far during 2015, the price of a bitcoin has ranged between $175 and $315 with prices centered around $225.

Although the skepticism about whether the bitcoin standard could come into being is warranted to some extent, it should be remembered that if currencies other than bitcoin exist under the bitcoin standard, the fluctuations of their prices in terms of bitcoin will be limited or may be even eliminated because these currencies will be backed by bitcoin. This is not the case for current fiat currencies vis-a-vis bitcoin. Thus, the current experience with the price of bitcoin in terms of dollars is not relevant for how goods prices in terms of bitcoin (the price level in terms of bitcoin) would behave under the bitcoin standard.

[1] A cryptocurrency is one in which users come to agreement about changes in the transactions ledger using cryptographic techniques. In the case of bitcoin, the unique private key associated with every bitcoin transaction is encrypted.

Figure 1: $ per bitcoin, January 2013 to August 2015

The purpose of this paper is to examine the historical experience with the gold standard to determine what lessons can be learned about what might be the experience if the bitcoin standard were to come into existence. The paper proceeds as follows: The basics of the gold standard are described in section 2. In this section, I discuss the reasons that countries adopted the gold standard, how exchange rates were determined, and the concept of gold points In this section, I also discuss how countries conducted monetary policy under the gold standard and the "rules of the game" countries operating under the gold standard were supposed to follow. Finally, in this section I examine the historical experience of countries that operated under the gold standard in terms of price stability, exchange rate stability, real output growth, and financial crises. In section 3, I describe in more detail the bitcoin standard and the banking system the would exist under it. I also discuss how monetary policy could be conducted under the bitcoin standard, and I present my conjectures about how prices, exchange rates, and real output would behave under the bitcoin standard. Section 4 concludes the paper and gives conjectures and conclusions about how stable the bitcoin standard would be if it were to come into being.

2 The Gold Standard

The gold standard did not come about as a joint agreement among countries to adopt it. Rather, it came about over a period of time as one country after another chose to abandon its silver or bimetallic standard in favor of the gold standard. The reason for the choice of gold, rather than some other commodity or basket of commodities, as the "anchor" was that Britain was an extremely important player in the world financial system. It was on the gold standard, and, perhaps most importantly it had a strong commitment to maintaining the

gold backing for its currency.

The history of the gold standard was marked by changes over time in the number of countries that adopted it.[2] The origins of the gold standard are usually dated to England in 1717 "when Sir Isaac Newton, then Master of the Mint, set too high a silver price for the gold guinea." (Eichengreen and Flandreau, 1985, 4) However, England did not legally adopt gold as the sole backing for its currency until 1821 with the passage of an act on 2 July 1819 that required the Bank of England to redeem its notes in gold.

Canada adopted a gold backed currency on 14 June 1853 with the passage of the "Act to regulate the Currency," which set the value of the Canadian dollar and the Canadian pound in terms of grains of standard gold. Germany went off of silver and established the gold based mark in 1871. France and the other countries of the Latin Monetary Union went off a bimetallic standard for their currencies and adopted gold in 1873.[3] The United States effectively adopted the gold standard on 1 January 1879 with the resumption of convertibility of U.S. notes into gold, although the gold standard was not officially adopted until the passage of the Gold Standard Act in 1900.

Because the gold standard was so prevalent in the late nineteenth and early twentieth centuries, the period 1880 to 1914 is sometimes referred to as the "Classical Gold Standard" period. According to Bloomfield (1959), "By the end of the [nineteenth] century nearly all the leading countries had linked their currencies to gold in one form or another; and many of the smaller Asiatic and Latin American countries did so in the late 1890's and early 1900's" (14-15). Countries also changed whether or not they were on the gold standard. Again, according to Bloomfield (1959),

> "A number of countries dropped out of the "club" during the course of the period, such as Argentina (1885), Portugal (1890), Italy (1891), Chile (1898), Bulgaria (1899), and Mexico (1910); but Argentina, Italy, and Bulgaria returned to gold ... in 1900, 1902, 1906" (15).

2.1 Details

Under the gold standard, each country had its own monetary unit. In the United States it was the dollar; in the United Kingdom, the pound; in Canada, initially both the dollar and the pound although eventually it became only the dollar. This monetary unit was defined to consist of a given number of Troy grains or ounces of gold of standard fineness.[4] For example, when Canada went on the Gold Standard in 1853, the Canadian pound was defined to have 101.321 grains of gold and the Canadian dollar was to have one-fourth of that, so that there were 20.67 Canadian dollars per Troy ounce of gold. The ratio of the monetary unit to the quantity of gold was known as the "mint price." There were no restrictions on the importing or exporting of gold under the Gold Standard.

[2]This historical discussion is based on Bloomfield (1959), Frieden (1992), Eichengreen (1992), and Eichengreen and Flandreau (1997).

[3]A bimetallic standard is a monetary system based on both gold and silver. See Redish (2000) for a discussion of bimetallism and an argument for why bimetallic standards evolved to the gold standard.

[4]The difference between a Troy ounce and a avoirdupois ounce is that a Troy ounces is 480 grains, whereas the avoirdupois ounce is 437-1/2 grains. The standard fineness of gold is $\frac{22}{24} = 0.9167$ karats.

Coins

There were three widely-used media of exchange in countries on the gold standard. The first was gold coins.[5] Each country had its own mint that would produce gold coins of various denominations. These mints would accept bullion in unlimited amounts and exchange coins for bullion.[6]

Central Bank or Treasury Fiduciary Currency

The second widely-used medium of exchange was fiduciary currency issued by central banks or government treasuries. Central banks or government treasuries issued (paper) currencies that were not 100 percent backed by gold, but were tied to gold in some manner. For example, in the United Kingdom, the Bank of England issued bank notes that had to be redeemed in a specific amount of gold on demand. In the United States, the Treasury issued U.S. notes, and later, the Federal Reserve System issued Federal Reserve notes. Both were redeemable in gold on demand. In Canada, the Treasury issued Dominion notes, which were also redeemable in gold.

Among the countries that adopted the gold standard, there were differences in the manner in which their fiduciary currencies were tied to gold. One difference was the nature of the legal convertibility of the fiduciary currency. In the three countries mentioned above and in most other countries, the issuer of the fiduciary currency was required to redeem it in gold on demand. This was not the case in all countries that adopted the gold standard, however. Some – France is an example – made the legal convertibility of the fiduciary currency the option of the monetary authority.[7]

A second difference in the nature of how countries tied their fiduciary currencies to gold was the required gold backing of the fiduciary currency. Some fiduciary currencies were fractionally backed. That is, the central bank or treasury issuing the currency had to gold in given proportion to the currency issued. For example, in the United States, the Federal Reserve System had to back Federal Reserve notes 40 percent with gold. Other countries required their fiduciary currencies to be 100 percent backed above some amount with fractional or no backing of the currencies up to this amount. In Britain, the "Bank Charter Act 1844" (Peel's Act) permitted the Bank of England to issue notes up to a specific amount with no gold backing. However, note issuance above that amount had to be 100 percent backed by gold. Canada first authorized the issuance of fiduciary currency by the Dominion Notes Act passed in 1868. Under the terms of this Act, the initial issuance of Dominion Notes was capped at CAD 8 million. The first CAD 5 million had to be 20 percent backed by gold; the next CAD 3 million, 25 percent backed by gold. Canada changed the maximum issuance and required backing for Dominion notes over time. By 1913, the first

[5]There were also non-gold subsidiary coins, but I ignore them because they are not relevant to the discussion.

[6]That bullion could be brought in in unlimited amounts was known as "free coinage." It did not mean that might not be a charge for minting. A mint might change for the cost of coinage (brassage). In addition, it might change a tax (seigniorage). The result was that persons bringing bullion to a mint might receive less than that weight in coinage in return.

[7]When a country imposed legal convertibility on demand, Bloomfield (1959) refers to it as being on the "full" gold standard. When convertibility was at the option of the issuer,Bloomfield (1959) refers to a country as having adopted a "limping" gold standard.

CAD 30 million had to be 25 percent backed by gold; issuance over CAD 30 million had to be fully backed by gold.

Commercial Bank Fiduciary Currency

The third widely-used medium of exchange was callable liabilities issued by the private commercial banking sector. These callable liabilities were redeemable in gold on demand. The callable liabilities were primarily bank deposits, but in some countries, the United States and Canada for example, banks also issued bank notes. Banks were not required to fully back their callable liabilities with gold reserves held either in their vaults or in reserve accounts with the country's central bank.

2.2 Reasons for Adoption

With a convertible fiduciary currency some of an economy's resources are idle because they must be stored as reserves. One advantage of an inconvertible fiduciary (fiat) currency is reserves are not needed, so that these resources are available for other uses. The presumption under a fiat currency regime is that these other uses are productive. However, it could be the case that the resource are idle because they are being used for non-productive uses, such as hedging against possible inflation.

Despite this possible advantage of a fiat monetary standard, there was a major concern that contributed to the adoption of the gold standard. This concern was that under a fiat monetary standard it would be inevitable that monetary authorities would eventually end up continually depreciating a country's money. Linking a country's money supply to a commodity like gold would prevent this from occurring. In this way, gold would be an "anchor" to the monetary system. Requiring convertibility into gold would limit the issuance of fiduciary currency and help achieve the goal of price level stability. According to Bordo (1984):

> A stable price level in the long run that an automatically operated gold standard produced, in line with the commodity theory of money, was invariably contrasted to the evils of inconvertible fiduciary money. At the hands of even well-meaning policy-makers the latter would inevitably lead to depreciation of the value of money. (23)

The reasoning follows from the Quantity Theory of Money, which in terms of growth rates is

$$\Delta P = \Delta M - \Delta Y + \Delta V, \tag{1}$$

where ΔP is the rate of inflation; ΔM, the rate of money growth; ΔY, the rate of real output growth; and ΔV, the rate of growth of velocity. The key assumption is that under the gold standard, ΔM is limited by the rate of growth of a country's stock of monetary gold, which is out of the control of its central bank or treasury. As a consequence, the rate of inflation is also limited. Note that if a country's output growth outstrips the rate of growth of its stock of monetary gold, then the county would experience deflation.[8]

[8]This discussion ignores the role of the rate of velocity growth. The implicit assumptions are that ΔV is not large, does not fluctuate very much, and is not under the influence of the central bank.

If other countries also adopt the gold standard, then not only would they all avoid inflation, but their price levels also would be linked through a mechanism known as the "price-specie flow" mechanism. In fact, the price levels would be more than simply linked. The price-specie flow mechanism argues that price levels would be equalized across the countries that have adopted the gold standard.

Two basic ideas underlie the price-specie flow mechanism. The first idea is gold arbitrage: gold will flow from countries where it has a low degree of purchasing power (where the price level is high) to the countries where it has a high degree of purchasing power (the price level is low). The second idea is one stated above: under the gold standard, the money supply in a country depends on the quantity of gold in that country. Thus, following the Quantity Theory of Money, the price level in a country increases when it receives gold and declines when it loses gold.

To see how the price-specie flow mechanism is supposed to work, let there be two countries, call them Country A and Country B. Let P_j be the price level in country j (monetary units/good) and X_j be the mint price in country j (monetary units/ounce gold), $j = A, B$. Consider an agent who has one ounce of gold. This agent faces the question of where to buy commodities. If the agent takes the ounce of gold to country A, the ounce of gold is worth X_A units of country A currency, which buys $\frac{X_A}{P_A}$ units of goods. If the agent takes the ounce of gold to country B, the ounce of gold buys $\frac{X_B}{P_B}$ units of goods.

If $\frac{X_A}{P_A} > \frac{X_B}{P_B}$, then the ounce of gold buys more goods in country A than in country B. According to the price-specie flow mechanism, the result is that gold flows from country B to country A. Agents want to buy goods where they are the cheapest. This is the gold arbitrage. The flow of gold into country A increases its money supply, and the flow of gold out of country B decreases its money supply. And because the price level in a country related to its money supply, the price level will increase in country A and decrease in country B. The gold flows, the arbitrage, continues until $P_A = P_B$. The price levels in the two countries are equalized.

Achieving price level stability was a major reason why a country might adopt a commodity standard such as the Gold Standard. Given that other countries, especially countries like Britain that were important in international trade and finance, were on the gold standard, there was another reason for a country to choose the gold standard. This reason was that the gold standard would serve to maintain balance of payments equilibrium among the countries that adopted it.

To see how, suppose that Country A was running a balance of payments surplus. Then Country A would be experiencing a gold inflow. This gold inflow would increase its money supply and increase its price level. The increase in the prices of its goods would tend to make them less attractive to foreigners and, thereby, reduce its balance of payments surplus. The reverse mechanism would work if a country were running a balance of payments deficit. Further, the adjustment would be automatic. The gold flows induced by the trade imbalances would lead to money supply changes that would lead to price changes that would undo the trade imbalance.

The supposed automaticity of balance of payment adjustment under the gold standard would have had the added benefit of removing the incentive for countries to change gold content of their fiduciary currencies; i.e., to devalue or revalue their currencies, in order

to achieve balance of payments surpluses or overcome balance of payments deficits. Any short term effects of such actions would have been undone by the changes in gold flows they effected.

2.3 Exchange Rate Determination

Achieving price level stability and having a mechanism that would work to automatically reducing balance of payments surpluses and deficits were two reasons for adopting the gold standard. However, according to the Macmillan Committee Report, which was written in 1931, "The primary objective of the international gold standard is to maintain a parity of foreign exchanges within narrow limits; this has the effect of securing a certain measure of correspondence in the levels of prices ruling all over the gold standard area."[9]

To see how the gold standard would work to "maintain parity foreign exchanges," which I interpret to mean relative constancy of exchange rates, let there be two countries on the gold standard each of which issues its own fiduciary currency. For convenience, call these countries Canada and the UK. There is a spot market for the two currencies, and the spot exchange rate is $S = CAD/£$. Further, let X_{CA} be the mint price of the Canadian dollar and X_{UK} be the mint price of the UK pound. Recall that mint prices are in monetary units/ounce gold.

Consider the question of when should Canadian citizens import gold from the UK. Canadians could take 1 CAD to the spot market and get $\frac{1}{S}$ pounds. They could then take these pounds to the Bank of England and get $\frac{1}{SX_{UK}}$ ounces of gold. Then, they could ship the gold across the Atlantic Ocean, take it to Canadian Treasury, and get $\frac{X_{CA}}{SX_{UK}}$ Canadian dollars. The alternative to using the CAD to buy gold is to buy a security that bears interest at the rate i_{CA} over the period that it takes to complete the transaction involving gold.[10] Thus, the importation of gold is profitable for the Canadians iff $\frac{X_{CA}}{SX_{UK}} > 1 + i_{CA} + k$, where k is the proportional cost (cost per ounce of gold) of making the gold transaction. The cost k arises because there are shipping, insurance, and time costs involved with importing or exporting gold. The spot exchange rate

$$S_{CA} = \frac{X_{CA}}{X_{UK}} \left(\frac{1}{1 + i_{CA} + k} \right)$$

is known as the Canadian gold import point. For spot exchange rates less than S_{CA} it is profitable for Canadians to import gold from the UK. Of course, when there are many countries on the gold standard, there is a gold import point for each pair.

Next, consider the question of when should UK citizens import gold from Canada. The British could take 1£ to the spot market, get S CAD. They could then the Canadian dollars to the Canadian Treasury and get $\frac{S}{x_{CA}}$ ounces of gold. They could then ship this gold across the Atlantic Ocean, take it to the Bank of England, and get $X_{CA}\frac{S}{X_{UK}}$ £. Assume the British citizens also have the alternative of buying securities that bear interest rate i_{UK}. Then the

[9] Macmillan Committee on Finance and Industry, 1997, 247

[10] This example is much like that of the price-specie flow mechanism except that instead of the alternatives being buying domestic goods versus foreign goods, the alternative is which capital investment to make.

transaction is profitable if $\frac{SX_{UK}}{X_{CA}} > 1 + i_{UK} + k$. The spot exchange rate

$$S_{UK} = \frac{X_{CA}}{X_{UK}}(1 + i_{UK} + k)$$

is known as the UK gold import point. For spot exchange rates greater than S_{UK} it is profitable for British to import gold from Canada.

Putting the two gold points together yields a condition for no gold flows to occur. The condition is that S satisfy[11]

$$\frac{X_{CA}}{X_{UK}}\left(\frac{1}{1 + i_{CA} + k}\right) < S < \frac{X_{CA}}{X_{UK}}(1 + i_{UK} + k). \tag{3}$$

2.4 Monetary Policy

There are two types of monetary policy to be considered. The major one is interest rate policy: the ability to change interest rates to affect the domestic economy. The other one is the ability to act as a lender of last resort by providing reserves to the banking system in times of financial crisis. In this section, I discuss how these two types of monetary policy were carried out under the gold standard.

Interest Rate Policy

Under the gold standard, interest rate policy worked through bank rates (discount rates), or, more correctly, it worked because monetary authorities in different countries could set bank rates that were different from each other. That is, countries had some latitude to raise or lower their bank rate to raise or lower interest rates generally in their country, and in this way affect the domestic economy.

One might think that monetary authorities would not have this ability because gold arbitrage would work to equate equate interest rates across countries. Gold would flow to the country where it would earn the highest rate of return and that would limit the differences in interest rates among countries on the gold standard. However, gold arbitrage could not eliminate differences entirely because gold arbitrage was costly. These costs are the same ones that gave rise to k in the discussion of gold points. It was the presence of these costs that gave monetary authorities some independence in setting interest rates in their country.

To see how these costs gave monetary authorities some independence in setting interest rates, I slightly modify the discussion of gold points. Consider an agent in Country A who has one ounce of gold and who faces the question of whether to invest the gold domestically

[11]The "price" at which coins trade at the mints of different countries is called the mint ratio, which I denote as MR and define to be (monetary units of country j/monetary unit of country j'). For this example, MR is the price of CAD in terms of £ or $MR = \frac{X_{CA}}{X_{US}}$. With this notation, equation (3) can be written as

$$\text{MR}\left(\frac{1}{1 + i_{CA} + k}\right) < S < \text{MR}(1 + i_{UK} + k). \tag{2}$$

or export it to Country B and invest it there.[12] If the agent invests domestically, the gold earns r_A, where, for the sake of explanation I assume that r_A is the bank rate in Country A. If the agent exports the gold to country B and invests it there, the gold earns $r_B - k$, where r_B is the discount rate in Country B and k is the proportional cost of moving gold from Country A to Country B. As long as $r_A > r_B - k$, gold will not be shipped out of Country A. Therefore, the monetary authority in Country A had some latitude in lowering its discount rate without suffering the deflationary consequences of gold flowing out of the country.

Using analogous reasoning, the monetary authority in Country A had some latitude in raising its discount rate without suffering the inflationary consequences of gold flowing into the country. Consider an agent in Country B who has one ounce of gold. This agent faces the question whether to invest the gold domestically or export it to Country A. If the agent invests domestically, the gold earns r_B. If the agent exports the gold to country B, the gold earns $r_A - k$. As long as $r_B > r_A - k$, gold will not be shipped to Country A. Therefore, the monetary authority in Country A had a constraint in raising its bank rate without suffering the inflationary consequences of gold flowing into the country.

Combining these two arguments, the latitude that the monetary authority in Country A had with regard to setting its bank rate was

$$\underbrace{r_B - k}_{\text{gold outflows}} < r_A < \underbrace{r_B + k}_{\text{gold inflows}} \tag{4}$$

Although monetary authorities had some ability to affect domestic interest rates, as the argument above shows, the ability was limited by the possibility of gold flows. To see how this worked, suppose, for example, a central bank wanted to stimulate the economy by lowering the bank rate to encourage bank lending and investment. If it lowered its the bank rate below $r_B - k$, there would be loss of gold reserves by the banking system that could make banks reluctant to increase their lending and would eventually cause them to reduce lending and thereby decrease the money supply. In this way, the loss of reserves would offset some of the effects of the lower bank rate. A central bank attempting to reduce inflationary pressures in its economy faced the same type of constraints in the opposite direction is it attempted to increase its bank rate by too much.

The restriction (4) also shows that countries also faced the consequences of discount rate actions by taken monetary authorities in other countries. During the Classical Gold Standard period, the major player was the Bank of England, and changes in its discount rate had major effects on the gold reserves, and consequently the economies of the other countries on the gold standard.

Lender of Last Resort

It was the ability of monetary authorities to issue fiduciary currencies that enabled them to act as lenders of last resort, because these currencies could serve as reserves for the banking system. The policy tools for acting as a lender of last resort were determination of the collateral eligible for discounting and the haircut on that collateral.

[12]The discussion of the mechanism here is similar to the discussion of the price-specie flow mechanism except that here other side of the arbitrage is capital whereas it was commodities in the case of the price-specie flow mechanism.

A stylized description of how a central bank acted as lender of last resort in a financial crisis under the gold standard is the following. A central bank set up reserve accounts for financial institutions on its books. When financial institutions were facing deposit runs and were in danger of running short of reserves in a crisis, a monetary authority could supply financial institutions with reserves by purchasing ("discounting") commercial paper from them. The monetary authority made the discount by simply crediting the reserve accounts these institutions had with them. They did not have to make the discount purchases by paying out gold.

Should financial institutions have had to meet the withdrawal demands by depositors, they would draw on their reserve account with the monetary authority and obtain the paper form of the fiduciary currency. Because these fiduciary currencies were accepted as media of exchange, they would satisfy depositors withdrawal demands.

Of course, because the fiduciary currencies had to be backed by gold, the ability of a monetary authority to act of lender of last resort under the gold standard was not unlimited as it almost is under a fiat monetary standard.[13] However, there were cases the limits were circumvented because central banks loaned gold to each other. An example: the Bank of France loaned gold to the Bank of England during the Baring Crisis of 1890.[14]

2.5 "Rules of the Game"

If a country adopted the gold standard, its monetary authority was supposedly to follow certain "rules of the game." The usual specification of the "rules" applied to how monetary authorities should adjust their bank rates in the face of persistent gold inflows or outflows. The "rule" was that a country's monetary authority was supposed to take actions to supplement that effects that the gold inflows or outflows were having on the country's balance of payments.

Consider the case of persistent gold inflows and assume that they were due to Country A running a balance of payments surplus. Without any central bank actions, the gold inflows would have served to raise prices in Country A, which would have had the effect of reducing the balance of payments surplus. Thus, as discussed above, there was automaticity of balance of payments adjustment under the gold standard.

The "rule" in this case was that the central bank in Country A was supposed help the balance of payments adjustment by lowering its discount rates. Lowering the discount rate would have two effects. First, it would reduce the incentive for gold to flow into Country A. Second, the lower interest rates would serve to stimulate the economy of Country A, which would increase its imports and reduce its balance of trade surplus. Monetary authorities were supposed to take the opposite action, increase bank rates, when experiencing persistent gold outflows.

Of course, the incentives for central banks to take these actions were asymmetric. The monetary authority of a country experiencing gold outflows had to raise interest rates. If it

[13] I say almost because all fiat money economies have at least two equilibria, one of which is that the fiat money is not valued. If agents in the economy expect that the amount of fiat money issued by the central bank acting as lender of last resort would be too large, then the economy might switch to the equilibrium in which the fiat money is not valued.

[14] For a discussion of other instances of central banks lending gold to other central banks, see Eichengreen (1992) loc. 1597 - 1648.

did not do so, it faced the possibility of running out of gold and being unable to redeem its fiduciary currency. The monetary authority of a country experiencing gold inflows faced no such pressure.

The question of whether countries moved their discount rates as the "rules of the game" required was explored extensively by Bloomfield (1959). Eichengreen and Flandreau (1997) characterized his findings as:

> [he] found that pre-World War I central banks violated those ["rules of the game"] in the majority of years and countries he considered. Rather than draining liquidity from the market when their reserves declined (and augmenting it when they rose), they frequently did the opposite. (14)

Bordo and Kydland (1995) have argued that the was a second part to "rules of the game" that applied to a country's commitment to redeem its fiduciary currency under the Gold Standard. When a country adopted the Gold Standard, it committed to redeem its fiduciary currency in gold at the established mint ratio. However, Bordo and Kydland (1995) argued this commitment was state-contingent. A country was permitted to suspend redemption in the case of an exogenous emergency; e.g. war or if it were in danger of running out of gold during a financial crisis. Once the emergency was over, the country was committed to restore convertibility at pre-emergency parity.[15] An example of this state-contingent commitment is the actions of the Bank of England during the Napoleonic Wars. It suspended convertibility of its paper pounds in 1797 and resumed convertibility at the old parity in 1821.

In the context of multiple countries on the gold standard, this commitment to restore convertibility at par after suspensions meant that countries were implicitly agreeing to maintain close to fixed exchange rates and to not engage in competitive devaluations after the emergency ended.

2.6 How the Gold Standard Worked in Practice

In this section, I examine how the gold standard performed with regard to achieving price level stability and exchange rate stability. I also examine how countries performed with respect to economic growth, and I present evidence on the frequency of financial crises in countries that adopted the gold standard.

Price Level Stability

The price data for a sample of countries between 1880 and 1913 reveals four facts:

1. Countries experienced very little inflation when the period 1880 to 1913 is considered as a whole. In the second column of Table 1, I show the average inflation rates for 11

[15] This state-contingent commitment was similar to that which banks had with respect to redemption their notes. They were permitted to suspend redemption in emergencies, such as bank panics which caused runs on their specie holdings, but they were to resume redemption once the panic was over. The difference between the commitment of banks and that of a country on the gold standard is that the banks' commitment was a legal requirement. Failure to resume meant that a bank would be put of out business. A country's commitment was more implicit.

countries that were on the gold standard from 1880 to 1913.[16]

	Average			
Country	1880 - 1913	1880 - 1895	1895 - 1913	Std. Dev.
Belgium	0.06	-1.87	1.67	3.79
Canada	0.77	-0.89	2.15	3.86
Denmark	-0.25	-1.12	0.48	2.64
France	0.05	-0.53	0.74	3.43
Germany	0.42	-1.26	1.83	4.73
Netherlands	0.17	-0.53	0.74	1.93
Norway	0.62	-0.81	1.82	2.83
Sweden	0.29	-1.75	1.98	3.83
Switzerland	-0.07	-1.92	1.47	3.81
United Kingdom	-0.32	-2.35	1.38	3.88
United States	-0.10	-1.31	1.45	2.00
Overall	0.19	-1.32	1.45	3.85

Table 1: Average and standard deviation of annual inflation for 11 Countries, 1880 - 1913

2. The lack of inflation between 1880 and 1913 was achieved by countries experiencing deflation over the first part of the period and inflation over the remainder. The actual behavior of the price levels of these same 11 countries is plotted in Figures 2 and 3, and the average rates of inflation in the periods 1880 to 1895 and 1895 to 1913 are given in the third and fourth columns of Table 1. From 1880 to 1895 countries experienced deflation averaging between 0.53 percent (France) and 2.35 percent (United Kingdom). From 1895 to 1913 they experienced inflation averaging between 0.53 percent (France, again) and 2.15 percent (Canada).[17]

   The change from deflation to inflation appears to have been due to an increase in the rate of gold production, which is shown in Figure 4. The rate of increase in the world stock of gold was less than two percent per year prior to 1892. However, the rate at which the world gold stock increased was larger after that date, and, except for 1912, was consistently above three percent per year from 1894 to 1913. The change in the rate of gold production was due to the discovery of gold in South Africa (the Rand) in 1886 and the invention of the cyanide process for smelting gold in the late 1880s.

   The change in the rate of gold production and the change in the rate of inflation before and after 1895 accord reasonably well with the Quantity Theory. The average rate of increase of the world gold stock between 1880 and 1895 was approximately 1.5 percent per year. From 1895 to 1913, it was approximately 2.9 percent per year. If the change in the world stock of gold is interpreted as ΔM in Equation (1), then the Quantity Theory predicts that inflation should have increased by about 1.4 percent per year

[16] All inflation rates are computed as $100 * (ln(P_t) - ln(P_0))/t)$.

[17] Although 1895 is not the year in which the price index is the lowest for all countries, I choose it as the breakpoint because is the year with the minimum price level for the majority of countries considered.

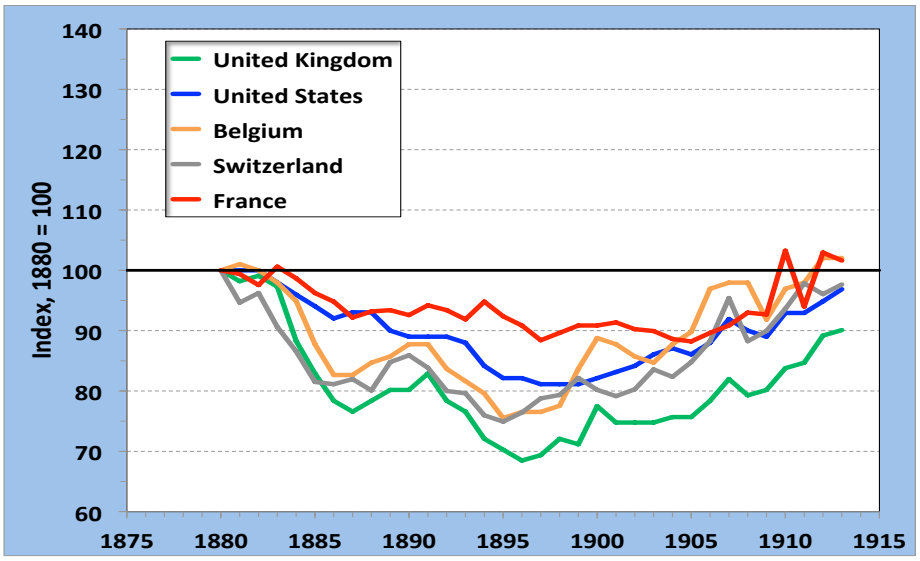

Figure 2: Price levels in selected countries, 1880 -1913

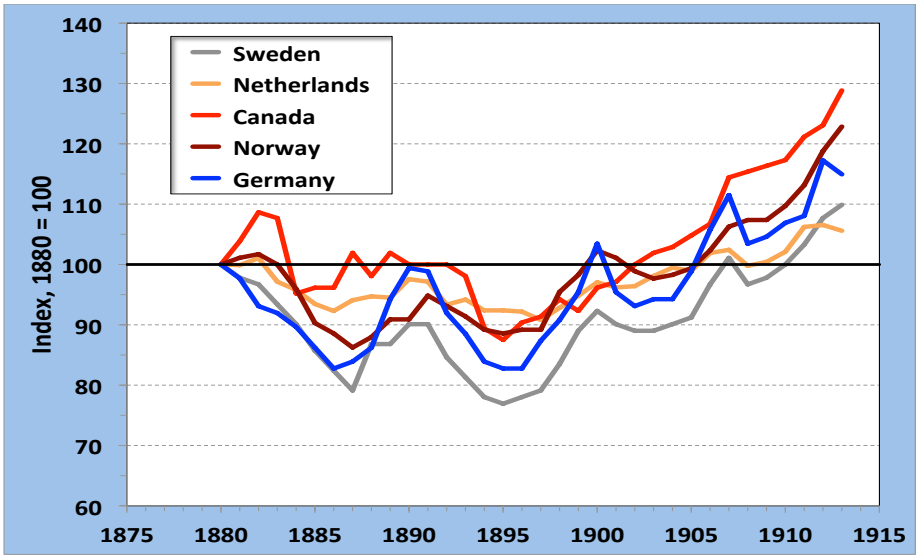

Figure 3: Price levels in selected countries, 1880 -1913

in the latter period over the earlier. This is bit below the difference in the overall inflation rates in the last line of Table 1, but it must be remembered that this crude calculation assumes that there was no change in the rate of output growth between the two periods.

3. Overall, the price levels of the countries in Table 1 moved closely together. The average of the correlations is 0.70 and the median is 0.76. However, a country-by-country

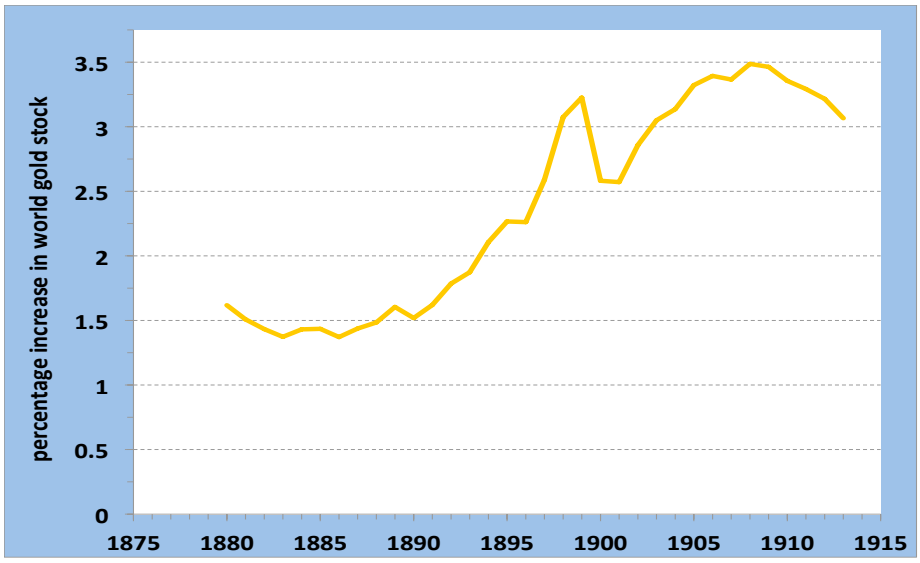

Figure 4: Percentage Change in the World Gold Stock, 1880 -1913

examination of the correlations given in Table 2 shows that price level movements were closer for some countries than for others.

In Table 2, I have separated countries into blocks with correlations of 0.9 or greater. Three blocks emerge: Block 1: the U.K., U.S., and Denmark; Block 2: Belgium and Switzerland; Block 3: Sweden, Netherlands, Canada, Norway, and Germany. France appears to be different from the other countries, so I keep it by itself.[18]

Table 2 and Figures 2 and 3 show the following. Blocks 1 and 2 appear highly correlated with each other. This is shown in Figures 2. The price levels in these countries fall until approximately 1895 and then rise until 1914, but only Belgium's price level is higher at the end of the period than it was in 1880. Blocks 2 and 3 also have price levels that are highly correlated. However, the price levels in Blocks 1 and 3 are not highly correlated.

4. There was a large amount of year-to-year fluctuation in annual inflation rates. This is shown in the fifth column of Table 1 and Figures 5 and 6. The sample standard deviations are between 2 and 5 percent.

5. Inflation rates among countries were not highly correlated, in general, as is shown for 11 countries in Table 3. The average of the correlations in the table is 0.43 and the median is 0.45. These are much lower than the average and media for the price levels of these countries. The table shows that inflation rates of the other countries in the

[18]I have included Denmark in the U.K./U.S. since the pattern of its correlations with other countries is most similar to that of those two countries. However, I have omitted it from Figure 2 because the figure was getting crowded.

	United Kingdom	United States	Denmark	France	Belgium	Switzer-land	Sweden	Nether-lands	Canada	Norway	Germany
United Kingdom	x	0.92	0.93	0.78	0.83	0.82	0.67	0.57	0.51	0.45	0.39
United States		x	0.83	0.77	0.76	0.77	0.57	0.51	0.54	0.34	0.28
Denmark			x	0.70	0.80	0.75	0.64	0.56	0.46	0.45	0.38
France				x	0.64	0.63	0.53	0.43	0.47	0.45	0.32
Belgium					x	0.92	0.93	0.87	0.79	0.79	0.76
Switzerland						x	0.90	0.87	0.81	0.76	0.75
Sweden							x	0.95	0.87	0.93	0.92
Netherlands								x	0.90	0.91	0.90
Canada									x	0.88	0.84
Norway										x	0.91
Germany											x

Table 2: Price level correlations for selected countries, 1880 -1913

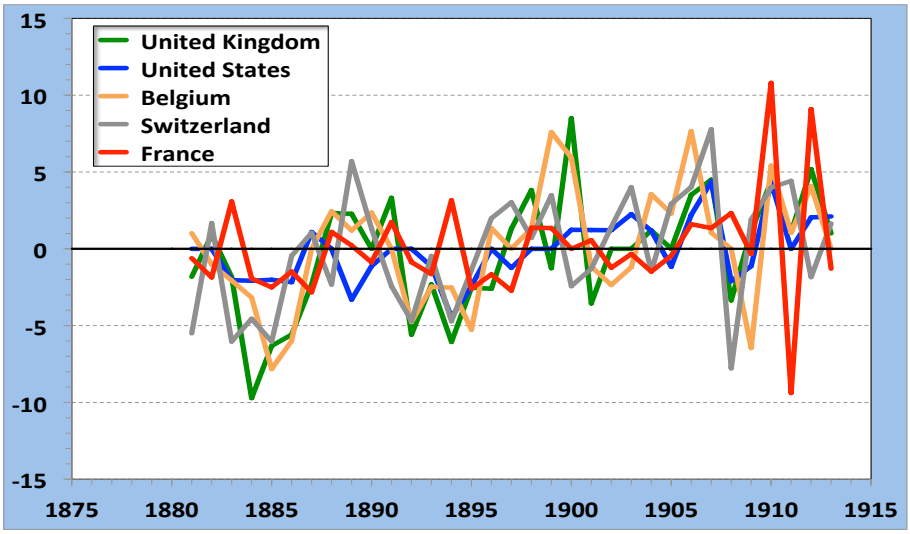

Figure 5: Inflation rates for selected countries, 1880 -1913

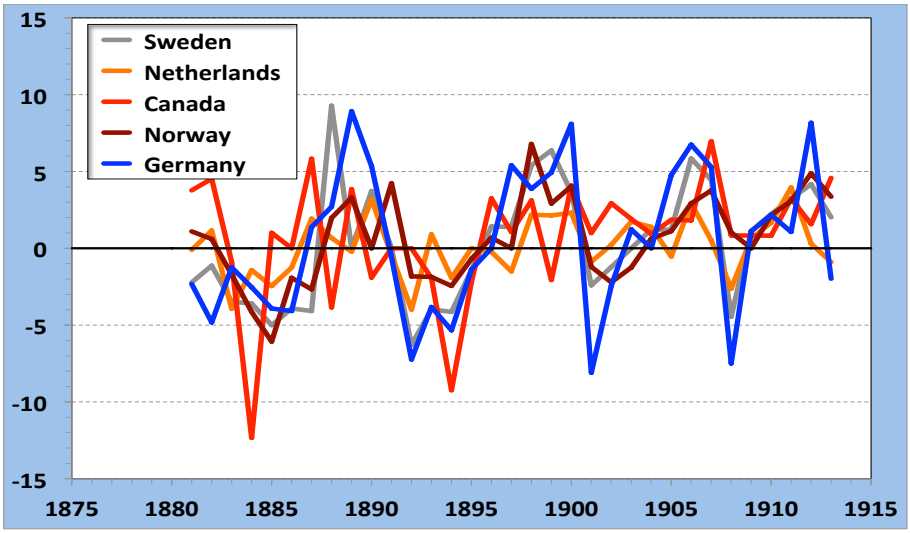

Figure 6: Inflation rates for selected countries, 1880 -1913

sample are mostly highly correlated with the British inflation. The table also shows that France once again appears to be an outlier. It has the lowest correlations with other countries in the sample. Further, in three cases (Netherlands, Switzerland, and Canada) France's inflation rate is slightly negatively correlated with the inflation rates in those countries, although the correlations are so small as to be considered essentially zero.

	United Kingdom	United States	Denmark	France	Belgium	Switzer-land	Sweden	Nether-lands	Canada	Norway	Germany
United Kingdom	x	0.58	0.53	0.32	0.65	0.50	0.74	0.57	0.56	0.81	0.72
United States		x	0.21	0.30	0.50	0.46	0.46	0.45	0.53	0.42	0.28
Denmark			x	0.24	0.33	0.05	0.36	0.30	0.29	0.59	0.31
France				x	0.37	-0.09	0.19	-0.12	-0.10	0.30	0.20
Belgium					x	0.37	0.72	0.58	0.23	0.69	0.65
Switzerland						x	0.54	0.61	0.45	0.41	0.58
Sweden							x	0.66	0.20	0.75	0.75
Netherlands								x	0.28	0.47	0.55
Canada									x	0.42	0.27
Norway										x	0.60
Germany											x

Table 3: Inflation rate correlations for selected countries, 1880 -1913

Exchange Rate Stability

The second major reason for countries to adopt the gold standard was to achieve stability of their exchange rate against those of other countries that also adopted the gold standard. Given the closeness of the movements in the price indices of various countries, it would be expected that exchange rates would be quite stable.

The empirical evidence bears out that this was in fact the case. In Figure 7 I plot the premium, in percent of par, on the \$ versus the CAD, the U.K. £, and the French franc. The figure shows three points:

1. On average, exchange rates were close to their par values.[19] The \$ averaged a 0.025 percent premium over the CAD and a 0.012 percent premium over the franc. It averaged a 0.079 percent discount against the £.

2. The fluctuations in exchange rates were generally quite small. The standard deviation of premia were only 0.104 percentage points, 0.234 percentage points, and 0. 353 percentage points for the CAD, £, and franc, respectively. Further, in only one case was the premium on the \$ greater than one-quarter of a percent against the CAD. It was greater the greater than one-quarter percent in absolute value against the £ in 9 years, with the vast majority of cases (7) having the \$ at a larger discount against the £. Against the franc, the \$ was at a discount or premium in almost half of the years considered.

[19]By par values I mean the value that would be given by the ratio of the quantity of pure gold in which the currencies were defined. For example, the \$ and the CAD were defined to equal to 1.50463 grams of pure gold. Thus, their par value was 1. The £ was defined to equal 7.322381 grams of pure gold, so that the ratios of the \$ and the CAD to the £ was 4.86656331. Similarly, the French franc was defined to be equal to 0.290322581 grams of pure gold, so that the ratio of the franc to the \$ and CAD was 0.1929581.

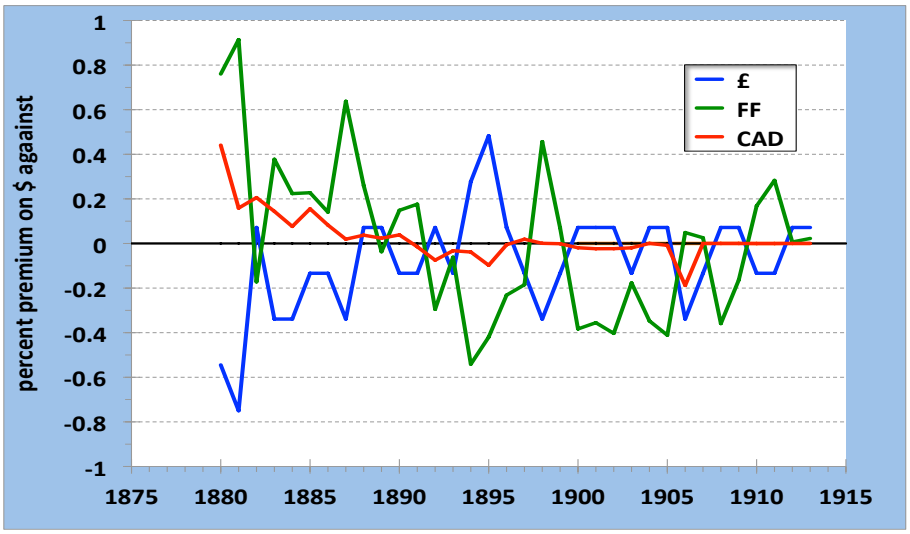

Figure 7: Percentage premia of selected currencies against the dollar, 1880 -1913

3. The range of exchange rate fluctuations was directly related to the costs of undertaking gold arbitrage. This range was the smallest for the $ and the CAD. The cost of gold arbitrage between the United States and Canada was very small. The countries were close together geographically, so the time and freight costs of shipping gold were quite small. Further, it is likely that many Canadian dealers in gold maintained accounts with banks in New York. The range was next smallest for the $ and the £. Although separated by the Atlantic Ocean, which would have meant the physically transferring gold that would have taken time and involved shipping costs, the financial markets of the U.S. and the U.K. were closely connected. Further, London was the predominant financial market at the time. The range was highest for the $ and the franc. The physical transportation costs of getting gold from New York to Paris were at least as large as getting it from New York to London, and Paris was a much less developed financial market and the trade connections between the U.S. and France were not as strong as those between the U.S. and the U.K..

Real Output Growth

Real output growth was strong in some countries and weak in some others under the gold standard. The time series of real GDP for Canada, the U.S. the Netherlands, Norway, the U.K. and France are plotted in Figure 8. Over the 33 year period shown in the figure, Canada and the U.S. experienced strong growth. Real GDP grew at an annual rate of 4.41 percent in Canada and 3.45 percent in the U.S. during that time. However, real output growth was much slower in the four European countries shown in the figure. Annual real output growth averaged only 2.28 percent in the Netherlands, only 2.18 percent in Norway, only 1.79 percent in the U.K., and a meager 1.28 percent in France.

Annual rates of real GDP growth were not highly correlated among the six countries shown in Figure 8. The highest correlation was 0.46 between annual rates of output growth in Canada and the U.S. The only other strong correlations were 0.41 between the U.K. and the U.S., and 0.40 between the U.K. and the Netherlands. Some of my results agree with those of Easton (1984).[20] He finds the same order of magnitude correlations for real output for Canada - U.S. and U.K. - U.S. However, unlike Easton (1984), I find no correlation of real output annual growth rates between the U.S. and Norway. Further, I find no correlation of annual real output growth rate between any pairs of France, the Netherlands, Norway.

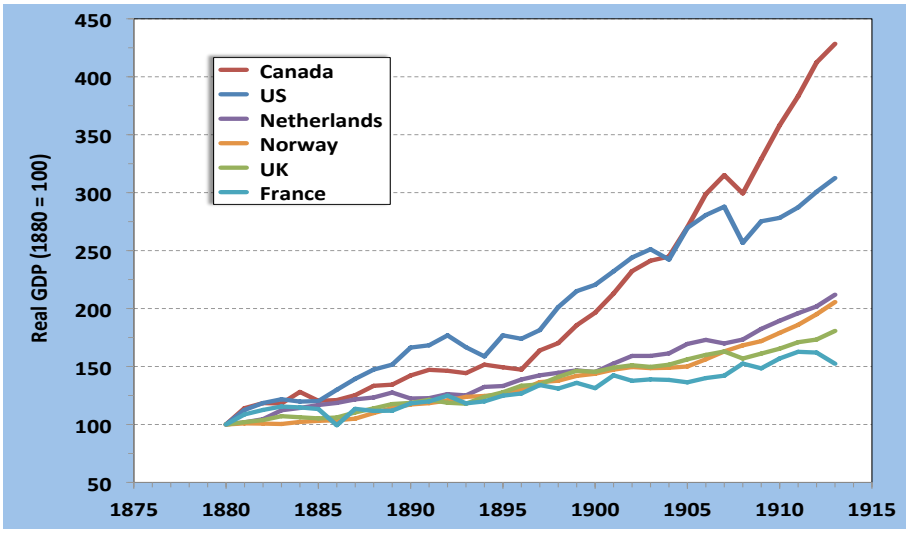

Figure 8: Real GDP in Selected Countries, 1880 -1913

Financial Crises

To determine the likelihood of financial crises under the gold standard, I use the data on banking crises from Reinhart-Rogoff Table A.3.1. The data show that financial crises were quite likely:

1. At least one country had a banking crises in about a third of the years during the period 1880 to 1913. According to the Reinhart - Rogoff data, there were banking crises in 1880, 1882, 1885, 1889, 1890, 1891, 1897, 1898, 1901, and 1907 in one or more countries that were on the gold standard at the time. In most cases, the banking crisis was only in a single country. However, in 1891, 1892, and 1897 more than one country experienced a banking crises, and in 1907 there were banking crises in five countries.[21]

[20]Easton (1984) computes his correlations using "annual deviation of the log of actual GNP from the log of (exponential) trend GNP." (516) He also relies on different sources for his real output data.

[21]The Reinhart - Rogoff table lists 8 other countries that experienced banking crises between 1880 and 1913. However, I have been unable to determine whether these countries were on the gold standard at the time the crisis occurred. Therefore, these crises are not included in my calculations.

	Years on gold standard	Number of banking crises		Years on gold standard	Number of banking crises
Austria-Hungary	18	0	Italy	20	2
Argentina	17	0	Netherlands	34	1
Belgium	34	0	Norway	34	1
Brazil	9	0	Portugal	11	1
Canada	34	0	Russia	17	0
Denmark	34	2	Sweden	34	2
France	34	2	Switzerland	34	0
Germany	34	2	United Kingdom	34	1
Greece	4	0	United States	34	3

Table 4: Number of banking crises in countries on the gold standard

2. There was a 50/50 chance that a country would experience a banking crisis while on the gold standard. In the table below, I present a list of 18 countries that were on the gold standard during this period. The shows that 9 countries had at least one crises, 5 had two crises, and the United States had three.

However, this discussion is not to imply that financial crises were due to countries being on the gold standard. Financial crises have occurred in all financial systems, whether commodity-backed or fiat, in which financial institutions have demand liabilities that are not matched by assets with the same maturity.

2.7 Summary

The consensus is that during the Classical Gold Standard period, 1880 - 1914, the gold standard performed quite well. As the evidence given above shows, it provided for price level and exchange rate stability and for reasonably good real output growth. One argument for why the gold standard worked so well during this period is given by Kindleberger (1973). He argues that the success of the gold standard was due to the effective management of the Bank of England. Specifically, the Bank of England "increased its foreign lending whenever economic activity turned down, damping rather than aggravating the international business cycle" and "by acting as international lender of last resort." (Eichengreen (1992) loc. 471)

Eichengreen (1992) has a different view.

> The stability of the prewar gold standard was instead the result of two very different factors: credibility and commitment.... The credibility of the gold standard derived from the priority attached by governments to the maintenance of balance-of-payments equilibrium. In the core countries – Britain, France, and Germany – there was little doubt that the authorities ultimately would take whatever steps were required to defend the central bank's gold reserves and maintain the convertibility of the currency into gold.... The very credibility of the official commitment to gold meant that this commitment was rarely tested. (loc. 484)

He goes on to argue that this commitment was not on a country-by-country basis.

> Ultimately, however, the credibility of the prewar gold standard rested on international cooperation. When stabilizing speculation and domestic intervention proved incapable of accommodating a disturbance, the system was stabilized through cooperation among governments and central banks. (loc. 523)

3 The Bitcoin Standard

In order to set the stage for a discussion of how monetary policy might be conducted under my imagined bitcoin standard and what the outcomes might be in terms of price levels, exchange rates, real output and financial crises, in this section I discuss the bitcoin standard in more detail. I also highlight the ways in which it is similar to and different from the gold standard.

3.1 Details

Under the bitcoin standard, a country may or may not have its own monetary unit. The analysis does not to any extent depend on which choice countries make. If a country does choose to have its own monetary unit, then it would be defined to equal some amount of bitcoin. Throughout the rest of this discussion, I assume that countries have their own monetary unit.

Bitcoin

The media of exchange under the bitcoin standard would differ from those under the gold standard. One difference is that there would be no coins. Instead, there would be bitcoin. The rationale for coins is that "raw" gold is not a convenient medium of exchange. The weight and fineness of the amount of gold being offered in a transaction have to be verified, which can be time consuming and costly. These costs were reduced by governments establishing mints that produced coins of a known weight and fineness. In contrast, a bitcoin is a bitcoin. There are no differences in weights or fineness of different bitcoin. And payments and P2P transfers can be made with bitcoin

Central Bank or Treasury Fiduciary Currency

It is possible that the bitcoin standard could exist without each country's monetary authority issuing a fiduciary currency. Nonetheless, I assume that monetary authorities would choose to issue fiduciary currencies in order to have the ability to finance fiscal deficits through money creation.

Thus, I assume that in addition to bitcoin, the addresses in the decentralized ledger, there would be Bank of Canada dollars, Federal Reserve dollars, ECB euros, Bank of England pounds, and so forth.[22] These central bank currencies would be separate currencies that circulate along side bitcoin. They would be tied to bitcoin because they would be redeemable

[22]If a countries did not have their own monetary units, there would be Bank of Canada bitcoin, Federal Reserve bitcoin, ECB bitcoin, Bank of England bitcoin, and so forth.

in bitcoin on demand. These central bank currencies would be fiduciary because the central banks would not fully back their issues with bitcoin, just as under the gold standard central banks did not fully back their note issues with gold.

My expectation is that these fiduciary currencies would be liabilities on the balances sheet of the central banks and would appear under two headings, just as fiduciary currencies did under the gold standard and fiat currencies do today. The first heading would be the accounts that central banks set up on their ledges for banks in their countries. These accounts would be denominated in terms of the central banks' individual currencies would exist solely on the ledger of the central bank; they would not be part of the decentralized bitcoin block chain. Commercial banks could use the accounts for settlement or reserve purposes similar to how today banks in Canada use the Deposit account at the Bank of Canada labelled "Members of the Canadian Payments Association" and banks in the U.S. use the account at the Federal Reserve Banks labelled "Term deposits held by depository institutions."

The second heading on the balance sheets would be one that pertains to the fiduciary currency that was in circulation in the hands of the nonbank public. These accounts would be similar to the Bank of Canada's "Bank notes in circulation" and the Federal Reserve Banks' "Federal Reserve notes" headings. Under the bitcoin standard the form of the fiduciary currency in circulation with the nonbank public could be in paper (or plastic or perhaps some metallic alloy like today's coins) and/or digital form.

The redemption of these fiduciary currencies would mean transferring bitcoin from the central bank's "wallet " to the "wallet" of the commercial bank or person requesting the withdrawal rather than transferring gold coin or bullion as was the case under the gold standard.

Of course, there are issues involved in the issuance of central bank non-digital currencies, such as the choice of the minimum denomination and of the number of denominations. However, although these choices are significant, they would not affect how the bitcoin standard would work.

Commercial Bank Fiduciary Currency

Under the bitcoin standard the private banking system would continue to exist and would engage in maturity transformation in the sense that it would not hold assets with the same maturities as its liabilities. However, there a question about whether or not banks would issue liabilities that were callable. In other words, there is a question of whether banks would still issue bank notes or deposits. I assume that they would.

Which leaves two questions to be answered. The first is, In what would the bank notes or deposits be redeemable? There are three possibilities:

1. Central bank fiduciary currency (for ease of exposition call them dollars) only. Banks' reserves against these deposits would be dollar deposits at the central bank and dollars held in their vault (vault cash). Banks would not have to hold any bitcoin reserves against these accounts because they are not required to pay out bitcoin. Clearing would be done very much clearing is done with checks today.

2. Bitcoin only. Banks' reserves against bitcoin deposits would be held in "wallets" in which they hold bitcoin. It is part of my vision that these bank "wallets" would be

provided by a private provider rather than by a central bank. In fact, I think it is unlikely that central banks would offer such wallets unless there was a public policy case that the banks' wallets for bitcoin should be provided by a central bank because central bank wallets would be more secure than those provided by the private sector.

3. Bitcoin or dollars. I leave open the question of whether the form of payout to a liability holder is at the holder's or the bank's discretion.

Under the bitcoin standard, bitcoin held in an agent's wallet would serve all the functions that banks' callable liabilities would serve. Consequently, agents would not see the need to have or use callable liabilities of bank that were redeemable in bitcoin. This would argue for that proposition that the only type of callable liability offered by banks under the bitcoin standard would be the dollar only one.

The second question to be answered is, Would the banks be narrow banks; that is, would their callable liabilities be fully backed by safe assets, or would the banking system be fraction reserve? I assume that it would be fractional reserve because historically banks have not issued liabilities that were fully backed.[23] Thus, I assume that under the bitcoin standard there would be a second type of fiduciary currency – one issued by commercial banks.

3.2 Monetary Policy

I now discuss whether monetary policy can be conducted under a bitcoin standard, and if it can, how would monetary policy be conducted. As was the case when considering monetary policy under the gold standard, I will consider whether a central bank can affect interest rates and the extent to which it can act as lender of last resort. Throughout I assume that central banks have reserve bitcoin in"wallets" just as central banks held gold reserves under the gold standard.

Interest Rate Policy

Under a bitcoin standard, it will be impossible for a country to conduct an interest policy to affect domestic economic conditions. Above I noted that the fluctuations in the exchange rate between the $ and the CAD were smaller that those of the $ against the £. I hypothesize is that this was due to the fact the cost of gold arbitrage was smaller for the $ - CAD than for the $ - £. And it was these costs of engaging in gold arbitrage that allowed a country to set an interest rate that differed from those in other countries under the gold standard.

Such arbitrage costs do not exist for the bitcoin standard as the cost of arbitrage between the fiduciary currencies of any two central banks would be essentially zero. The time cost of obtaining bitcoin for fiduciary currency or fiduciary currency for bitcoin would be extremely small, and because the ledger containing transactions history is open and transactions are recorded regardless of location, no shipping or insurance costs are involved. Thus, the spot exchange rates for all fiduciary currencies would be one-to-one, and monetary authorities would be unable to set interest rates different from those in other countries.

[23]See Wallace (1996) for a theoretical model in which a fractional reserve banking system is superior to a narrow banking system.

In a sense, the bitcoin standard would look like a single currency world, but with multiple issuers of that single currency. If that single currency were a fiat currency, then there would be an incentive for a country (an issuer) to issue large amounts of the currency because some (perhaps most) of the inflation tax would fall on citizens of other countries. Under the bitcoin standard, however, the issuer of the currency would be identified and the quantity that issuer could issue would be restricted by the redemption requirement.

Lender of Last Resort

There are two different kinds of financial crises that can potentially occur under the bitcoin standard. The first is runs on fiduciary currency accounts (dollar only accounts) at banks or other private financial institutions. Here, it would be possible for central banks to act as lenders of last resort, at least to some extent, because they can issue fiduciary currency. A central bank can act as lender of last resort by discounting ("purchasing") commercial paper and other assets presented commercial banks with its own fiduciary currency. The transaction amounts to crediting a bank's reserve account at the central bank. In this way, a central bank supplies reserves to banks when there are financial crises. Because these reserves are in terms of the fiduciary currency, the central bank does not have to possess before making the transaction the amount of bitcoin equal in value to amount that it credits to the bank. In order words, it can simply create reserves for banks.

It is this lender of last resort function of central banks under the bitcoin standard that led me to assert that a central bank's fiduciary currency would not only exist on a central bank's ledger, but would also exist in paper form. During this type of financial crisis, agents in the economy want to withdraw fiduciary currency deposits from their banks because of uncertainty about their banks' financial condition. Facing such withdrawal demands, banks go to the discount window to obtain fiduciary currency to pay those requesting withdrawal. The existence of the fiduciary currency in this second form allows for these withdrawal requests to be met.

The second type of financial crisis is runs on the central bank because of concerns about their ability to meet demands to redeem their fiduciary currency. The possibility of such runs means that a central bank can only issue its fiduciary currency up a point. Facing such a run, a central bank is limited in what it can do because a central bank cannot act as lender of last resort to itself. There are two possible actions it can take. One is to suspend payments as the Bank of England did in 1791. The problem with this action is that unless there is a credible commitment to redeem in the future, existing fiduciary currency will very likely depreciate in value and the central bank may never be able to issue fiduciary currency again. The other possibility is to borrow bitcoin from from other central banks with the promise to repay once the crisis in its country abates.

3.3 How Would the Bitcoin Standard Perform?

In this section, I conjecture how well the bitcoin standard would be expected to perform with regard to achieving price level stability and exchange rate stability. I will also conjecture about how well countries could be expected to perform with respect to economic grow and about whether there will be financial crises in countries that adopt the bitcoin standard.

Price Level Stability

I have three conjectures about the behavior of country price levels under the bitcoin standard.

Conjecture 1: Price levels of the various countries would be highly, but not perfectly, correlated, much as they were under the gold standard.

My reasoning is that under the bitcoin standard, just as under the gold standard, the money supplies of different countries would not necessarily move together, although the more tightly a group of countries are linked in terms of trade and finance, the more closely their money supplies would be linked.

The supply of bitcoin in a country will be determined by the same three factors that determined the supply of gold in a country under the gold standard. These three factors are:

1. Flows due to arbitrage. The rationale for such flows to occur under the gold standard were described above in section 3 on the price-specie flow mechanism. The same incentive for agents to make purchases where their currency obtains the largest quantity of goods will also exist for bitcoin. And the fact that exchanges of bitcoins for goods would occur virtually instantaneously should cause a large quantity of such arbitrage to occur. How large these flows are was not under the control of a monetary authority under the gold standard and will not be under the bitcoin standard.

2. Balance of payments deficits or surpluses. There are many reasons that agents in one country will import from or export to another country. The associated balance of payments deficits or surpluses have to be settled in some form. Under the gold standard, gold was one such form of settlement; under the bitcoin standard, some settlement will be in bitcoin. The size of a country's balance of payments deficit or surplus and the form in which agents choose to settle it is not under the control of the country's monetary authority under either standard. To the extent they are settled in bitcoin, the stock of bitcoin in a country will be affected

3. Production of the "anchor" in the country. Under the gold standard, the quantity of gold in a country would be incremented by the quantity of gold newly mined in the country. The same would be true under a bitcoin standard. New bitcoin are generated by the action of the "miners." The more mining that is done in a country, the faster the stock of bitcoin in the country will increase. The monetary authority has no control over the number of miners in a country or how much mining they choose to do, just as monetary authorities did not control how much gold mining was done in the countries on the gold standard.

Of course, under a bitcoin coin standard, the stock of bitcoin in a country can be affected by government action. The government could collect taxes in the form of bitcoin, or the government could sell bonds for bitcoins. If the proceeds from these actions are not subsequently spent, then the quantity of bitcoin in the country would be reduced which should

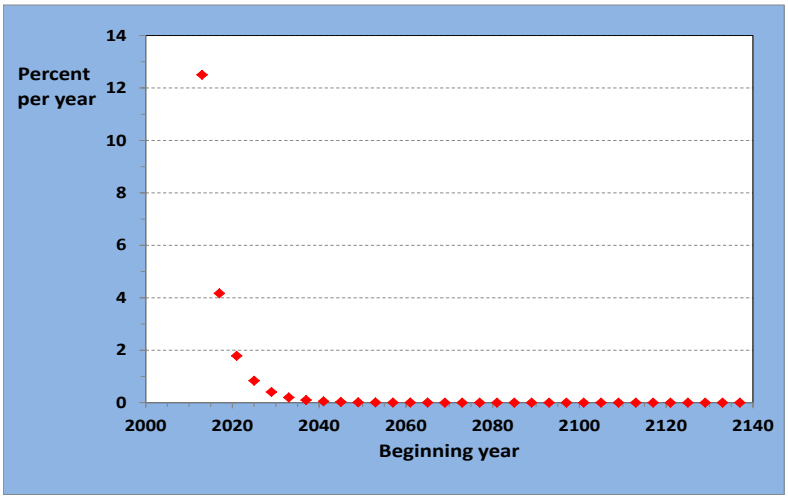

Figure 9: Percentage change in world bitcoin stock, 2009 to 2140

serve to reduce bank reserves and the country's money supply. However, such actions are more properly considered fiscal policy rather than monetary policy.[24]

Conjecture 2: In the long run, price levels would not be stable, but would decline at a rate of about 3 percent per year.

The reasoning follows from the Quantity Theory. Changes in the world stock of bitcoin are set according to the algorithm that determines how many new bitcoins "miners" receive for verifying transactions. In Figure 9, I show the percentage change in the world stock of bitcoin in each year from 2015 until 2040.[25]

The figure shows that beginning around 2030 and thereafter there will be virtually no growth in the stock of world bitcoin. Consequently, $\Delta M = 0$. Then, assuming that world output (ΔY) would grow at a rate of about 3 percent per year, assuming world velocity growth (ΔV) would be close to zero, and substituting into (1) leads to this result.

Suppose that real interest rates are also somewhere around 3 to 4 percent. Then if this conjecture is correct, the Fisher Equation implies that nominal interest rates on safe assets would be approximately 0. So, I also conjecture that under the bitcoin standard countries would have nominal interest close to those in the major developed countries today and would

[24]Under a gold coin standard a monetary authority can choose then number of different coins, how much gold is in each, and the seigniorage rate. This decisions could be considered monetary policy. However, since bitcoin is digital and expressed to eight decimal places such possibilities are not relevant for the discussion here.

[25]Actually the timing is approximate because to make the figure look good I have plotted the percentage changes at four year time intervals. The time intervals in the bitcoin algorithm specifying how many bitcoin are to be created makes the changes at time intervals that are only approximately four years. In addition, percent change is approximate because bitcoin can be lost if the private keys associated with them are lost or destroyed through hard drive crashes or losses of paper wallets. I am indebted to Hanna Halaburda for these examples. Nonetheless, the deviations of actual production from my figure will be extremely small.

be close to the Friedman Rule.

Exchange Rate Stability

My conjecture is that under the bitcoin standard the exchanges among the fiduciary currencies of various countries would be fixed at one-for-one. This conjecture is based the fact that there the cost of bitcoin arbitrage is essentially zero. Hence, the "bitcoin import point" and "bitcoin export point" would be identical and the same as the spot exchange rate.

Real Output Growth

I also expect that the growth would vary widely across countries. Figure 8 shows that this was definitely the case under the gold standard. The recent experience of the Eurozone countries shows that this can also be the case of countries on the same monetary standard today. I see no reason why that would not continue to be the case under the bitcoin standard.

My conjecture is that under the bitcoin standard average annual real output growth for the countries on that standard would be in the 2.5 to 3.5 percent range. The lower end of this range comes from average of the six countries in Figure 8 which was 2.56 percent per year. The upper end of the range is based the IMF's estimate that world real GDP grew at an average rate of 3.5 percent over the period 1969 to 2014.

Some might be concerned, using Phillips Curve reasoning, that real growth would be extremely slow under the bitcoin standard because of the deflation that would occur under it. The evidence from countries on the gold standard shows that this concern is unwarranted to some extent. During the period 1880 to 1895 when there was generally deflation in countries on the gold standard, all six countries in my sample experienced real growth. For the U.S., it was 3.80 percent per year; 2.67 percent per year in Canada, 2.55 percent per year in Norway, 1.91 percent per year in the Netherlands, 1.64 percent per year in the U.K., and 1.48 percent per year in France. Nonetheless, for Canada , the Netherlands, Norway, and the U.K. these growth rates were markedly lower than in the period 1896 to 1913 when there was generally inflation. The U.S. and France, however had lower average annual growth in the inflation period than in the deflation period.

Financial Crises

Finally, I conjecture that there would be financial crises under the bitcoin standard. History shows that financial crises can and do occur in any financial system in which financial institutions have demand liabilities that are not matched by assets with the same maturity. I expect that the financial systems of countries on the bitcoin standard would exhibit such maturity mismatches. Of course, such crises can be mitigated to some extent by government deposit insurance, which under the bitcoin standard would require the existence of fiduciary currencies.

There is one other type of potential crisis under the bitcoin standard that did not exist under the gold standard. It is that bitcoin would suddenly no longer be accepted in trade and lose all of its value. As discussed above, this was not a possibility for the gold standard as gold is intrinsically useful. However, for an intrinsically useless medium of exchange like

bitcoin, it is a possibility. Nonetheless, I think the probability would happen is virtually zero. For an intrinsically useless medium of exchange to be valueless, it must happen that no agent expects it to be accepted by any other agent either now or in the future. As long as there is some agent, say a government willing to accept the medium of exchange for taxes, that other agents believe will always accept the medium of exchange, then it will always have value.

4 Conjectures and Conclusion

Canada permanently left the gold standard in 1929; Britain and Germany in 1931; the United States in 1933; France in 1936. If the gold standard was so successful, why did it not last? Why did countries replace their gold backed currencies with fiat currencies in the 1930s?

The answer, at least according to Eichengreen (1992): the political and economic changes that occurred or were accelerated by World War I. Two of the most important were:

1. Changes in the composition of voters in countries on the gold standard, so that domestic priorities became more important and balance of payments concerns less important. The gold standard limited the ability of policymakers to address issues such as unemployment and inflation, especially in times like the Great Depression.

2. The center of the international finance shifted away from London and to New York. This was due in large part to the large gold reserves that the U.S. accumulated during World War I.

This experience with the gold standard raises a question about the bitcoin standard: If it were to come into being, would it last for a substantial period of time or would it be replaced by some other monetary system? In answering this question, I am going to assume that what is being asked is whether a monetary system based on some cryptocurrency would last for a substantial period of time. However, that cryptocurrency would not necessarily have to be bitcoin. There are many cryptocurrencies in existence today and more will arise in the future. One of them could be the cryptocurrency anchoring the monetary system instead.

My conjectures about whether the bitcoin standard would last a substantial period of time depends on how the bitcoin standard came into existence. The first case I consider is that in which the bitcoin standard came into being gradually over time. That is, the number of merchants accepting bitcoin gradually increased over time and using bitcoin became increasingly more convenient as the time to verify and complete transactions became shorter and shorter to the point where no one used the old media of exchange.

My conjecture for this case is that the bitcoin standard would not last long. There would be a major cyclical downturn or financial crisis that would lead to political pressure and demands for central banks to remove the "bitcoin fetters" that prevent them from inflating to stimulate the economy or from providing assistance to financial institutions in trouble.[26] Central banks or governments would eventually yield to this pressure and break the ties

[26] According to Keynes (1932) when Britain went off the gold standard in 1931, "There are few Englishmen who do not rejoice at the breaking of our gold fetters." (288)

between their currencies and bitcoin, just as central banks and governments went off the gold standard before and during the Great Depression. In other words, the currencies of central banks or governments would become fiat currencies rather than fiduciary currencies.

However, I conjecture further that in this case in which countries have gone off the bitcoin standard, bitcoin would continue to play a role as a medium of exchange. In fact, since it been the anchor of the monetary system, I conjecture that it would have a large role as a means of payment for exactly the same reasons that it has a role as a medium of exchange today. One reason is it would eliminate the transactions costs of switching between central bank currencies when making transactions in different countries. Also, because there would now be fluctuations in in the exchange rates between central bank currencies, bitcoin would provide as a means of hedging against these fluctuations. Reaping these benefits was one of the major reasons for European countries gave up their individual currencies and adopted the euro.

The second case I consider is that in which countries have been on a fiat monetary standard, but for some reason their fiat currencies are no longer valued, have gone out of existence, and have been replaced by the bitcoin standard. One of the major reason that this could occur is that countries have been following bad monetary policies that have led to high rates of inflation.

Here my conjecture about the stability of the bitcoin standard arises from the instability problem occurs with any monetary system based on an object, such as bitcoin, that is intrinsically useless. In any such monetary system, there are two equilibria. In one equilibrium the money is valued; in the other it is not. Whether an intrinsically uselessly medium of exchange is valued depends upon whether agents expect it will be accepted in transactions in the future. If at any point in time people expect that bitcoin will not be accepted in future transactions, it will lose its value at that time. In other words, the economy could switch from the equilibrium in which bitcoin is valued to the other equilibrium in which it is not. The switch could occur to due extrinsic uncertainty ("sunspots"). Or, in the case of bitcoin, it could occur due to concerns about either the block chain or the underlying algorithm determining the supply of bitcoin being hacked. Were that to happen with bitcoin, the bitcoin standard would disappear.

Because of these concerns about the possibility that bitcoin could become valueless, there could political pressure and demands for central banks or governments to offer a intrinsically useful fiduciary currency to compete with bitcoin. By a intrinsically useful fiduciary currency, I mean that it would be one backed by some commodity or basket of commodities.

If central banks or governments could credibly commit to redeem this currency on demand and if they were willing to give up their own monetary units and adopt a uniform one, then this might be widely accepted as a medium of exchange and might drive out bitcoin to a great extent. My reason for including the elimination of individual country monetary units is to make clearing simpler and to facilitate the use of the currency across country lines. In others words, the bitcoin standard might not be stable because a Euro-like commodity backed money could provide the benefits of the bitcoin standard without its inherent stability issues.

This raises the question of whether this backing should be gold or something else. As Bordo (1984) points out "an important defect of the gold standard" was that it based "a nation's money supply on one commodity subject to changing demand and supply conditions."

(27) It was because of this defect that in the 1920s through the 1940s there were numerous suggested alternatives to the gold standard. Among these alternatives were bimetallism, symmetallism, and the generalized commodity reserve currency.[27]

[27]For references to these proposed schemes and a discussion of how they could work, see Weber (1980)

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Appendix: Data Sources

Prices

Belgium, Denmark, France, Germany, Netherlands, Norway, Sweden, Switzerland, United Kingdom: http://eh.net/database/global-finance/. Prices are from worksheet "13. Prices." The prices in the original database are base 1913 = 100. I have rebased them to 1880 = 100.

Canada: Urquhart (1986) rebased to 1880 = 100.

United States: Officer and Williamson (2014) rebased to 1880 = 100.

Real output

Canada: Urquhart (1986) rebased to 1880 = 100.

France: Saint Marc (1983) rebased to 1880 = 100.

Netherlands: computed from Data Archiving and Networked Services (2000) rebased to 1880 = 100.

Norway: Grytten (2004) rebased to 1880 = 100.

United Kingdom: Column A in worksheet "Real GDP" in the Data Annex to Hills, Thomas, and Dimsdale (2010) rebased to 1880 = 100.

United States: Williamson (2014) rebased to 1880 = 100.

Exchange Rates

CAD/$: computed on an annual basis from Bank of Canada Archives (n.d.). The premium of the $ against the Canadian dollar was computed using a par value of $1 per CAD.

£/$: Officer (2015). The premium of the $ against the British pound was computed using a par value of $4.8665 per £.

*FF/$*: Computed from the £/FF exchange rate from http://eh.net/database/global-finance/ worksheet "18. Exchange Rates" and the £/$ exchange rate given above. The premium of the $ against the French franc was computed using a par value of $0.193 per FF.