Six Solutions to the Money Supply Problem

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September 16, 2025

Abstract

In the money supply problem, the goal is to design a mechanism for controlling the money supply that results in the least distortion of transactions. This paper explores six solutions to this problem, including two novel proposals based on an auction mechanism.

1. The money supply problem

The price of goods and services is determined by their own supply and demand, as well as the *supply and demand for money*. As a result, the mechanism used to control the money supply can influence prices and change transactions. This paper investigates this phenomenon.

We use a theoretical framework based on a thought experiment to understand the effects of various money supply control mechanisms. In the thought experiment, the supply and demand for real goods and services remain unchanged, but the demand for money experiences a dramatic shock. We identify transactions with the following properties:

1. Regardless of the choice of mechanism, these transactions occur at the same rate both before the shock and in the final equilibrium after the shock.
2. For some period of time before the final equilibrium is achieved, these transactions are disrupted, meaning that they occur at a higher or lower rate.

If different mechanisms lead to different disruptions of this kind under identical conditions, the differences can be attributed to the choice of mechanism. A *distortion* refers to this kind of change to transactions. Throughout this paper, we use the following thought experiment:

Thought Experiment

The world consists of two large countries, A and B, separated by a vast ocean that severely restricts trade. The people of A use a currency controlled by the mechanism under evaluation, while the people of B use a different currency. A loss of confidence in B's currency leads its government to adopt the currency of A. This represents a sudden increase in the demand for the money used in A. The choice of the mechanism used in A can lead to distortions, and we evaluate the mechanism based on the magnitude of these distortions.

In this thought experiment, change to the trade between the two countries is a good example of a distortion. Because the ocean is a significant barrier to trade, there is negligible trade both before B adopts the currency of A, and in the final equilibrium after adoption. However, as we discuss in detail below, the choice of mechanism to control the money supply leads to prices that incentivize new trade for some period of time. This change to trade is an example of a distortion.

Having defined distortions, we can state the money supply problem:

Definition 1. *The* money supply problem *is the challenge of designing a mechanism to control the money supply that minimizes distortions.*

Any thought experiment that identifies distortions can be used in this framework. This particular thought experiment is used for two reasons: first, it is similar to well-known historical events. In the early 1920s, a widespread loss of confidence in the German Mark led to a sudden increase in the demand for foreign currency. Several countries have abandoned their failing currencies in favor of the U.S. Dollar, including Ecuador (2000), El Salvador (2001), Panama (1904), Timor-Leste (2000), and Zimbabwe (2009). China pegged the Yuan to the U.S. Dollar from the mid-1990s to 2005, which is a similar event, though there are differences. Secondly, in this thought experiment, the only significant change is a dramatic increase in the demand for money. There is no change to the other physical realities or economic needs of the two countries. This allows us to identify distortions.

1.1. Conclusions

The insights from this thought experiment extend beyond this specific scenario. The same distortions are likely to occur whenever there are significant changes to the supply or demand for money; when a technological innovation leads to an increase in the demand for investments, or when the demand for loans increases, or when more people adopt a currency, or when a government suddenly increases the supply of money.

Six approaches to the money supply problem are explored in this paper: four standard mechanisms are discussed in Section 2, and two novel alternatives are discussed in Section 3. As far as we know, all known mechanisms to control the money supply belong to one of these categories. The thought experiment suggests that current cryptocurrencies are associated with significant costs because of the way their supply is controlled. Because the supply of many of these currencies does not increase in response to increases in the demand for money, they lead to distortions when demand for the currency increases. Some cryptocurrencies do control their supply via pegs to fiat currencies. These currencies simply acquire the distortions of fiat currencies.

This paper does not identify a clear winner among the available mechanisms to control the money supply, because our methodology does not give a way to make comparisons between various kinds of distortions. At best, our framework allows us to reason about the time for which distortions may persist. It is an interesting open problem to find new ways to reason about mechanisms to control the money supply to quantify their advantages. It is also open to find reasonable solutions to the money supply problem that have significantly different properties from the six mechanisms studied in this paper.

1.2. Acknowledgments

I am grateful to Ariel Gabizon, Daniel Halperin, Mike Hearn, Kamal Jain, Travis Kriplean, Tovi Newman, and Darcy Rao for discussions that improved the presentation of this paper.

2. Four standard solutions

Let us begin by discussing the standard solutions to the money supply problem, starting with the most obvious approaches.

1. Fixed supply The simplest way to control the money supply is to keep it fixed. A fixed money supply, like Bitcoin's ultimate limit of 21 million coins, can cause distortions because the supply of money does not respond to the demand for money.

Consider our idealized world with two countries, A and B, separated by a vast ocean. There is almost no trade. The people of A use Bitcoin, which has reached its supply limit, while the people of B use a different currency. Due to a loss of confidence in the currency of B, the government of B adopts Bitcoin. This decision has significant economic consequences for both A and B.

Since the amount of Bitcoin in B is much less than in A, there is great pressure for Bitcoin to flow from A to B, and this flow is accompanied by changes to the economic activity in both countries. The imbalance in money supply means that Bitcoin-denominated prices for goods in B are significantly lower than those in A, creating a powerful incentive for new trade. New ships are built, and merchants buy goods in B and transport them across the ocean to sell them for a profit in A, creating a flow of Bitcoin from A to B. As the money supply gets rebalanced, prices fall in A and rise in B.

The largest flow of Bitcoin from A to B is likely to be created by the financial system, because this flow is not limited by the transfer of physical goods across the ocean. Anticipating the future trajectory of prices in B, speculators in A amass Bitcoin from investors and use it to acquire real estate and make investments in B. Banks from A that hold Bitcoin are incentivized to open offices in B and offer loans to businesses and individuals. These loans make sense because worthy borrowers in B can expect to acquire more Bitcoin in the future when the supply of Bitcoin in B is larger, and so repay their debt with interest.

This sudden allocation of large quantities of Bitcoin for loans in B means less Bitcoin is available for loans in A, causing interest rates in A to rise, and disrupting prices and economic activity in A. Less Bitcoin becomes available for car loans and mortgages in A, so the revenue of car companies in A suddenly declines, and home construction falters. Car manufacturers shut down some of their factories and lay off workers, and car and home prices drop. This shock spreads through the economy of A, eventually affecting all prices.

After enough time has passed, sufficient Bitcoin will be transferred from A to B for prices to reach a new equilibrium. One would expect that prices in A will settle at a level lower than they were before Bitcoin was adopted in B, while prices in B will settle at a level higher than they were initially. Car and home sales in A should return, and traffic across the ocean should reset to negligible levels. The unnecessary changes to transactions before the new equilibrium is achieved are a direct consequence of the fixed money supply. They are caused by the monetary system, not by the physical realities or economic needs of the two countries. We refer to the distortions in the transactions related to transportation across the ocean as *trade distortions*, and the distortions due to the loss of loans and rising interest rates in A as *liquidity distortions*.

This scenario is not an isolated or improbable event. With a fixed money supply, any increase in the demand for money in one sector of the economy can disrupt transactions in unrelated sectors. For instance, a new technological innovation may lead to new demand for business investment, but a fixed money supply creates a zero-sum constraint. Every Bitcoin allocated to investment immediately reduces the amount available for car loans and mortgages. New transactions in one sector

stifle activity in completely independent sectors until prices adjust to accommodate all transactions.

As an aside, note that a fixed supply also leads to steady deflation as the population grows and the demand for money increases. Historically, deflation has often sparked a vicious deflationary spiral: falling prices lead consumers to delay purchases in anticipation of even lower prices, further depressing prices and reducing transactions. However, it is not entirely clear if this spiral would occur in a world with a known fixed supply, where falling prices have been normalized, and it is not clear that this kind of deflation is a barrier for transactions in such an economy.

2. Gold From the perspective of the money supply problem, gold coins offer a key feature that Bitcoin lacks. Because more gold can be mined, the money supply increases in response to demand. This provides an escape valve for the pressure created by increases in the demand for money.

Let us discuss our thought experiment using gold coins. If country A uses gold coins and B adopts them, the supply in B will be smaller, and prices will be lower. This leads to the same initial effects as with a fixed supply, but they can be dampened by increased gold mining. Because of the increased demand for gold in B, the profitability of mining rises, leading to more gold being mined in both countries. So, the trade distortions and liquidity distortions discussed earlier do still occur, but they are likely to be of smaller magnitude.

Just as in the case of a fixed supply, banks may allocate fewer gold coins for car loans so they can fund loans to people in B. However, instead of shutting down some of their car factories, car companies that see a sudden drop in revenue from car sales may pivot some factories to manufacturing equipment for mining gold. This equipment is shipped to B, where it is more valuable. The resulting gold can be used to mitigate liquidity distortions. Thus, the supply of gold in B increases via a flow of gold from A, as well as via increased mining activity, until the supply of gold in B achieves parity with the supply available in A.

The production of gold struggles to keep pace with sudden changes in the demand for new money, as mining takes significant time and effort. For these reasons, the use of gold coins still leads to significant distortions for some period of time. However, all things being equal, one would expect faster convergence to new equilibrium prices as compared to a fixed money supply, because the market has the freedom to increase the money supply if doing so is profitable.

3. Currency backed by gold Instead of gold coins, governments in the last century have issued money in the form of notes that can be redeemed for gold. Notes are certainly easier to use than gold coins, and that is their obvious advantage. But notes also have a subtle advantage: they can be printed *before* the gold backing them is acquired. The money supply now has the additional freedom to expand before new gold is mined. In times when the demand for money increases, governments and banks can issue new notes expecting that the gold required to back the money can later be acquired from the economy via taxation or interest payments.

In our thought experiment, if country A is using notes backed by gold and B suddenly decides to adopt the same notes, banks from A can issue loans to people in B using newly printed notes, even before the new gold is mined. Banks can expect the loans to be repaid with interest because the increased demand for gold means that additional gold will be mined in the future to satisfy the new demand. This instant creation of money reduces both trade distortions and liquidity distortions. The flood gates can be opened to allow a massive flow of new money into B, and prices in A and B can converge to their new equilibrium at the speed of the printing press and the banking system.

Unfortunately, this system introduces new kinds of distortions. It is very difficult for banks to compute the correct number of new notes and make good decisions about who should acquire them.

If the banks play it safe and issue fewer than the correct number of notes, then we face the same distortions to the economies of A and B as with a fixed money supply. If the banks issue too many notes in the form of new loans, there are dramatic consequences. If loans default and the required gold is not acquired, the banks can no longer redeem all outstanding notes for gold, and we have the beginnings of a liquidity crisis. When people suspect that the banks do not have the gold to back the notes, there is a run on banks and hoarding of gold, which worsens the crisis. Such a crisis can only be resolved by a structured default: the notes are devalued to a lower quantity of gold, which leads to dramatic changes in economic activity and prices. So, the banks are forced to perform a delicate balancing act, with negative consequences at either extreme. In theory, well-meaning banks could perform the balancing perfectly and achieve minimal distortion.

This system's central problem is the *moral hazard* it creates: the costs of poor decisions are ultimately borne by others, not by the institutions that make them. When a few banks make bad decisions and face a liquidity crisis, other banks are incentivized to bail them out with loans to prevent a panic that could spread to the entire system. If these loans are insufficient, the government is forced to intervene and devalue the currency by defaulting on its gold backing. Therefore, there is a race towards risk; there is little incentive for individual banks to restrain themselves. We refer to the resulting distortions as *moral hazard distortions*. The historical record includes at least five major banking panics in the United States between 1880 and 1933, when currency backed by gold was used. Many countries were eventually forced to abandon the gold standard entirely, as the U.S. did in 1971.

4. Fiat money The fiat money system, adopted by the U.S. dollar since 1971, is the most widely used form of money today. Under fiat money, the government is allowed to print money when it is needed. Banks issue deposits (similar to the notes backed by gold discussed above) backed by reserve currency that can be printed by the government. The government promises to protect banks and their customers by printing this reserve currency when required. Liquidity crises can be ended by printing money or even just by promising that money will be printed in the future.

As with notes backed by gold, fiat money can be instantly generated to satisfy new demand for money. In the thought experiment, if country A is using a fiat money supply and country B suddenly adopts A's currency, then new money can be generated to satisfy the increased demand. With the approval of the government in A, banks from A can issue loans to people in B on a massive scale, without disrupting loans in A. In this way, liquidity distortions can be minimized, and the money supply in B can quickly reach parity with the money supply in A, quickly reducing trade distortions.

The fiat system amplifies the moral hazard described above because it completely eliminates the need to back currency with a physical resource like gold. With no need to acquire a physical asset, banks and governments face fewer negative consequences for issuing too much money. A misguided bank may look at the initial price differences between A and B and decide that companies that build ships to cross the ocean deserve significant long-term funding. This sudden allocation of newly created money leads to an explosion of activity building new ships that are ultimately destined to be salvaged for scrap metal when the two economies eventually reach equilibrium prices. Similarly, other banks may fund the unrestrained acquisition of real estate in B, fueling a bubble. No entity in the system has the incentives to block such spending. Although this system is good at preventing runs on the bank, it can lead to a misallocation of resources, and corresponding distortions.

Under the fiat system, knowing that the government can print the required money, the parties involved in expanding the money supply have little incentive to restrain themselves. During the 2008

financial crisis, banks irresponsibly issued mortgages for overpriced houses that fueled a housing bubble. None of the participants—bankers, real estate agents, buyers, or sellers—had incentives to refuse these loans because they were fueled by newly created money. When the bubble finally burst, the economy was left with a surplus of new houses.

The fiat system concentrates the power to create money in the hands of banks and government officials. The role of the market in creating money is reduced. The privileged few with access to the levers of the money printer are likely to make mistakes and are certain to make profits.

3. Solutions based on auctions

To minimize distortions, an ideal mechanism should respond to new demand for money quickly. At the same time, the mechanism should be subject to market forces, to avoid moral hazard distortions. I propose an auction-based mechanism with these features. A similar auction was first explored in [1]. The motivation there was to develop a form of money that is elastic, but not governed by a central body. In [2], I discussed how banks and central banks can incorporate another variant of the same mechanism to create a novel decentralized currency for international trade. This gives a currency that can be jointly controlled by multiple countries without requiring a consensus on how the money supply should change. In this paper, I explain how similar auctions lead to two solutions for the money supply problem. These auctions can be conducted by a government to control the money supply, or they can be carried out on the blockchain of a cryptocurrency to incorporate the mechanism into the cryptocurrency.

Bond auction mechanism An auction is used to decide how much new money is generated daily, and who receives it. Users place bids to buy a financial instrument that represents a claim on newly created money. Each such claim costs \$1, and returns $\$(1+r)$ at the end of the day, where $\$r$ is newly created money. The users make bids specifying the value of r that they are willing to accept to lock up their \$1 for the day, and the claims are given to the users that bid the smallest values of r. The users would like to obtain the most money each day, but not all bids are accepted, so users run the risk of getting no newly created money if they bid with high values of r.

Now, let us give a rigorous description of the rules of the auction. The mechanism uses a financial instrument called $\mathsf{Bond}(r)$. This object always costs \$1, expires 1 day after it is created, and returns $\$(1+r)$ to the holder upon expiration. New bonds are allocated according to the following rule:

Bond Rule

If the total money supply is $\$T$, then $T/2$ bonds, each costing \$1, are issued daily. Users participate by submitting (possibly multiple) bids of the form:

$$\text{user U bids for } \mathsf{Bond}(r)$$

indicating that user U is willing to buy $\mathsf{Bond}(r)$ for \$1, with the yield r chosen by the user. The $T/2$ lowest yield bids win the daily auction.

The daily rate at which the money supply grows is determined by the yields of the winning bids in the auction. It is the $T/2$ users that are willing to accept the lowest yields that obtain the newly created money. The choice of the constant 2 is arbitrary, any fixed constant between 0 and 1 can be used. Because r can be arbitrarily large, all $T/2$ bonds will sell. We note that a practical implementation of the auction need not involve daily bidding by users. Users can instruct their banks to automatically submit standing orders specifying their desired allocation towards the bids. Banks can aggregate this information for the central bank, which can execute the auctions and distribute newly created money to the winning bidders' accounts.

There are two ways that the bond auction mechanism can be used to control the money supply. The first is that the money generated by the mechanism can be used directly. This corresponds to a synthetic version of gold coins, where new coins are synthetically mined according to the rules of the bond auction given above. Alternatively, banks can issue notes backed by the money generated in the bond auctions. This corresponds to currency backed by gold. Let us discuss each of these arrangements.

5. Bond money The bond yields in the auctions represent the market interest rate for a risk-free loan, and these interest rates determine the rate at which new money is created. The issued bonds will certainly sell, because users can place bids with arbitrarily large r. The risk-free interest rate is higher when money is more valuable now than in the future. Thus, the creation of money accelerates exactly when there is an increase in the demand for money in the present.

Let us work through our thought experiment using this new mechanism. Imagine that country A is using dollars generated by the bond auctions when country B abandons its own currency and adopts the currency of A. As before, the immediate effect is that prices in B will be much lower than in A, and money will begin to flow from A to B using a variety of channels. The bids in the bond rule immediately begin to react to the increased demand for money.

When banks from A begin to make loans in B, they face a choice. Each dollar can be allocated to a loan in A, a loan in B, or a bond generated by the bond rule. As demand for loans in B rises, interest rates for loans in A rise, and yields in the bond rule also rise. This rise in bond yields corresponds to the immediate creation of new money that is delivered to holders of bonds. The sudden allocation of money for loans to people in B certainly reduces the money allocated for loans in A, but the effects are mitigated by the newly generated money. Savers obtain these higher yields, which can be routed to borrowers in A and B by the market. Therefore, the increased demand for money leads to the creation of new money to satisfy that demand.

Unlike with gold coins, the rate at which money is created is unlimited and entirely determined by the market. Anticipating the future trajectory of prices, speculators amass money to acquire assets and make investments in B. This activity can be funded by large quantities of new money generated by the bonds. Speculators sell investment funds to holders of money in A and use the money raised to fund their activities in B. As some savers are drawn to these investments, the savers that continue to bid in the auctions of the bond rule can expect to obtain larger yields, which can be invested in B soon after.

There are no physical limits on the rate at which money is created by the bond rule, and the rate is controlled by the market, so the system finds new equilibrium prices at the speed of market forces. We should expect this to happen much faster than the system based on gold coins, leading to fewer trade and liquidity distortions than gold coins. At the same time, there are no moral hazard distortions.

6. Currency backed by bond money While the bond auctions generate new money via market forces, there may still be some lag before the market makes the correct allocations. History has shown that if the lag is significant, banks are likely to begin issuing notes that can be redeemed for bond money to close the lag. Just as with notes backed by gold, such notes can be issued *before* the bond money that backs them is generated.

In our thought experiment, if country A uses currency backed by bond money and B abandons its own currency to adopt A's currency, the situation is similar to the use of currency backed by gold. Banks can issue the money required in B instantly, but they run the risk of a liquidity crisis if they issue too much money. In [2], I addressed how central banks can plan for this situation by amassing enough bond money to play a significant role in the bond auction and so force large bond yields in times of crisis. The money so obtained can be routed to banks in the event of a liquidity crisis. The bond auctions given in [2] are a little more complicated than the auctions defined here to accommodate this application.

Unlike with the use of fiat currency, no particular group controls the printing press of bond money. In particular, speculators that anticipate a liquidity crisis can hold onto their bond money and profit from the large yields that emerge when the liquidity crisis is resolved by the central bank. Thus, bad investments made by banks are a source of profit for those that anticipate their failure. Unlike with the use of fiat money, institutions involved in such bad decisions will see a relative loss of their holdings of money, because all holders of money can always keep pace with the growth of the money supply simply by participating in the auctions for bonds.

So, currency backed by bond money can generate new money at the same rate as a fiat system, but unlike with the fiat system, banks and governments that make bad decisions using the money do face consequences in the market. So, the moral hazard distortions are similar to those obtained for currency backed by gold. Unlike with gold-backed currency, the money supply does have the ability to grow at any rate. This may reduce the occurrence of liquidity crises, but we do not have the ability to make such comparisons within the current framework.

4. Other money

Sections 2 and 3 contain all ways to control the money supply that are known to me. Currencies sometimes switch between mechanisms. For example, the U.S. dollar has been backed by gold in the past, and is now a fiat currency.

Although Bitcoin currently generates new coins through mining, the money supply of Bitcoin is unaffected by the demand for money, so from the perspective of the money supply problem, it has a fixed supply. Ethereum currently regulates the money supply by decreasing supply in response to increases in transactions, so the supply does respond (mildly) to the demand for money, but in the wrong direction. Therefore, it also generates the same distortions as a fixed supply mechanism. If Bitcoin were to abandon the hard cap and issue coins to miners proportionally to electricity consumed, it would become similar to gold coins from the perspective of the money supply problem.

Stablecoins pegged to the dollar, while ostensibly distinct from the dollar, are the same as fiat currencies from the perspective of the money supply problem. That is because newly created dollars can be converted to stablecoins through the peg. Cryptocurrencies like DAI, which maintain pegs to other instruments, inherit the properties of the mechanisms used to control the supply of those instruments.

References

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