BITCOIN BANKING SYSTEMS: FULL RESERVE VS. FREE BANKING

A theoretical and practical discussion of prospective bitcoin native banking systems

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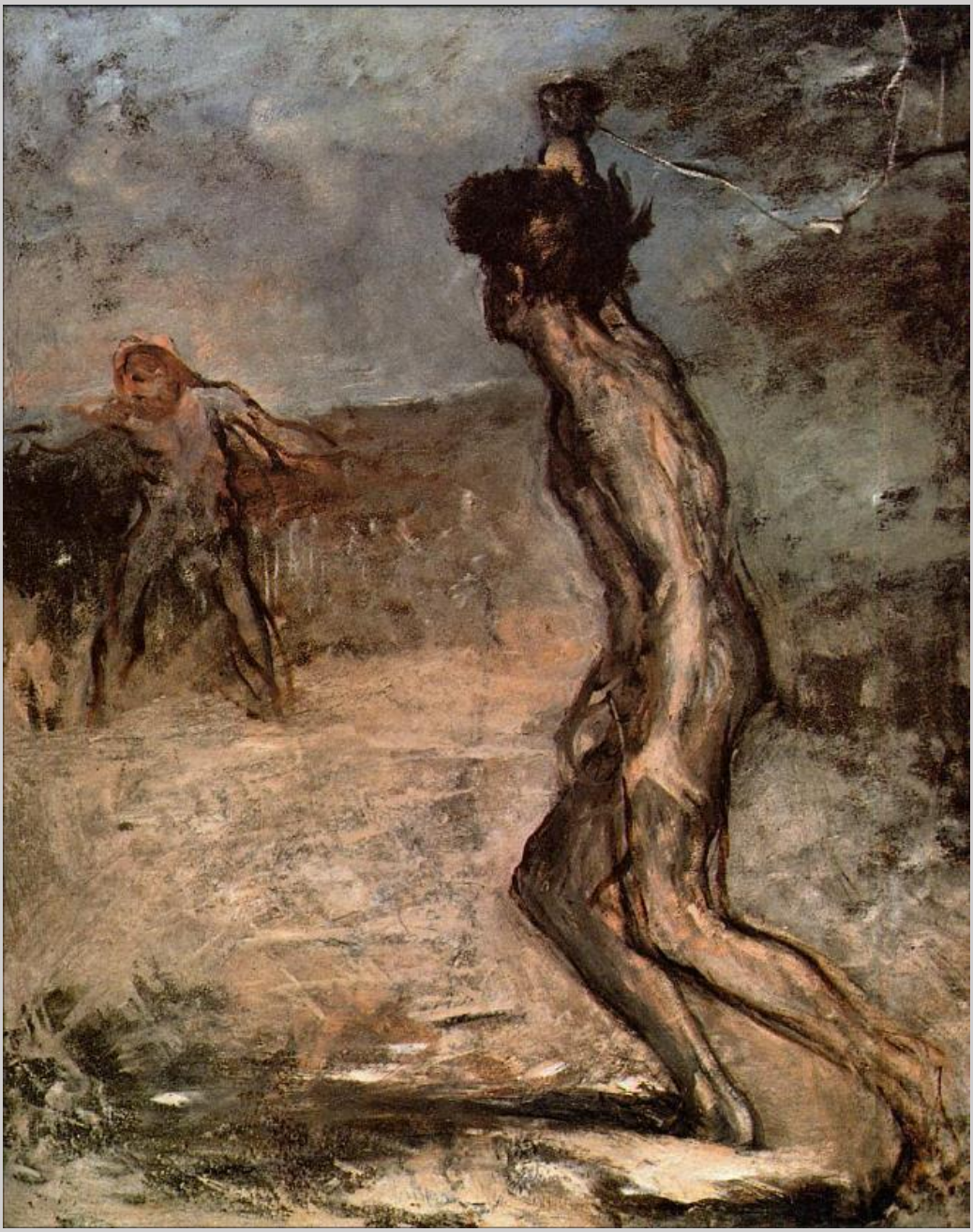


David and Goliath – Edgar Degas, 1863

The beauty is in the attempt. – Dave Chappelle

INTRODUCTION

The year is 2050. Inside your home you have a safe where you store partial bitcoin keys for savings. There is also a 3rd party intermediary that holds the other partial keys in a secure location. Your bitcoin isn't worth anything to you; things are now worth bitcoin to you. Each year your bitcoin buys a little more than the last, and you don't call them bitcoins anymore – you call them sats. While sipping a dirty chai latte at your local coffee shop, you recall the days when your sats would buy twice as much as the year prior, a rate of deflation that has been slowing for some time. Thoughts of purchasing power remind you to check your investment accounts, so you pull up your financial app. Your investments are segmented into three categories: low-risk, medium-risk, and high risk. Your low-risk account is earning interest by providing liquidity to the lightning network with money you don't plan to use in the near future. Your medium-risk account has sats deposited with a financial intermediary which lends to entrepreneurs and pays you a portion of the yield. Your high-risk account is invested in various securities that you hope will earn a rate of return beyond your bitcoin savings. All looks good. As you leave the coffee shop your phone buzzes with a notification that you have just been charged 1 sat for your latte.

Bitcoin has yet to reach maturity but when it does what will it look like? Will it all be self-custody? Will there be banks and if so, what will the credit system look like?

Credit is a word that reeks of distrust. History is littered with instances that have given people a reason for this distrust. Banks and fractional reserve lending have been paired with some of the worst crises in history. However, financial intermediation is a necessary economic function to match savers with borrowers, and credit has proven to be an extremely important function within an economy. It is the nature by which credit is created that ultimately determines its economic impact. I believe Bitcoin's relationship with credit will be paramount to its ultimate success in the long run.

The goal of this essay is to distill the theory behind credit systems and apply them to bitcoin following this structure:

1) Discussion of a full reserve system – covering the general theory of the system
2) Discussion of a free banking (fractional reserve) system – whereby no central bank exists, and private markets are free to issue credit money subject to market incentives
3) A comparison of full reserve vs. free banking systems
4) A conceptualization of the lightning network, its enabling technologies, and the potential for full reserve and free banking systems to emerge upon it

FULL RESERVE BITCOIN STANDARD

Once bitcoin has reached maturity it will have assumed the textbook three functions of money: store of value, medium of exchange, and unit of account. Individuals will save and spend bitcoin. Some individuals will be entrepreneurs and posed with a dilemma: save enough money until they can start their venture organically, or borrow money and start it today. Much of entrepreneurship is predicated upon market timing and thus having the capital needed at the time it is needed is critical. While some may be able to source this capital from their close networks, many will need to find it from alternative sources and not everyone will be rich enough to personally finance complex new ventures. Conversely, many savers will want to invest their savings to earn a higher rate of return by assuming risk, but not have viable investments within their immediate network. Remember, we've reached hyperbitcoinization and the increased purchasing power gained from holding bitcoin will be relatively less than investing in riskier enterprises, as bitcoin has saturated the market of money. Financial intermediaries will exist to fulfill the function of lending bitcoin to others because the assessment of credit risk requires specialization. Not everyone will know how to make loans and do it directly – doctors and lawyers (and others) would rather delegate this responsibility to individuals who specialize in it.

For example, individuals can deposit their money in a bank and earn a rate of return on that deposit. The digital analog for a deposit could potentially be providing liquidity to the lightning network (LN), to be discussed later. For collateralized loans (loans that are made only when the borrower offers assets as collateral) these will likely be done through an automated protocol if the collateral is digital. In many respects, centralized non-digitally native companies will be needed as financial intermediaries because not all collateral will be digital and the assessment of counterparty risk will require centralized intermediaries.

The bank (or financial intermediary) can then take that money and lend it to entrepreneurs who attempt to create wealth. Under a full reserve system, banks will not lend beyond the amounts they hold in deposit and thus will not create new money by the extension of credit. A rate of return is earned on their investments in aggregate and from that the depositors are paid interest while the bank pockets the rest to cover operational expenses and earn a market rate of profit.

Further, a full reserve system requires that banks do not lend demand deposits, only time deposits. Demand deposits allow the depositor to withdraw amounts on demand while time deposits effectively lock the depositors' funds with the bank for a set period. If banks only loan amounts with the same maturity as their time deposits, there will be no **maturity mismatching –** a mismatch in the maturity of a bank's assets with its liabilities. If banks were to loan amounts of their demand deposit accounts, there is the possibility that if depositors demand their deposits, they cannot be fulfilled because the money is loaned out at that time.

There is disagreement as to how full reserve banking should be defined. We don't have much in the way of examples of full reserve, but ostensibly the idea is that there can't be a run on the bank. There exists the possibility of bank failure from making poor loans, but not of a bank run from maturity mismatching. For this discussion we'll define a full reserve bank as one that does not engage in maturity mismatching and thus only makes loans (assets) with liabilities (deposits) of the same maturity.

Under a full reserve bitcoin standard, banks will effectively act as credit intermediaries that specialize in conducting due diligence on loan risk as well as other digitally native functions to

be discussed later on. Investment firms will also have a large role to play as capital allocators for more complex structures of credit and equity investments. The various types of lenders can utilize digital protocols and smart contracts to perform some of these functions.

The Innovation of Bitcoin Incentivizes Full Reserves

Credit is the oldest form of money. Delayed reciprocal altruism (i.e., credit) was used as a currency based on trust prior to the existence of commodity money. Bitcoin is a synthetic commodity money with a precisely defined quantity and quality. What were the advantages of credit money over commodity money prior to bitcoin and what are they now that bitcoin has rendered many of them obsolete?

Let's consider six common monetary properties:

Scarcity *Limited in supply relative to other goods*	**Acceptability** *Used by others and accepted widely*	**Divisibility** *Easily divided into smaller units*
Durability *Can be used repeatedly without losing functionality*	**Portability** *Easily moved across distances*	**Fungibility** *One unit is exactly the same as another*

Paper money (credit money) was far superior to gold (commodity money) in terms of portability and divisibility. Nobody wanted to lug around gold and thus trading paper receipts instead of gold increased portability and divisibility. In the age of digital money, this contrast is only more apparent. With bitcoin and the lightning network, these costs of commodity money have been removed – a true innovation. There is no obvious reason to create digital receipts on bitcoin to trade (that are solely intended to be a one-to-one backing of bitcoin as opposed to a more involved financial instrument) assuming scaling mechanisms such as the lighting network reach maturity. Thus, people will likely demand actual bitcoin on their loans as opposed to a contractual derivative (digital receipt).

This should cause one to pause and ask: if bitcoin has innovated away this advantage of credit money, then why would we still need such a system? Because bitcoin has innovated away many of the tradeoffs between commodity money and credit money, there is a strong argument that a bitcoin standard reduces the need for credit money. It's likely that credit money and fractional reserve banks will become less relevant (to be discussed later).

There is a distinction that is relevant here between *credit* and *credit money* (i.e., fiduciary media). In the broadest sense credit encompasses any form of deferred payment. In this writing, I'm referring to credit in a formal sense whereby its extension is legally enforceable. This generally includes any form of lending whereby one party lends money to another party with the obligation to pay back with contractually defined interest. This definition of credit is distinct from fiduciary media (i.e., credit *money*) whereby money is created that is not commodity money, but simply a promise to pay commodity money. In the latter case, the money itself is created based on credit.

With basic credit, its extension does not expand the money supply as it is simply moving the savings of one party to another – no new money is created. With fiduciary media, the money

supply expands as it does not require the savings of another for it to be extended. A full reserve system, as defined above, will not expand the money supply with credit issuance; it is simply reallocating capital. A fractional reserve system will expand the money supply by issuing new money backed by the promise of delivering commodity money at some future date.

FREE BANKING BITCOIN STANDARD

In 2010, Hal Finney stated on bitcointalk.org:

> *Actually there is a very good reason for Bitcoin-backed banks to exist, issuing their own digital cash currency, redeemable for bitcoins. Bitcoin itself cannot scale to have every single financial transaction in the world be broadcast to everyone and included in the block chain. There needs to be a secondary level of payment systems which is lighter weight and more efficient. Likewise, the time needed for Bitcoin transactions to finalize will be impractical for medium to large value purchases.*
>
> *Bitcoin backed banks will solve these problems. They can work like banks did before nationalization of currency. Different banks can have different policies, some more aggressive, some more conservative. Some would be fractional reserve while others may be 100% Bitcoin-backed. Interest rates may vary. Cash from some banks may trade at a discount to that from others.*
>
> *George Selgin has worked out the theory of competitive free banking in detail, and he argues that such a system would be stable, inflation-resistant and self-regulating.*
>
> *I believe this will be the ultimate fate of Bitcoin, to be the "high-powered money" that serves as a reserve currency for banks that issue their own digital cash. Most Bitcoin transactions will occur between banks, to settle net transfers. Bitcoin transactions by private individuals will be as rare as ... well, as Bitcoin based purchases are today.*

The discussion of a full bitcoin reserve assumed bitcoin was fully mature and thus adopted as money across all functions. This assumption is made because the dynamics of a monetary system are different when a system has not achieved maturity. The same logic applies to a free banking system. It starts with an initial expansion of fiduciary media but eventually reaches maturity and finds an equilibrium price level whereby the expansion and contraction of fiduciary media supply mildly fluctuates.

The Austrian School and Free Banking Theory

Imagine a world in which banks were allowed to competitively issue their own private monies and markets were allowed to sort out whether these monies were valuable. This system is built on the assumptions that (1) information transparency is high; (2) it exists within a competitive market environment; and (3) it is subject to minimal regulations. If such a system emerged and was predicated upon voluntary agreement and exchange amongst market actors, who's to say that it would not be just?

Many of the Austrian school would disagree and are advocates of a full reserve system, Murray Rothbard being an example. Ludwig Von Mises appeared to be of two minds about free banking during his career. In *The Theory of Money and Credit*, Mises stated:

> *Fiduciary media are scarcely different in nature from money … Hence, they should logically be subjected to the same principles that have been established with regard to money proper; the same attempts should be made in their case as well to eliminate as far as possible human influence on the exchange ratio between money and other economic goods…. Now it is obvious that the only way of eliminating human influence on the credit system is to suppress all further issue of fiduciary media. The basic conception of Peel's Act ought to be restated and more completely implemented than it was in the England of his time by including the issue of credit in the form of bank balances within the legislative prohibition.*[1]

In the above quote Mises is advocating for regulators to restrict private markets from choosing a fractional reserve system (fiduciary media means fractional reserve bank notes). However, this quote must be taken in context as he was referring to actions needed to reconstruct monetary institutions after WWII (in fact, this quote was an addition in 1958 to the 1912 edition). Let's put aside the argument for or against regulators limiting the voluntary contractual arrangements of private markets and focus on Mises' thoughts on free banking:

> *The establishment of free banking was never seriously considered precisely because it would have been too efficient in restricting credit expansion.*[2]
>
> *No government is willing today to give any thought to the program of free banking because no government wants to renounce what it considers a handy source of revenue.*[3]
>
> *Free banking is the only method available for the prevention of the dangers inherent in credit expansion…only free banking would have rendered the market economy secure against crises and depressions.*[4]
>
> *Credit expansion in itself does not expand a bank's clientele, viz., the number of people who assign to the demand-claims against this bank the character of money-substitutes. Since the over-issuance of fiduciary media on the part of one bank, as has been shown above, increases the amount to be paid by the expanding bank's clients to other people, it increases concomitantly the demand for the redemption of its money substitutes. It thus forces the expanding bank back to a restraint.*[5]

Mises believed that free banking provides a limit to credit expansion, allowing the market to find a natural price level. He thus believed it to be superior to fiat money and a gold-standard system with central bank intervention. However, he did not necessarily perceive a free banking system to be perfect because (1) the elasticity of the money supply (when defined as fiduciary media) distorts the pricing feedback loop necessary for entrepreneurs to make decisions and (2) this system would inevitably be captured by government regulators and ultimately used as a tool for centralized control.

I'll return to this discussion later, as we first need to understand how free banking naturally limits credit expansion. The concepts I will be drawing on are from the works of George Selgin and Lawrence H. White on free banking.

Free Banking Emergence and Credit Expansion

The emergence of a free banking system would create an initial credit expansion, but it would ultimately plateau as market forces naturally impose limits. Let's start with describing this emergence and how the system self-regulates in traditional banking (a bitcoin standard will have material differences from the following description, but for the sake of conceptualizing it let's put aside these differences for now).

Private banks emerge that accept deposits of bitcoin on a full reserve and subsequently lend these reserves to earn a rate of interest and pay a portion of that back to depositors. Amounts in outstanding loans would not exceed amounts of reserves at the bank.

As these banks have garnered a reputation of trust with their depositors and the broader public, they can begin issuing their own notes (redeemable in bitcoin) to borrowers, as opposed to giving them the bitcoin outright. Borrowers, rather than redeem their notes for bitcoin when paying someone, can simply trade the note itself to whomever they are paying, as this is more efficient. As the bank has built up enough public trust, their notes will begin to circulate as de facto money without the need for redemption into bitcoin. Once this level of trust is established, banks can begin issuing notes beyond the amount of bitcoin reserves they have backing them, to be used as money while *still* maintaining the promise that these notes are redeemable for bitcoin. Why wouldn't borrowers just want bitcoin instead of notes? This is an important question, as it could significantly hinder the actual emergence of fractional reserve based on bitcoin. To explain the theory for the time being, assume that receiving notes is preferable in the mind of the public. I will address this point in more detail later in this essay.

Such a system is based on trust, and various notes would be in competition with one another, either trading at par or at a discount. Individuals would be incentivized to verify that the reserve levels of a bank issuing a particular note are sufficient to meet regular demands for redemption. Of course, not everyone would care to constantly conduct this due diligence and traditionally this due diligence was conducted by a broker class that would arbitrage various notes between locales. For example, brokers could purchase notes that are less trusted at a discount and go to the bank that issued the notes for their redemption at full value, pocketing the difference. Thus, by seeking arbitrage opportunities, brokers unintentionally increase information transparency, the incentive to maintain adequate reserves, and wide acceptance of various bank notes.

Banks probably would ultimately adopt the function of brokers and begin accepting each other's notes at par. If the banks don't accept notes of other banks, this would ultimately lead to a drain on the less accepting banks' reserves, because they would be having their notes redeemed from other banks more rapidly than they would be redeeming notes from other banks for reserves themselves. Thus, the expansion of note acceptance is facilitated by market incentives and is constantly testing the adequacy of banks' reserves.

Note Dueling: an interesting practice common to free banking was note dueling – banks accumulating large amounts of competing bank notes and redeeming them all at once in an attempt to drain their reserves and render them insolvent. During the first half of the Scottish free banking system banks held relatively much higher reserves to protect themselves from these attacks, benefitting depositors. This was operationally intensive and there were limits to the scale at which banks could attack one another. To be discussed later, a bitcoin free banking system could likely see algorithmic execution of these attacks at a much larger scale and ultimately prevent fractional reserve systems from reaching maturity.

This constant process of gross note redemption is complicated and operationally intensive, so banks need a way for netting their redemptions to ultimately reduce the operational burden of the system by settling their debts in one place (or certainly *fewer* places). This results in the establishment of clearing houses where all banks go and net their liabilities between one another to settle only the net difference in their debts. The centralized clearing of debts places the clearing houses at the center of the system, and they ultimately evolve to serve even more functions such as:

1) Acting as credit monitors for banks, removing membership of those indulging in poor banking practices
2) Facilitating agreement among common reserve ratios, interest rates, exchange rates, and fee schedules for their members
3) Assist banks during times of crisis by facilitating short-term liquidity, i.e., the lending from more liquid to less liquid institutions

With the banks and clearing houses set up, note acceptance increases widely, settlement is conducted efficiently, and information transparency increases. All the while credit is expanding, and thus money is expanding, increasing the overall price level. However, this system eventually reaches a point of maturity where credit expansion plateaus and the system maintains long-run equilibrium.

At maturity the demand for reserves and available stock of bitcoin would be equal, and the supply of notes is equal to the demand for them. There exists a market rate of demand for credit notes and bitcoin reserves that is constantly being tested through market forces. The *principle of adverse clearings* is that if some banks attempt credit expansion while others do not, then clearing balances would ultimately benefit the more conservative banks above those expanding credit. The notes of the credit-expanding banks would subject them to more frequent redemptions, and therefore they would be quickly compelled to limit their expansion. As a result, banks providing cheap credit to capture market share would ultimately lose reserves to rival banks – punishing them for overexpansion. There exist diseconomies of scale in this system that can only be further scaled by increasing reserve levels.

In aggregate, if credit money expands beyond equilibrium, prices and reserve demands will increase. Rising prices will further increase the demand for money and reserves will fall below a sustainable level. The solvency of banks will be tested by reserve demands, credit will reduce to the sustainable level, and prices will subsequently fall. These market dynamics maintain a price level at which demand for reserves and credit money are stable. At equilibrium, aggregate credit expansion can only occur if additional reserves emerge from outside the system (e.g., the rising supply of bitcoin from the process of mining). Reserves within the Scottish free banking system ranged from 10-20% in the 2nd half of the 18th century and decreased to 1-3% in the 1st half of the

19th century.[6] This change was largely due to the practice of note dueling and its subsequent decline as private clearing houses supported the system.

The Demand for Money and Limitations of Inelastic Money

The concept of monetary demand is often conflated with the demand of bank borrowers to acquire money and immediately spend it on goods and services. When notes are created and granted to private market participants, and those notes are then immediately traded for goods and services and redeemed at the bank, there is no long-term increase in credit. Thus, the demand for credit money should be understood as the desire to hold that money, rather than receive it and immediately redeem it. Think of this as the desire to hold, or save, money, and this fluctuates when expectations of the future economic state changes. On this Selgin states:

"A bank borrower contributes no more to the demand for money than a ticket agent contributes to the demand for plays and concerts; only holders of money or actual occupants of concert seats contribute to demand."[7]

Further, this demand exists for the base money (bitcoin) and the credit money (bank notes). In this discussion we're referring to credit money and its demand is defined as an increase in the aggregate demand to hold bank liabilities. Monetary equilibrium exists when there is neither an excess demand for money nor an excess supply of it at the existing price level. When a short-term change in the supply of money is accommodating a short-term excess demand for it, it is accommodating demand and maintaining monetary equilibrium.

Elastic money, defined as the ability for the money supply to respond to changes in demand, has benefits which are best understood by illuminating the limitations of a money with inelastic supply. Selgin, in The Theory of Free Banking, uses the wage earner as an example:

> *The wage earners attempt to increase their money balances by reducing their purchases of consumer products, but there is no offsetting increase in demand for products due to increased, bank-financed expenditures. Therefore, the reduction in demand leads to an accumulation of goods inventories. Businesses' nominal revenues become deficient relative outlays for factors of production. Since each entrepreneur notices a deficiency of his own revenues only, without perceiving it as a mere prelude to a general fall in prices including factor prices, he views the falling off of demand for his product as symbolizing (at least in part) a lasting decline in the profitability of his particular line of business. If all entrepreneurs reduce their output, the result is a general down-turn, which ends only once a general fall in prices raises the real supply of money to its desired level.* [8]

I think the best way to consider this concept is as follows: Entrepreneurs are forced to plan for the future and their expectations of that future fluctuate. They invest their money into productive capital that will accommodate their expectations of future demand. If this demand is beyond their expectations, they need to invest in more productive capital to accommodate it. But if demand falls below their expectations, they're now sitting on unproductive capital and its associated costs, creating a financial burden. For those entrepreneurs on the edge of solvency, this demand decline could lead to insolvency. They're thus forced to sell off productive capital in

response to their expectations of future demand. It is only once prices have ultimately decreased, which takes time, that the demand decline will even itself out within the economy. Thus, an elastic credit money is more responsive in supply, less in price. This quality can ultimately decrease the costs of short-term declines in demand by not having to suffer insolvency because of it. Consequently, greater stability in prices via the elasticity of the (credit) money supply result. The tradeoff is that this increases the risk of malinvestment within the economy.

Considered at the individual level, entrepreneurs have a cost structure built out based on their expectations, rather than having to downsize or go insolvent for short-term fluctuations in this cost structure; an elastic supply of credit money helps them weather the storm. Considered at the aggregate level, elastic credit money from a banking system mitigates the costs of natural business cycles that emerge. The point is for credit to be a solution in the short-term without the persistent accumulation of credit to unsustainable levels in the long-term. The natural market-correcting mechanisms of free banking allow the money supply to respond to short-term fluctuations in demand without the costs associated with long-term expansions and contractions in credit.

Selgin states on the matter: *"Nevertheless deflation has been an important factor in historical business cycles, and a banking system that promotes deflation disrupts economic activity just as surely as one that promotes inflation."*[9]

Friedrich Hayek agreed that adjustments in the money supply are desirable, stating: *"Any change in the velocity of circulation would have to be compensated by a reciprocal change in the amount of money in circulation if money is to remain neutral toward prices."*[10] but he did not believe monetary elasticity could be formulated in practice.

Further, a system with inelastic money can still respond to economic shocks via credit (not credit money … credit!). However, it is more restricted in doing so.

If a full reserve system (with no maturity mismatching) has X amount in deposits, then theoretically X amount of credit can be allocated to alternative purposes. If only 50% of X has been allocated as credit and there is an economic shock, then more credit can be allocated to the relevant sectors to allow economic actors to weather the shock. However, if 100% of X has been extended, then no more credit could be extended through the banking system to mitigate the economic shock. Of course, credit could be extended outside of the banking system, but this would require individuals to pull their money out of the banking system. Those withdrawing would have to wait until their time deposit account is available for withdrawal, and this would reduce the reserves in the banking system. However, if credit is being extended outside the banking system, there isn't a reserve amount that would exist, and thus the limits that exist upon the full reserve banking system would not restrict credit issuance external to it. Thus a full reserve system is much less efficient for credit extension beyond amounts held within the banking system.

A banking system with fiduciary media is less limited and responsive to credit demands via the issuance of credit money and is thus more malleable. Any bank can issue more fiduciary media, although it in turn risks future insolvency by doing so. Thus, full reserve systems can still allocate credit during economic shocks, but a free banking system is much more efficient because the terms of credit are standardized and liquid. This is analogous to the liquidity of a secondary market for trading public shares vs. conducting an IPO or private placement. While

the elasticity of a given money supply has some desirable properties, as well as undesirable consequences, it is not a necessity.

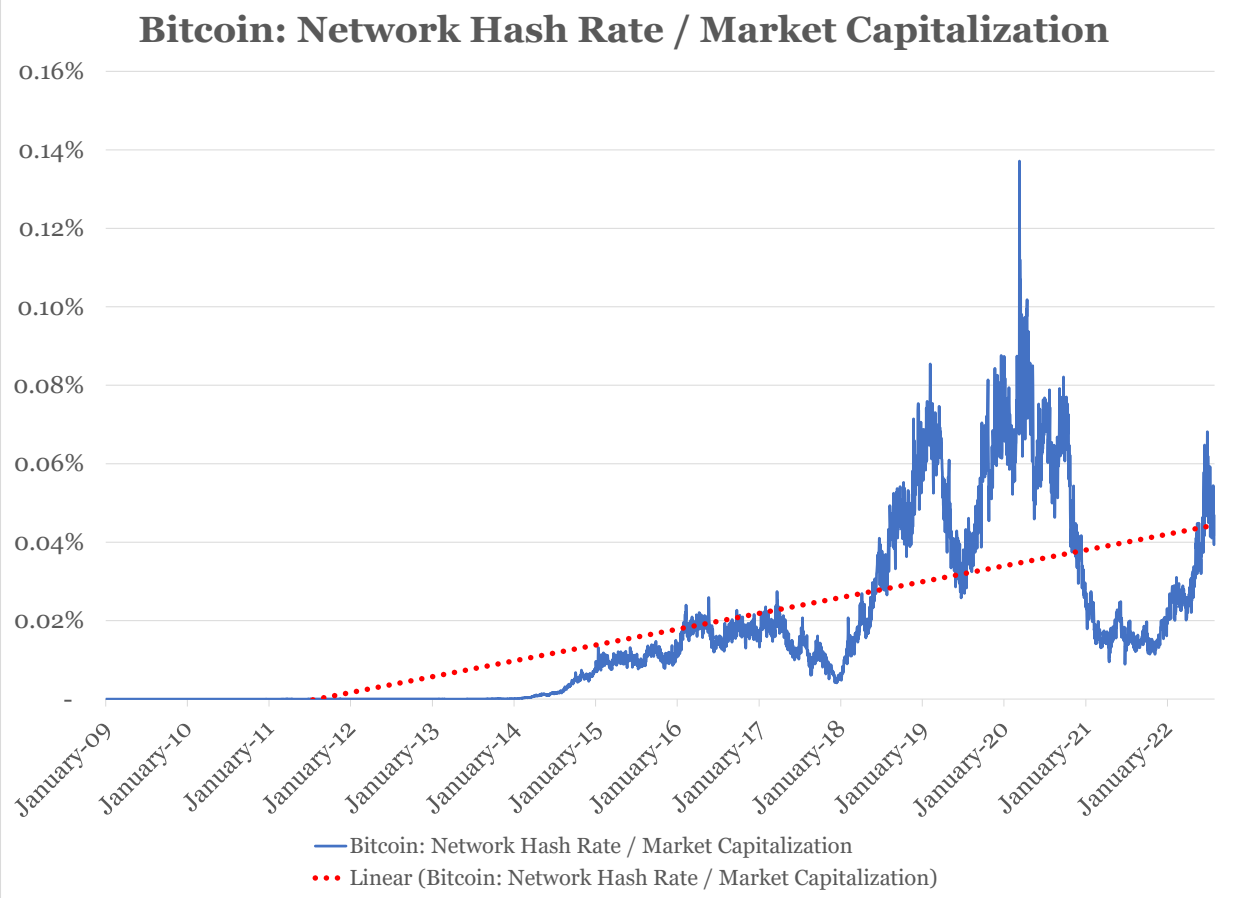
As a final point, fiat central banking takes the credit expansion beyond a natural market rate and persistently exacerbates its negative consequences until it is no longer sustainable. Free banking is bound to market incentives and places natural limits to credit extension. Free banking isn't perfect and creates credit fluctuations as well as malinvestment. However, the consequences of free banking fractional reserve are fundamentally distinct from the persistent credit expansion of fiat central bank fractional reserve.

THEORETICAL IMPLICATIONS OF FULL RESERVE VS. FRACTIONAL BANKING

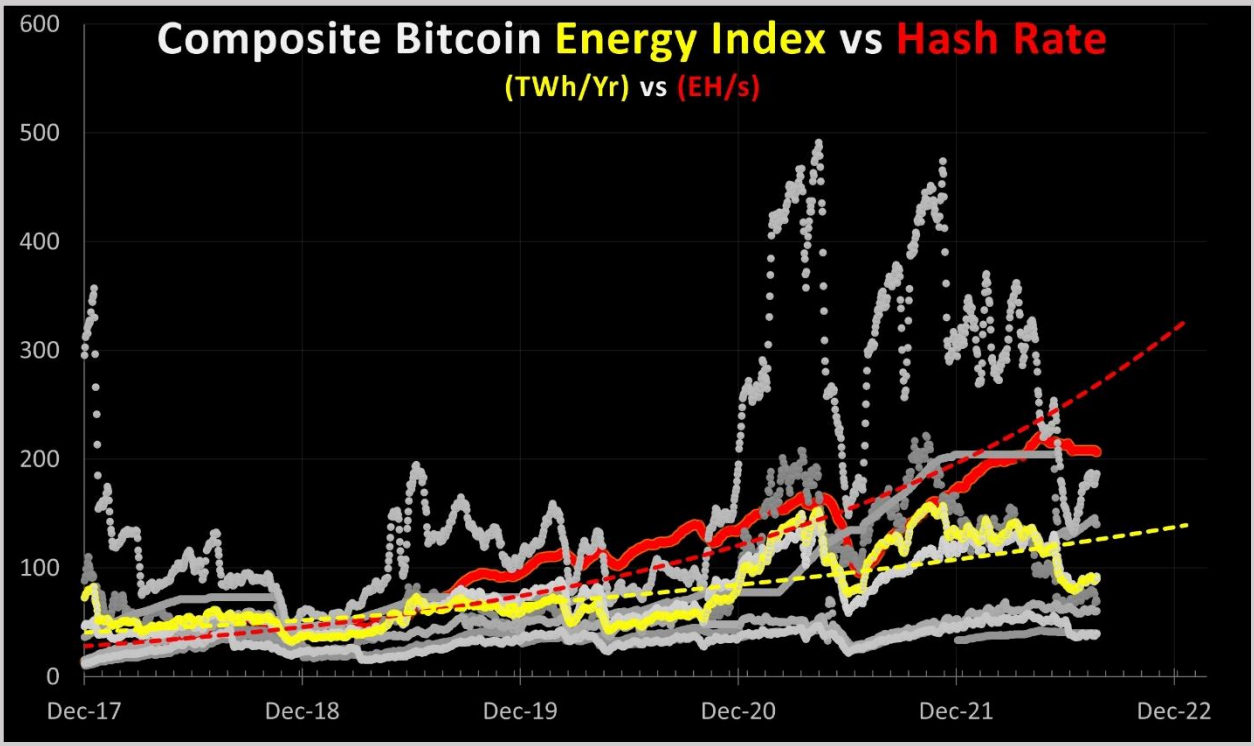
Costs of Monetary Production

One of the primary criticisms of a full reserve gold standard by economists is the opportunity cost of economic resources necessary to produce and store gold. A popular estimate by Milton Friedman during the 1960s estimated that the cost of a 100 percent full reserve gold standard would equate to approximately 2.5 percent of net national product.[11] That is a substantial quantity of resources, and I expect history to repeat itself. We are already witnessing this criticism in relation to the "environmental costs" of bitcoin.

The costs of mining – capital, labor, and ongoing energy costs – will likely be multiples greater at maturity than today. We want mining bitcoin to be expensive because securing the decentralized monetary substrate of the global financial economy upon which all other resource allocation depends is worth it. However, how high will these costs become? If bitcoin is the only form of money in the world, then the security levels to support it would potentially be proportional to this demand for it. Currently, this proportion appears to be increasing:



However, it's the effective costs of producing this hash rate that matter, which have been decreasing in proportion to hash rate over time as mining infrastructure becomes more efficient.



Source: Tyler Bain

This trend can be expected to continue but it doesn't capture labor and capital associated with the infrastructure, which are a large component of total costs. One estimate of the cost to 51% attack bitcoin is ~$35B in hardware (at the cheapest rate) and ~$25M per day in energy. You would have to expend energy from mining for ~1,400 days to spend as much on energy as you did on hardware up front. This is a simple back of the envelope way of considering the issue and more research needs to be done estimating the total economic costs associated with mining. If Bitcoin's price increases 100x, how much will hash rate increase and how much will the total economic cost of producing that hash rate be? Whether or not the reader cares particularly, this will be a key area of criticism from the economic community and needs to be understood.

What matters is that the network is secure. In a perfect world we would want to expend resources on ensuring 100% probability of security, and nothing more. The practical challenges to effectively execute a 51% attack on the network makes the probability of success at Bitcoin's current level of security very low. If the price of bitcoin increases only 10x over the next 10 years, how much will the cost of mining increase? If it's only 5x, would that be securing the network beyond what is necessary to protect against a 51% attack?

I don't know the answer to these questions, and I don't think it is possible to know, even in principle. There is a potential tragedy of the commons down the line because the market

incentives of individuals are not directly related to the social consequences of mining. Individuals are bidding on block space, not security, and these may or may not align. It's very possible that market incentives will push the mining hash rate to grow beyond the amount necessary for complete security, and thus utilize inefficiently economic resources that could have been utilized for alternative productive purposes. There will be some optimal level of the security budget required in a hyperbitcoinized world, and it's possible we aren't far from it today.

Circulating fiduciary media would reduce the demand for bitcoin and thus less economic resources would be committed toward mining it. Bitcoin's price would be less, mining would be less attractive, and fewer resources would be spent on mining. Bitcoin is different from gold in that more resources spent on mining do not create any more of it in the aggregate. I believe this will be a major argument for the introduction of alternative forms of monetary media within the system – such as CBDCs. The existence of fiduciary media from free banking would be an argument against the political purveyors of the CBDC narrative. As the politically captured media organizations cry "Bitcoin is too expensive, we need CBDCs," it would be better to have a free-market alternative that exists with the same economic benefit purported for CBDCs.

Thus, a theoretical benefit of a free banking system is that it could free up resources utilized to secure bitcoin beyond its optimal level for alternative economic productivity. It also would provide a strong argument against the CBDC narratives that will inevitably exist. Selgin states that *"would-be investments in commodity money … are translated into increased loanable funds. This is the principal economic advantage of fractional-reserve banking."*[12]

Business Cycles

For reasons discussed earlier regarding the benefits of an elastic money supply, a banking system that issues fiduciary media can respond to economic shocks more efficiently than a full reserve credit system. A full reserve credit system is still able to respond to economic shocks, but it is more limited in doing so. Although the relatively lower constraints of monetary elasticity is an advantage of free banking, an important question to ask is will this ultimately create the volatility in credit which itself causes business cycles?

In theory, free banking should maintain greater short-term price stability than a full reserve system. Free banking market incentives limit the creation of credit money, but historically fractional reserve systems have largely been associated with persistent credit expansions and subsequent contractions. The large fluctuations we are historically familiar with have been primarily driven by centralized intervention in the market system (e.g., government insurance, regulatory limitations, central banking, etc.). The free banking system theory is fundamentally different from these, as it is market-based and without centralized control. However, there are two primary issues with free banking, as theorized by Selgin:

1) Monetary disequilibrium caused by commodity-money supply shocks
2) Disturbances caused by bank runs and panics

Commodity-money supply shocks would not be an issue with bitcoin because its supply is known in advance and algorithmic. Further, it is a pure monetary good and is not subject to changes in demand for any market-based purposes, as is gold (e.g., demand for gold in electronics or as jewelry declines rapidly). This is a key innovation of bitcoin as money.

Disturbances caused by bank runs and panics is the primary concern of free banking and primary rationale for a full reserve standard. Bank runs and panics occur due to a lack of confidence in the banks themselves. Historically, war, recession, or the failure of large businesses were warning signs of a loss in public confidence. However, just as in any market, if banks are allowed to fail then the solvent ones will acquire them, or their shareholders will ultimately pay for losses and deposits should be well insulated from losses.

For example, the Scottish free banking system, which existed from 1716 to 1845, had only 19 banks suffer insolvency and the ultimate cost to depositors during this period was only £32,000.[13] However, there was a 20-year period (beginning in 1797) during which suspension of withdrawals occurred, driven by the Napoleonic wars, a time when countries were beginning to effectively abandon the gold standard. Reserve levels dropped materially among Scottish banks during this period (as stated earlier) and were not immune to geopolitical shocks. This system wasn't perfect and couldn't respond to everything – as is true of all market systems. If the world was operating on a neutral monetary standard like bitcoin, war would likely be reduced materially. Further, private insurance markets could emerge to protect depositors.

There is also the risk of not just a bank run, but a widespread panic caused by contagion. Panics are primarily driven, in theory, because liability holders lack bank-specific information regarding bank reserves in proportion to bank liabilities. Failure of individual banks never precipitated panics in the Scottish system or in Canada during its free banking period.[14] On a bitcoin standard, trust in a free banking system would likely be greater from information transparency due to innovations such as proof-of-reserves (to be discussed later). This innovation would also provide methods for private insurance providers to conduct proper risk assessments and provide depository insurance without public interference.

There exists a risk of business cycles occurring due to monetary phenomenon under a free banking system. The question is: are risks of free banking business cycles worth the benefits gained from a more elastic money supply?

Price Stability and Signals

Bitcoin has an asymptotic supply curve and because of this, the supply of bitcoin itself will be disinflationary. However, the purchasing power of bitcoin will likely be deflationary at maturity if economic productivity outpaces the rate of change in bitcoin's supply. As technology continues to increase productivity, the prices of goods and services the most subject to innovation will naturally decline. But will prices be stable in the short-term? Not exactly.

Bitcoin is a perfectly inelastic money and under a 100 percent reserve system, we're assuming no other material form of money exists other than bitcoin. Any supply and demand shocks will always be reflected in prices which could cause short-term economic fluctuations that are resolved by an adjustment in prices over the long term.

However, the overall price level should be stable and/or deflationary in the long term on a full reserve standard. Credit markets will still be responsive to short-term economic shocks but are relatively more limited by an inelastic money supply. Contrast this to an elastic monetary system whereby supply and demand shocks are not always reflected in prices as the supply of money (via fiduciary media) will adjust in response. While elastic money might make prices more stable in the short term (e.g., fiduciary media is issued to smooth the imbalances that occur from price

fluctuations), it has historically led to overall rises in the price level. Pointedly, elastic credit money throughout history has led to economic dislocations resulting from persistently high inflation caused by moral hazard inherent to the centralized control over these credit systems.

A free banking system could potentially create greater short-term stability in prices relative to a full reserve system. Remember that a free banking system would cause a general rise in prices as credit expands during its emergence, but will eventually find a stable price level via free market incentives. Historical examples of free banking systems such as Scotland, Canada, and others support this notion. Once this market price level is found, price stability is the general outcome.

However, this stability in prices distorts the reality of prices. This is a primary argument from the Austrian school against unbacked credit. If prices are not reflective of economic reality, entrepreneurs will not be able to respond effectively to market behavior, and thus malinvestment would occur. The other side of this argument is that there are short-term market shocks that without credit systems would be reflected in prices and cause entrepreneurs to make long-term decisions based on merely short-term changes which would otherwise resolve themselves with an elastic money supply. Thus, the belief that market prices will always provide the proper price signals to entrepreneurs isn't such a black and white argument. These arguments are theoretical in nature, and both have merit.

Investment

The primary risk of elastic credit money would be its effect on capital allocation by impacting price signals. The negative outcome is malinvestment. A full reserve system would mitigate the risk of malinvestment greatly in comparison to free banking. As credit would be constrained to the full amounts of bitcoin held in savings, capital allocators would be challenged to invest only in projects that they expect to have the greatest expected return on capital.

A free banking system would be less constrained in the issuance of credit via fiduciary media and would increase the supply of credit available relative to a full reserve system. While this increased investment would drive greater economic growth overall, it would also risk greater malinvestment, which increases the likelihood of more severe business cycles.

Consider the fiat central banking systems of today. Such systems structurally incentivize the providing of unsustainable amounts of credit which accumulates malinvestment over time. Eventually the music stops, and economies are sitting on a swath of malinvestment and must restructure their capital allocation toward relatively more productive enterprise in order for economic growth to resume. It is clear that central banking with fractional reserve lending creates moral hazard that directly incentivizes extending bad credit.

Malinvestment is bad because it causes business cycles. The question is: Is there such a thing as under-investment and, if so, what is it? This theoretical concept is challenging to qualify, but we can acknowledge its likely existence. Will a full reserve system ultimately neglect investment in projects that would benefit the world had credit been more expansive?

If a free banking system can expand credit through the issuance of fiduciary media, more capital projects would be funded at the risk of greater malinvestment. However, the potential for more rapid economic growth through greater credit extension has benefits that should not be thrown out the window because of the moral hazard inherent to fractional reserve central bank systems.

The question for free banking is: will the incremental malinvestment from free banking ultimately be worth it, due to the incremental gain in valuable enterprise?

Effectively, this is a question of what is the optimal level of time preference for a society. Neither extreme is good. One leads to only consuming and the other to only saving. There is somewhere in the middle that is optimal and rather than exert force on markets to regulate that time preference, I believe it is best to allow the market to decide. If market participants voluntarily agree to accept fiduciary media, so be it. If capital allocators choose to invest in more projects from the easier extension of credit, so be it.

Depositor Rates & Risk

In fractional reserve systems banks earn money by creating it – referred to as *seigniorage* – allowing them to create profits beyond just earning a spread between interest from their loans and amounts paid to depositors.

Consider if banks didn't loan at all. They would simply make money by charging a fee that covers their costs for storing depositor funds. Banks reasoned that lending is another avenue to earn profits, and by paying their depositors some of those profits through interest they can attract more depositors. Even so, these rates of interest paid to depositors could be too low, or potentially below their operating costs.

If banks issue their own money, maintaining a fractional reserve that they in turn lend to earn interest (i.e., seigniorage) they can earn even greater profits, allowing them to pay depositors a higher rate of interest. Put aside your beliefs about fractional reserve for the moment and consider this fact in isolation. The ability for banks to lend, and, more precisely, to lend beyond their reserves, increases the ability of depositors to share in the benefits of capital formation. This is one of the reasons fractional reserve systems have emerged throughout history and full reserve systems did not spread widely or sustain themselves for long. Of course, earning profits through seigniorage by fractional reserve institutions carries the increased risk of bank runs and panics. Further, it is crucial that banks not only allocate capital, but allocate it well. The relatively lower limitations on credit extension from the issuance of fiduciary media increase the risk of capital misallocation.

Ideally, depositors want a higher rate of interest and demand for it hinges on whether or not depositors perceive it to be worth the risk. If banks kept 99 percent reserves, I'm sure everyone would be fine. What if it was 90 percent? 80 percent? Ultimately the market determines this amount.

On the other hand, the digitally native banks to emerge in the future will have alternative avenues of earning depositors interest without assuming counterparty risk from lending, specifically through the lightning network. This makes a full reserve system more viable and fractional banks would have to compete with that. I will return to this point later, but for now understand that a full reserve system is more "expensive" to depositors than a fractional reserve system and this is one reason, along with others, that fractional reserve systems have emerged privately.

I believe the ideal outcome is that private markets are able to choose which type of system they want to participate in with full information transparency. Adam Smith would agree:

> *To restrain private people, it may be said, from receiving in payment the promissory notes of a banker, for any sum whether great or small, when they themselves are willing to receive them, or to restrain a banker from issuing such notes, when all his neighbours are willing to accept of them, is a manifest violation of that natural liberty which it is the proper business of law not to infringe, but to support.*[15]

Full reserve systems have always been legal, but free banking has been chosen by depositors in private markets. Adam Smith also acknowledges this idea:

> *By dividing the whole circulation into a greater number of parts, the failure of any one company, an accident which, in the course of things, must sometimes happen, becomes of less consequence to the public. This free competition, too, obliges all bankers to be more liberal in their dealings with their customers, lest their rivals should carry them away. In general, if any branch of trade, or any division of labour, be advantageous to the public, the freer and more general the competition, it will always be the more so.*[16]

In *The Wealth of Nations*, Adam Smith acknowledges that it was the freest banking systems which contributed to industrialization by incentivizing the employment of greater economic resources.

Wealth Inequality

Under a full reserve system, the Cantillon Effect does not apply. Because credit is not extended beyond the amount of money that exists, prices will not rise from monetary expansion in the long run and thus there won't be classes of individuals that benefit from or are hurt by the expansion of credit money.

A criticism of free banking is that credit extension will benefit those closest to the credit creation the most, while those more removed are hurt by rising prices. This is only true during the emergence of the free banking system as the price level rises, but isn't once the price level has found equilibrium at maturity. Of course, the rising price level isn't desirable as the system emerges, but a similar argument can be made for bitcoin as it emerges. The earliest adopters of bitcoin will benefit the most as it consumes the market of monetary media. This inequality will eventually even itself out as the system matures. In fact, this is a broader point of any emerging system whereby new rapidly, growing economies are subject to high wealth inequality in their "adolescence," but it tends to decline as they mature.

Thus, because the price level finds market equilibrium in free banking, there isn't persistent wealth inequality from persistent credit creation exacerbating the Cantillon effect. It is only in the emergence of the system that this is true, and it is true of all emerging economic systems.

Summary

In summary, when comparing a full reserve system to fractional reserve:

- **Costs of Monetary Production:** A full reserve system could incentivize the mining hash rate to grow beyond the amount necessary for complete security and thus utilize economic resources unnecessarily that could have been utilized for alternative productive purposes. The introduction of fiduciary media through free banking could allow the market of mining to find an equilibrium that reduces the security miners provide to the network to a more optimal level. This is highly theoretical and an area worthy of more research.
- **Business Cycles:** A full reserve system would only subject the economy to business cycles from shocks in supply and demand and not from monetary phenomena. The tradeoff is that this inelastic supply of money could allow economic shocks to cause short-term economic fluctuations, which could potentially be mitigated via a more elastic money supply. However, credit issuance under a full reserve system would still be responsive to economic shocks. A free banking system could create stability from economic shocks without persistent monetary inflation, as past experience has shown. The natural price equilibrium found will be more elastic and reduce short-term economic volatility.
- **Price Stability & Signals:** A full reserve system would maintain nearly perfect pricing signals for entrepreneurs, which has the consequence of short-term fluctuations in market behavior. Free banking would enable price stability at market equilibrium with the cost of distorting price signals for entrepreneurs. Neither system is perfect in this regard, and there are tradeoffs for each.
- **Investment:** A full reserve system would reduce malinvestment to as low as possible and only the most viable enterprises would be able to afford financing. A free banking system would potentially finance more business investment with the tradeoff of increased risk of malinvestment.
- **Depositor Rates & Risk:** A full reserve system may neglect the riskier lending opportunities of the economy and not be able to pass along these economic profits. However, their likelihood of solvency would be much higher. A free banking system would provide greater deposit rates through seigniorage, but maintains a higher risk of insolvency through increased risk of lending practices, bank runs, and panics. However, historical examples of free banking systems exhibited high stability due to the lack of government interference. That said, they are not immune to such risks.
- **Wealth Inequality:** A full reserve system wouldn't create wealth inequality from the Cantillon Effect. A free banking system would likely cause this during the emergence of the system as prices rise, but once a market-based price level is found it would likely be immaterial.

BITCOIN BANKING SYSTEMS IN PRACTICE

Thus far, we've seen that the debate between full reserve credit and free banking fractional reserve is theoretical in nature. Free banking has limited historical examples, some of which are more illustrative of the theory than others. The Scottish and Canadian systems are purported by Selgin to be the best examples of free banking. Many systems have been referred to as "free banking" but were restricted by regulators in many ways that distorted the market incentives and ultimately led to their failure. The brief US system from 1837-1863 is often cited as free banking, but was far from it – hindered by heavy regulation such as collateral restrictions (bond collateral laws) and geographical branching restrictions. However, none of the historical examples of free banking were perfectly in line with the theory.

What's more is that never in history has a full reserve system existed persistently and at scale. Banks have emerged that were relegated to act as pure depository institutions, but no widespread full reserve system was ever chosen by private markets. Even Ludwig Von Mises appeared to acknowledged that implementation of such a system would require a government prohibition on fractional reserve banking.

The fact is, whether you disagree with free banking based on its merits or for some ethical reason – it would be the first time in history if a full reserve system were to emerge at scale on bitcoin. As free banking systems were rare and full reserve systems non-existent, to consider either is an exception to history. But Bitcoin too is an exception to history.

Bitcoin and the innovations that have come with it make a full reserve system and a free banking system more likely to be chosen by markets than in physical world analogs throughout history. I believe that both systems are likely to exist, but there are considerable limitations native to a digital system that could prevent the issuance of fiduciary media from emerging. If the industry is capable of building enough decentralized infrastructure, I think it's possible to heavily reduce the amount of government overreach that has plagued financial history. Bitcoin's removal of moral hazard inherent in base money, and the ability to opt out of any financial system into a purely peer-to- peer economy sets the stage for private markets to drive what the future of the global financial system will look like.

The Lightning Network and Time Value

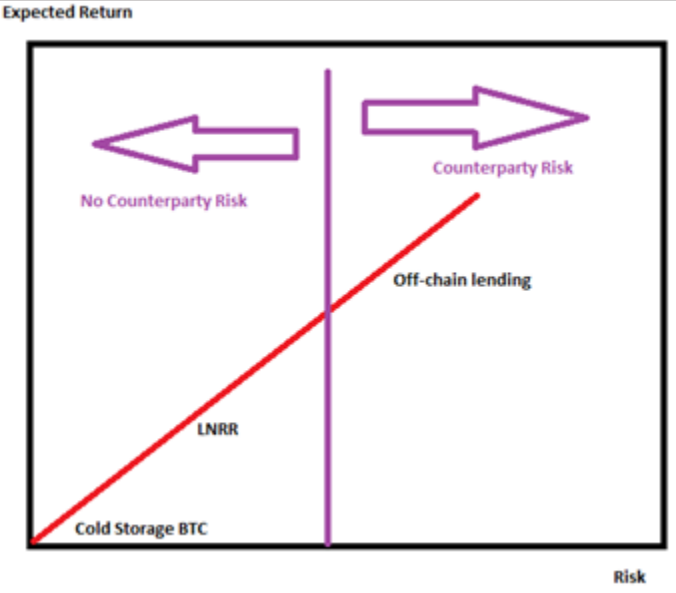
Hal Finney, as previously quoted, believed that bitcoin banks would be necessary as a scaling mechanism. While this is a strong possibility in the short-term, in the long-term the lightning network has created a plausible method for scaling bitcoin. This doesn't mean banks won't be necessary in the long run. What it does mean is that the nature of banks will likely be very different.

The lightning network (LN) is a secondary payment layer that optimizes around transaction efficiency for payments. Bitcoin owners can lock their bitcoin into a channel with a channel partner (i.e., another person agreeing to conduct transactions with you) and send payments back and forth with that person in a much more scalable way, not to exceed the amount of bitcoin you both have committed to the channel. Further, one can use the connections of their channels to forward payments to others that they don't have an active channel with, for a fee. These forwarded payments are routed by the various nodes of the LN until the payment reaches

its end destination. Each node forwarding the payment (i.e., routing the payment) receives a small fee for doing so.

One can lock their bitcoin into a payment channel and not only use that channel to conduct transactions with their channel partner, but also route payments of others and earn a fee for doing so. The more bitcoin you have locked in, the more payments you are capable of forwarding. The more channel partners you have, the more likely you are to forward payments that reach their end destination, and you receive your fee. Thus, individuals are compensated for integrating with the LN and providing liquidity to it.

By providing liquidity to the LN, you are effectively locking bitcoin up for a period of time and earning interest on it as compensation for the time spent locked up. Effectively, it is a form of fully collateralized lending to the LN with no counterparty risk, and can be conceptualized as a bitcoin native reference rate of interest. Nik Bhatia, USC professor and author of Layered Money, was the first to theorize that bitcoin cold storage ownership is the base "risk-free" rate (although there is still risk of loss from improper security just as with any other asset) and that routing fees are the lightning network Reference Rate (LNRR).



Nik Bhatia

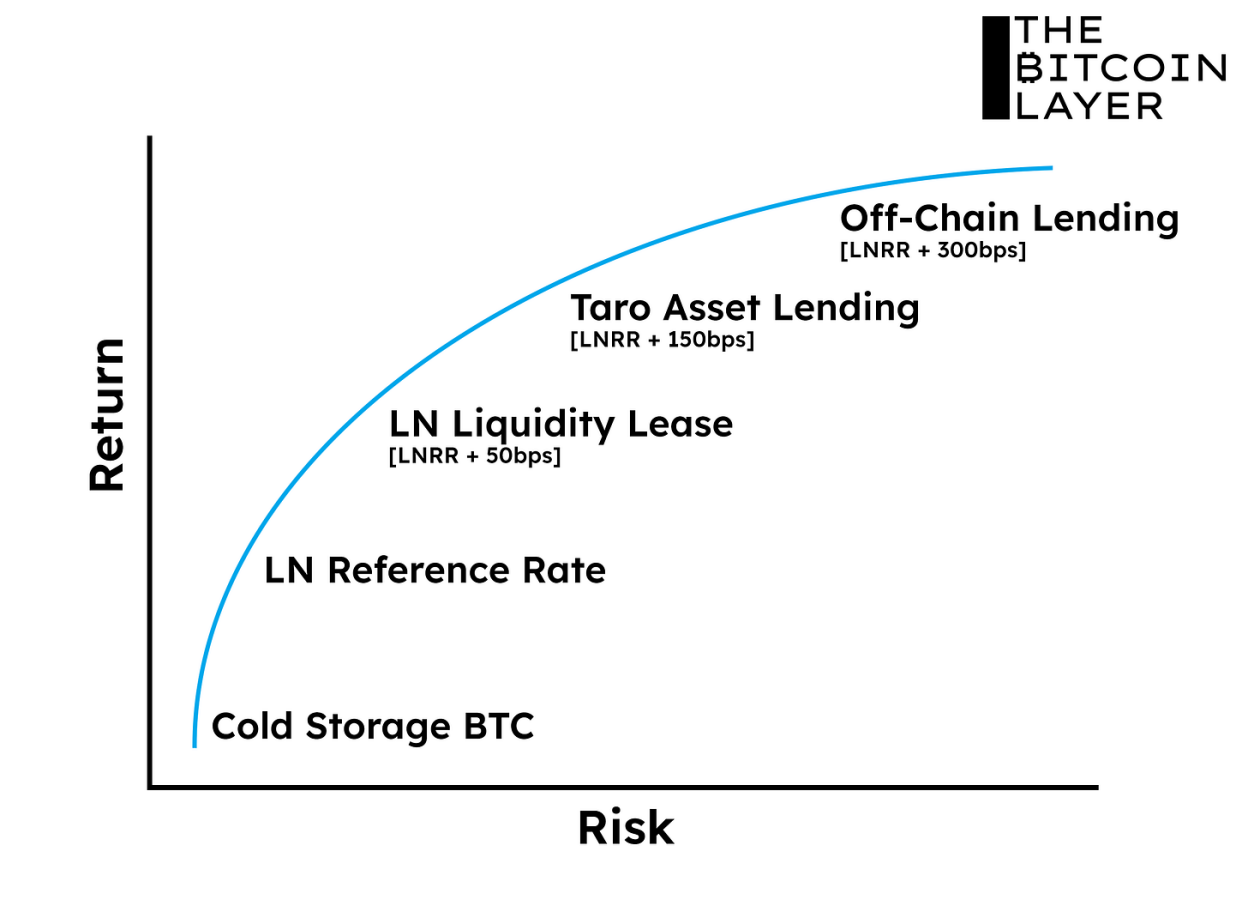
In traditional markets, reference rates such as Fed Funds, LIBOR, etc., are used in reference to other interest rates. For example, you take a loan for your business of LIBOR + credit spread, whereby the ultimate interest rate you pay is in reference to the LIBOR rate and is thus variable. This allows banks to be properly compensated for not only the credit risk (credit spread) they assume by lending to you, but also fluctuations in the market of credit (reference rates).

The LNRR is effectively compensating individuals for their opportunity cost of capital, or time value, as the capital is locked up for a chosen period (e.g., a week) and could otherwise have been spent or invested in other assets. It also is compensating individuals for security risk (e.g.,

by locking your bitcoin into the lightning network you must move it from cold storage to a hot wallet, which is a security risk). Thus, the LNRR is compensating individuals as such:

LNRR = time-value + security risk premium

Beyond the LNRR, greater interest can be earned by leasing liquidity. I won't get into all of the detail, but I encourage you to read the source of chart below by Nik Bhatia and Joe Consorti – it's a detailed explanation of how capital markets are poised to develop on the LN.



The Bitcoin Layer

At the bottom we have cold storage whereby individuals can maintain custody of bitcoin themselves. Perhaps they aren't technical enough to maintain self-custody of a material amount of their wealth in bitcoin, and want to utilize a LN bank with security expertise to custody their bitcoin. Further, they might be interested in earning the lowest-risk rate of return and ask the LN Bank to move their bitcoin from cold storage to a hot wallet that earns the LNRR. Further, banks could take their deposits and lease their channel liquidity to earn a rate of return on top of just routing fees by accepting greater risk through LN liquidity leasing.

Lightning Network Liquidity Leasing: To understand this, I will briefly explain an aspect of the LN. When you set up a LN node, you have a capacity limit whereby you and another party agree as to how much value will exist within the channel. The capacity limit of your channel is a key challenge of the LN and impacts how you optimize your node. Let's say you open a channel with 1M sats of capacity with your channel partner. You lock your 1M sats in and you now have 1M sats you can SPEND. Your channel partner now has 1M of sats that they can RECEIVE, as their side of the channel is empty. If you send 300k sats to them, you now have 700K sats you can still spend and you can also receive 300k sats – the difference between your capacity of 1M and the 700k sats you haven't spent. Because you cannot exceed your capacity limit you may want to optimize your node for a specific purpose. The amount you can spend is called outbound capacity and the amount you can receive is called inbound capacity. If your goal is to use your lightning node just to pay people, then you simply fund your node with the amount of sats you expect to spend within a given period. If your goal is to receive payments, it's trickier because now you need to find somebody that will commit an amount of capacity to a channel that allows you to receive payments. Merchants are a good example of this, as they will primarily be receiving sats to their LN node and will require a capacity that can support what they expect to receive. Thus, merchants need to find inbound liquidity and can go to a marketplace such as Lightning Pool or Magma to lease a channel that has the amount of capacity they desire. Thus, individuals sitting on bitcoins can lease their bitcoin to others (e.g., merchants) so that they can leverage that channel capacity to receive more payments than they make.

LN banks would be the perfect counterparty to LN merchants because the banks can lease their liquidity to the merchant for a fee beyond what they would receive by just simply routing payments. Liquidity leasing would be further up the risk spectrum as the banks must accept the risks such as reputation penalties, early or unplanned channel closure, and marketplace system failures. Because the LN Bank is ultimately selling its entire liquidity, there is a risk that the channel closes prematurely with the merchant. Thus, LN banks will compete based on their reputation to become trustworthy providers of inbound liquidity to those seeking it and earn a rate of return beyond routing fees for doing so.

A New Model for Full Reserve Banking

Notice that in traditional markets, the reference rates are created among short-term lending rates between banks. While they have a perceived low risk, they still maintain counterparty risk. Bhatia theorized that lightning has created a new reference rate ultimately removed from counterparty risk (see chart above). Further, banks of this nature would also be removed from the risk of maturity mismatching – described in the beginning of this writing.

This innovation is key, as I think it will fundamentally change the incentives of digitally native banks to pursue fractional reserve systems to the same degree banks have historically. With no counterparty or maturity mismatching risks associated, the opportunity cost of assuming these risks has been increased and thus the market for lending that assumes these risks would be less attractive. Individuals now have the option, which hasn't existed in traditional finance, to capture the benefits of supporting a payment network. This optionality will change the risk preferences of society toward the assumption of counterparty and maturity mismatching risks.

The LN is fundamentally a payment system that enables the base layer money (bitcoin) to scale for payments. Parties that enable this network of payments are compensated for doing so. The

enabling of individuals to capture the economic benefits of supporting a payment layer allows LN banks to pass along these economic benefits to depositors. This function does not exist in the traditional finance system, and thus a new model is formed whereby interest can be earned by supporting a payment network. Traditional banks or financial institutions provide interest for maturity mismatching and the assumption of counterparty risk. LN banks likely will not need to accept these risks and can provide interest to depositors by instead simply supporting a payment network. It is the fundamentally open nature of the LN that allows participants to capture the economic benefits of the payment infrastructure that was formerly captured by financial institutions. It's analogous to depositing in a bank that gives a right to the dividends of Visa, yet no exposure to the price of its stock.

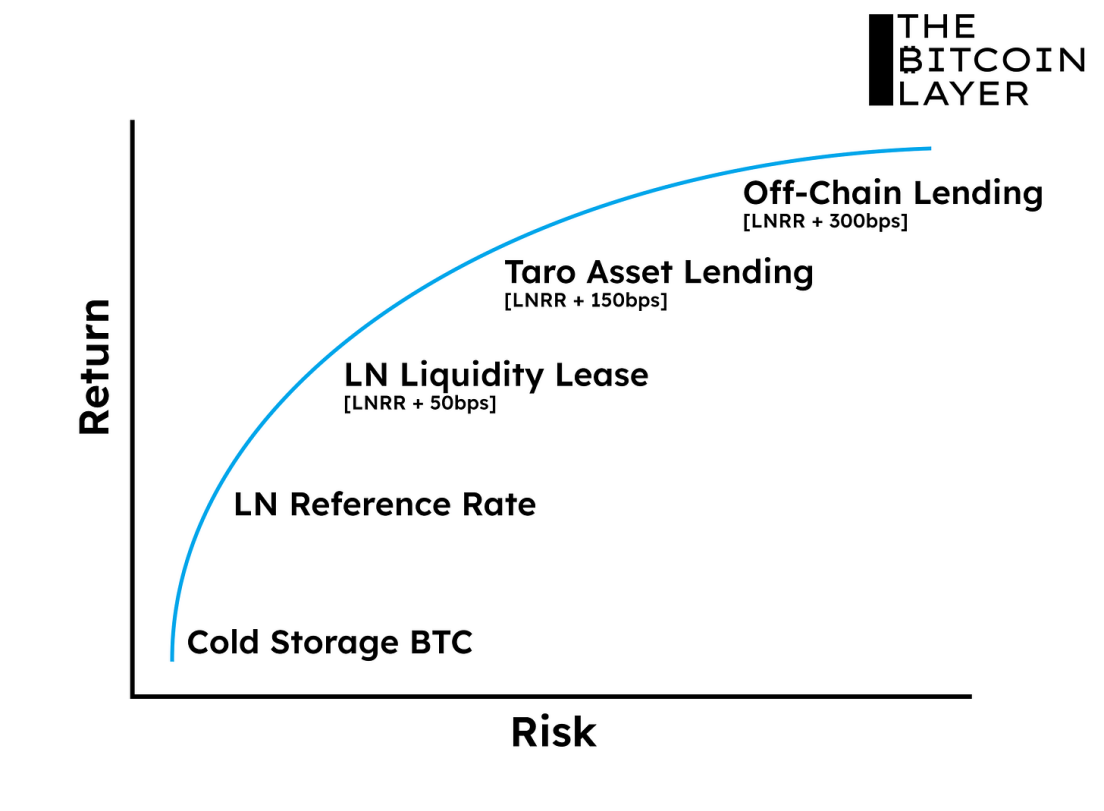
The first function of digitally native LN banks will be to provide liquidity to the LN. This will require specialized banks, as they will attempt to capture the highest amount of fees (interest) by optimizing their channel partner connections by operating LN node infrastructure. Depending on where the market rate of interest from fees ultimately ends up, there could simply exist full reserve banks that earn the LNRR + Liquidity Leasing and pass a portion of it to depositors after covering their expenses and taking a profit margin. Thus, a new model of full reserve banking could emerge with no counterparty or maturity-mismatching risk.

Recall that paper notes emerged in banking as a scaling mechanism for payments. Banks issued notes because notes were more portable than physical delivery of gold payments. Once these notes were accepted as money, banks were able to issue fiduciary media (unbacked notes) because people used the notes as money. Banks were rewarded by providing this scaling mechanism through seigniorage. With the LN, individuals can instead capture these rewards directly by supporting a payment scaling network.

Further, it was the emergence of bank notes that allowed fiduciary media to exist in the first place. If notes were never issued, banks wouldn't have had the ability to issue fiduciary media at all. The LN has innovated away the need for banks to issue notes and this could prevent a system of fiduciary media from ever emerging within the LN. To be discussed, I think there are other reasons why the emergence of fiduciary media within the LN is still possible.

A New Model of Free Banking

Banks and financial institutions that engage in maturity mismatching or assuming counterparty risk will have to compete with a lower-risk model. While this will likely reduce the amount of fractional reserve banks, it's unlikely that all banks would avoid these risks. Let's return to the previous chart.



The Bitcoin Layer

Further down the risk spectrum for LN banks is TARO asset lending. TARO is an emerging protocol by Lightning Labs that will enable the issuance of assets over the LN – not just bitcoin transactions. While there are many use cases for this protocol, I will focus on the possibility of bitcoin-backed assets from LN banks. Nodes could issue assets on-chain that could then be traded via the LN. A significant challenge to this will be if there is sufficient liquidity for these assets, as there will need to be some sort of onchain mechanism that distributes them to exchanges. If these limitations are ultimately overcome, banks would be enabled to issue their own notes.

Bank notes could be fully backed by bitcoin that conduct off-chain lending to earn a greater return for depositors. However, as LN banks garner trusted reputations they may be able to issue their own notes that are fractionally backed by bitcoin. The incremental interest LN banks would earn through lending their notes into the market would entice bitcoin holders to assume a greater risk of depositing with them for an increased rate of return on their bitcoin. If the history of the cryptocurrency industry is any testament to consumer preferences, such a system is likely to emerge.

While a need for the issuance of notes is not necessary because actual bitcoin can be used for payments at scale, the economic benefits derived from fiduciary media will still exist. Banks can pass along the benefits of seigniorage to their depositors, and this would likely create demand for fractional reserve banks by providing higher depository rates. The question is: how would

fractional reserve LN banks get borrowers to accept their fiduciary media instead of bitcoin directly? I think there are two primary reasons: economic benefits and privacy.

Economic Benefits: Just as the benefits of fiduciary media can be passed along to depositors, they can also be passed along to borrowers. Imagine borrowers applying for loans and credit at various banks. Some banks offer direct bitcoin while others offer their own notes with discounted terms. Many would-be borrowers would consider the discounted terms for notes if they knew others would accept these notes. While challenging, it's possible that networks for banks could bootstrap acceptance of their digital notes through incentive programs designed to garner their acceptance. Banks would likely not profit from seigniorage as they subsidize incentives that bootstrap acceptance of their notes, but once wide acceptance has been achieved the potential profits would be substantial. If greater economic wealth is possible from a system, then it's likely to emerge somehow. This will be a key test on whether free banking fractional reserve systems are worth their salt.

Privacy: Another factor that will drive the issuance of notes, and thus the potential for subsequent issuance of fiduciary media, is the need for privacy. Privacy is enabled by payments on the LN, but it isn't perfect. Another avenue for privacy that is already emerging are federated Chaumian mints. These are bank-like federations that allow users to deposit bitcoin and receive a token (i.e., bank note). These tokens utilize a cryptographic signature scheme, called blind signatures, that enables individuals to anonymously transfer their tokens. As these mints integrate with the LN, this could become a widely-used, privacy-enabling technology and will incentivize acceptance of these notes. Effectively, this system converts bitcoin into anonymous bearer assets, providing a strong incentive for individuals to trade these tokens and trust their value. While Chaumian mints may emerge as full reserve institutions, it is certainly possible that these mints provide a stepping-stone for the eventual issuance of fiduciary media.

The Limitations of Digitally Native Free Banking

While I see the emergence of fractional reserve systems as possible, their pervasiveness and degree of credit extension will likely be inhibited by competition with peer-to-peer systems and full reserve systems. Depositors will decide whether or not fractional reserve banks are worth the risk, and have strong alternatives if they decide they are not. This could materialize as fractional reserve banks existing as a minority group or maintaining materially greater reserve ratios than historical free banking systems. The enablement of a full reserve system will hinder the expansion of fractional reserve systems.

Another hindrance on the expansion of fractional reserves will be the digitally native nature of fiduciary media. Recall the historical occurrences of broker arbitrage and competitive bank note dueling in free banking systems. These practices were operationally intensive and challenging due to the limitations of the physical world. If notes and their corresponding reserve backing exists within a purely digital form, the operational challenges of arbitrage and note dueling would be reduced materially. These operational challenges would be reduced by increased information transparency, the relatively greater ease of digital transactions, and the potentially greater scale at which speculative attacks could be conducted.

Attacks on the fiduciary media could be conducted in a similar manner as note dueling, but much more efficiently and at greater scale. We can refer to these as ***redemption attacks*** –

whereby speculators accumulate a large proportion of an institution's digital notes and redeem them all at once to force the institution into insolvency. Redemption attackers could speculate on the liabilities of fractional reserve institutions in proportion to their bitcoin reserves. Such institutions will likely utilize a proof-of-reserves system whereby the assets (bitcoin) of the bank are digitally verifiable. The liabilities side will be more challenging to verify as it will require trust that the institution has not issued more liabilities than they claim to have. Liabilities will require trust, and economic actors will speculate on the fidelity of that trust.

The digitally native nature of banking institutions will subject them to efficient and scalable redemption attacks. Flash loans are a method of uncollateralized borrowing at a large scale and this technology would enable speculators to attack the reserves of fractional institutions at a large scale. For example, a redemption attack could observe the amount of bitcoin a fractional reserve bank owns, get a flash loan for that amount, purchase the fiduciary media of the bank in the same amount, and redeem it from the bank in bitcoin to pay back the flash loan. This would drain the reserves of the bank rapidly and the speculator could then use their own capital to further the call-in redemptions on the fractional bank until it reaches insolvency.

If a fractional system is able to survive redemption attacks, it will likely exist at a smaller scale with materially greater reserves. Just as banks maintained materially greater reserves during the note dueling era of Scottish free banking, the ease at which redemption attacks could be conducted on digitally native fractional banks would incentivize high reserve levels. Thus, if this limitation isn't fatal to fractional reserve banks, it would incentivize the emergence of relatively more competitive and sound institutions.

Despite the potential limitations, a fractional reserve system of LN banks competing with one another to attract bitcoin depositors could be precisely the technological innovation necessary for free banking to emerge in a material way. Recall that a well-functioning free banking system primarily requires (1) high competition, (2) minimal regulation, and (3) information transparency. Such a system will be poised to produce these attributes in a manner not yet seen in the history of banking:

1) High competition and minimal regulation will be incentivized by reduced barriers to exit of digitally native money. Don't like your LN bank? Operate peer-to-peer. If the regulatory environment becomes too burdensome? Operate peer-to-peer. The ease at which individuals could opt out of this system will enable high competition. Further, information transparency will encourage competition and lighter regulation.
2) Information transparency will be enabled by **Proof of Reserves** – a method by which banks can transparently advertise their outstanding liabilities and the amount of reserves that back them. Nic Carter has written that implementing a proof of reserve system is the single most important practice that will benefit the custodial industry. Proof of reserves is not a foolproof system. The assets are easy to verify with services such as hoseki, but the liabilities side will require auditors. Fractional reserve institutions will be transparently held to standards as speculators attempt to prove a lack of validity of institutional claims of reserve levels. Speculators will provide a valuable function toward ensuring reserve validity, but it will be important for a regulatory framework to emerge that reduces these risks and encourages transparency. Hopefully this comes from the bottom-up by setting industry standards – which I think is likely. The industry will be incentivized to self-regulate or risk the imposition of draconian top-down regulation. Further, increased transparency will enable much more sophisticated

risk pricing for private deposit insurance providers, ultimately protecting depositors from the insolvency of fractional institutions.

The beauty of the bitcoin and LN system is that individuals are enabled to conduct the bare minimum banking functions themselves, and this puts pressure on the banks to compete for clients that could otherwise operate in a self-sovereign peer-to-peer manner. Much of this system could function whereby individuals opt out of the digital banking system, self-custody their assets, and earn a rate of return on their assets by routing LN transactions and leasing liquidity. Some may simply hold bitcoin themselves without any want of interest on their capital, as its purchasing power will increase over time anyway. Further, individuals will likely demand actual bitcoin for their loans instead of digital notes backed by bitcoin, increasing the likelihood that full reserve systems emerge or even direct p2p lending. Free banks issuing fiduciary media will have to compete with self-sovereignty and full reserve banks to justify their credit extension via fractional reserves. Whether full reserve or free banking systems emerge at scale remain to be seen, but bitcoin and its subsequent innovations are postured to allow for a free-market banking system to emerge at scale.

A New Model of Interest Rate Risk

In our discussion of the risk curve, we focused on sources of returns in proportion to risk. We understand the potential sources of return for LN capital markets, but what are the potential sources of risk? An interest rate decomposition framework extrapolates the various sources of risk implied within a rate of interest. A full decomposition of interest rates in traditional markets can be expressed as follows:

Interest rate = real risk-free rate + expected inflation rate + maturity premium + liquidity premium + ***credit spread.***

A structure of LN financial markets will require a reframing of interest rate decomposition. New sources of risk inherent to a digitally native financial system require a distinct and more granular framing. The following is a proposal for this framework of consideration. It is by no means exhaustive and will require further development.

Interest rate = time value + self-custody security risk premium +3rd party custodial risk premium + fiduciary media premium + smart contract vulnerability risk premium - expected deflation rate + maturity premium + liquidity premium + credit spread

New risks inherent to a digitally native financial system require distinction for three primary reasons:

1) The ability to operate in a self-custodial peer-to-peer ecosystem
2) The ability to utilize bitcoin (base money) directly for payments as opposed to a contractual derivative
3) Property right enforcement via smart contracts

The table below describes each component:

Risk source components	Description
Time Value	The most basic risk by allocating capital towards one purpose you are compensated by the opportunity cost of capital allocation
Self-Custodial risk premium	There are a variety of sources that would impact this premium including: cold-storage security risks and hot wallet security risks.
3rd Party Custodial risk premium	The risk of custodying your assets with a third party. In the traditional system, 3rd party custody is a foregone conclusion but the ability to operate peer-to-peer with self-custody in the bitcoin system requires distinguishing this risk. This risk is beyond the security risks associated with self-custody and defined as the risks of trusting a 3rd party with control over your assets.
Fiduciary Media risk premium	The ability to operate directly with bitcoin in payments vs. some form of fiduciary media requires distinguishing this risk. For example, individuals receiving payments in fiduciary media would likely demand a premium for doing so as it is not bitcoin directly.
Smart Contract Vulnerability risk premium	The risks caused by smart contract vulnerabilities (e.g., errors in the code or unforeseen contract outcomes) will be another source of risk that demands a premium. Property rights of a digitally native system lack a supporting legal framework for recourse and much of the system will be enforced by smart contracts.
Expected Deflation Rate	While this could possibly be a rate of inflation, a bitcoin standard would likely be deflationary, and this would offset interest rates downward.
Maturity Premium	Same as the traditional system where a premium is paid for the time until contract maturity.
Liquidity Premium	Same as the traditional system where a premium is paid for the liquidity of asset.
Credit Spread	Same as the traditional system where a premium is paid for credit risk of the counterparty.

Each of these risks inherent to digitally native financial agreements will demand a premium or discount on the rate of interest offered. There are other risks inherent to digitally native asset ownership with its underlying blockchain. These are removed from consideration as they are presumed to be accepted by all participants of the system and largely mitigated upon the maturity of the system. Such risks include operational risks of the underlying blockchain and governance and regulatory risks.

Limitations of Lightning Network Banks

Let's come back down to earth. Bitcoin still must reach the scale of digitally native base money, or at least a scale where it is widely adopted as a medium of exchange and unit of account, for effective banking systems to emerge and mature. Many similar concepts exist in the cryptocurrency universe, but they're utilizing dollars and thus have linkages to the traditional banking system. This creates centralized points of risk that governments can and do control. For this system to emerge in a purely digital form, its base layer monetary asset needs to be purely digital. Bitcoin is best poised for this, but it is currently being primarily used as a store of value.

It will be some time before bitcoin matures to a medium of exchange and unit of account. However, for it to do so it requires the necessary infrastructure to conduct payments on a global scale. Thus, bitcoin's store of value function will be growing in tandem with its medium of exchange function to ultimately become a global unit of account. Once this occurs, we will have a global, neutral monetary reserve asset and currency upon which a digital banking system can emerge.

The LN has many limitations – for a detailed understanding check out this article by Lyn Alden. Its adoption has been slow. It has recently increased more rapidly but its scale is still very small. Much of this can be attributed to bitcoin's primary use as a store of value as opposed to a medium of exchange. This is a reason why bitcoin needs to mature for lightning adoption to further increase. Further, LN contributors aren't subsidizing adoption via incentive systems; it is growing organically in a responsible manner. One limitation to LN adoption is the ability to onboard self-custody users. Simply put, opening a lightning channel requires an on-chain transaction. If a billion people each wanted to open one channel tomorrow, and no other on-chain transactions were being conducted, it would take about three years to do this, as there is limited block space. There are emerging solutions to this problem such as Federated Chaumian Mints. The LN isn't perfect, but it is viable and appears to be a legitimate option for a digitally native financial system running atop a decentralized and neutral global currency.

Lastly, a key risk to digitally native banking systems will be encroachment of regulators. I'm not a legal expert. The success of these systems requires minimal regulations. Bitcoin is poised to reduce the level of regulatory encroachment by its peer-to-peer nature and global game theoretic incentives that enable its ability to maintain open markets. Ideally, the industry adopts transparent and open standards from the bottom up, but there are significant risks that exist from top-down regulation.

CONCLUSION

Full reserve and free banking theory is complex with numerous tradeoffs between the two systems. Whether or not you agree with either, their likelihood of emergence is probable. As long as the market is free to choose, I'm confident in the future of bitcoin's financial system. Its enabling technologies provide a ripe environment for an open, decentralized, free market banking system to emerge. Neither free banking nor full reserve will exist without flaws, as in all markets.

The nature of banking will likely be fundamentally different for digitally native service providers, providing ideal incentives for information transparency and consumer protection. With a digitally native financial system come novel technologies and models that haven't yet been fully explored in financial or economic theory. There are many limitations to bitcoin's adoption, LN expansion, and the regulatory environment to which these systems may be subject. Even when considering the potential limitations, I'm confident the permissionless nature of base layer money will ultimately encourage the expansion of an open and free financial system.

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