Lessons for Cryptocurrencies from Foreign Exchange Markets

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This essay brings insights from the academic literature on foreign exchange rate determination to the analysis of cryptocurrency markets. We present a simple framework to summarize the factors that determine exchange rates. To the extent that cryptocurrencies are like national currencies issued by central banks, their pricing can be analyzed using these models of exchange rates

As a preliminary, it is helpful to recall the traditional delineation of the three roles of *money*: it is a medium of exchange, a store of value, and a unit of account. The medium of exchange function refers to the usefulness of money for making transactions. Rather than the cumbersome search and matching problem that would arise if trade were by barter, money eases the process by allowing people to sell their goods and services for money, and to buy goods and services from other agents using money. Money is also an asset, which makes it a store of value. Often money earns very little or no pecuniary return. Forms of money include, for example, currency, demand deposits, and other checkable deposits. All of these pay a lower return than, for instance, short-term paper, but that difference reflects the implicit return to money arising from its utility in performing transactions. Finally, prices of goods and services are quoted in terms of money. Indeed, the convenience of money is connected to the stability of prices. When the prices quoted in terms of money are stable and predictable, people are more willing to hold money for transactions even though money provides little or no direct pecuniary return.

Currency is one form of money and has somewhat different properties than other forms of money such as checking deposits. For transactions that involve small amounts, it is very convenient, but is quite cumbersome relative to other types of money for larger transactions. An important property is that transactions using currency are nearly completely anonymous. It is impossible to trace the buyer or seller of a product or service when the business is conducted with cash.

Money, in turn, is one form of *liquid assets.* Nickolas (2018) defines liquid assets as: “cash on hand or an asset that can be readily converted to cash. An asset that can readily be converted into cash is similar to cash itself because the asset can be sold with little impact on its value.” There is a close relationship between liquidity and safety, when safety is defined as in Gorton (2017): “A safe asset is an asset that is (almost always) valued at face value without expensive and prolonged analysis. By design, there is no benefit to producing (private) information about its value, and this is common knowledge." From these definitions, we can conclude that safe assets are liquid, and liquid assets are safe.

Section 1 presents a framework for foreign exchange rate determination. The next section considers the similarities and differences of cryptocurrencies and national currencies, and applies lessons from the model of foreign exchange rates to the pricing of these digital currencies. The third and concluding section discusses implications for policy.

1. Basics of Foreign Exchange Rate Determination

A foreign exchange rate is the price of one money in terms of another – the price of euros in units of U.S. dollars, for example. Like other assets, money is a store of value and it offers a return. Its return comes from its usefulness in making transactions. That is, money is very liquid.

Pecuniary returns and liquidity yield

An asset might pay a tangible monetary return, such as an interest rate, but it also may have an intangible return arising from its liquidity. For example, money has a return even if it does not pay interest because it eases the burden of making transactions. We can designate the monetary return on an asset (designated with a subscript *j*) at time *t* as $i_{j,t}$. We label the non-pecuniary return $v_{j,t}$.

To keep to a simple example, suppose money (cash or demand deposits) pays no interest, so its return arises purely from its usefulness in completing transactions. The return on money is $v_{m,t}$.

A safe, short-term government bond pays interest, but it may also pay a non-pecuniary return. For example, in the U.S., government bonds are a good asset to use as collateral for overnight interbank borrowing. The market for government bonds is very deep, and there is no private information about their value, so government bonds are liquid. The return on government bonds, then, has a pecuniary and a non-pecuniary component: $i_{g,t} + v_{g,t}$. The non-pecuniary component of the government bond return is often called its "convenience yield."

Money and government bonds have very similar risk characteristics. Both are subject to losing value through inflation. But there is no uncertainty about the nominal return on money or government bonds.[1] Given these similarities, markets will equate the return on the two assets:

(1) $v_{m,t} = i_{g,t} + v_{g,t}$.

In words, the return on money that arises from its facilitation of transactions must equal the sum of the monetary and liquidity returns on government bonds. As the interest rate on bonds increases, the liquidity return on money must increase to satisfy the equality in (1). Using the general principle from economics of diminishing returns, as economic agents hold more money, its marginal value for transactions purposes decreases. When interest rates are high, households and businesses economize on cash balances and only hold them for transactions for which it is most valuable to have a liquid asset on hand. For example, when interest rates are very low, households might decide that it saves effort to keep the monthly rent money in their checking account. When interest rates are high, the opportunity cost of holding money in their current account is too high, so they may plan to keep the money in an interest-bearing account and then only turn their funds into money on the day the rent is due.

As noted previously, not all money is identical. Currency has different properties than demand deposits – it is more anonymous, but more cumbersome. We can speak of a non-pecuniary return on cash, $v_{c,t}$, as distinguished from the liquidity return on demand deposits, $v_{d,t}$. Households and firms adjust their cash balances and checking balances so at the margin those returns are equal, $v_{c,t} = v_{d,t}$, and that equality allows us to refer to the return on money $v_{m,t} \left(= v_{c,t} = v_{d,t} \right)$.

Returns on foreign currency instruments

How do we compare the returns on the government bills of one country to those from another country? Let's designate one country as the "home" and the other as the "foreign" (and we use a superscript * for returns from the foreign country.) The return on a foreign short-term

[1] We ignore here the possibility of default on short-term government bonds, though it is easy to extend the analysis to that case by including a premium in the return for default risk.

government bond includes its interest rate and its convenience yield: $i^*_{g.t} + v^*_{g.t}$. But those returns are in units of foreign currency. To compare the returns on the foreign government bond to those on the home government bond, we need to convert the foreign currency returns into home currency. Just like shares of stock pay a dividend and a capital gain, the foreign government bond pays its return in foreign currency, $i^*_{g.t} + v^*_{g.t}$, and a capital gain given by the percentage increase in the value of the foreign currency in terms of home currency: $\frac{S_{t+1} - S_t}{S_t}$. Here, S_t is the home currency price of foreign currency. For example, if the U.S. is the home country and France is the foreign country, S_t is the dollar price of euros. If the euro appreciates, so the exchange rate rises between time *t* and $t+1$, then $\frac{S_{t+1} - S_t}{S_t}$ is positive and the French government bond has a "capital gain" in terms of U.S. dollars. The return on the French bond, in dollar terms, is $i^*_{g.t} + v^*_{g.t} + \frac{S_{t+1} - S_t}{S_t}$.

Including the currency return introduces two complications into the comparison of returns on home bonds to foreign bonds. First, at the time the investment is made, the future exchange rate is not known. Investors must form expectations of the future exchange rate, S^e_{t+1}, so the expected currency return is $\frac{S^e_{t+1} - S_t}{S_t}$. The *expected* return on the foreign government bond in home currency terms is given by $i^*_{g.t} + v^*_{g.t} + \frac{S^e_{t+1} - S_t}{S_t}$.

Foreign exchange risk premium

The second complication is that given there is uncertainty about the exchange rate, investors face uncertainty about returns. The home investor is uncertain about the return on a foreign government bond because converting foreign currency returns into home currency is subject to the unknown level of the future exchange rate. The uncertainty about the return on the foreign bond might lead the home investor to require a higher expected rate of return on that bond if he is to hold it. But, conversely, the foreign investor might insist on a higher expected return on the home bond in order to compensate for foreign exchange risk. It should be clear that these two conditions cannot both be satisfied – it is not possible for each of the home and foreign investor to earn a higher expected return on the other's bonds.

There is a large theoretical literature that has promulgated various theories of the "risk premium" for foreign exchange, and the models can be quite complicated. It is impossible to give a thorough summary here. But it is important to note is that just because the return on an asset is uncertain, it does not mean that investors necessarily require a higher expected rate of return to be induced to hold the asset. For example, one could think of fire insurance as being an asset with an uncertain return. Most of the time, its payoffs are negative, because the holder of the policy pays the annual premium but doesn't make any claims on the insurance company. Only when there is a fire does the "investor" receive a positive payout on the asset. Most fire insurance policyholders never receive any compensation. Surely the expected return on fire insurance is negative. But people are still willing to hold that asset, even though its return is uncertain, and its average payoff is negative. That is because of the timing of the compensation – the fire insurance pays out exactly when the policyholder receives a large negative shock to his wealth. An asset that has properties of insurance – it tends to pay out more during bad times – may have a lower expected return than a riskless asset.

So it is with foreign exchange risk. Investors around the world might be willing to accept lower average returns on U.S. government bonds (or Japanese or Swiss bonds) because those bonds maintain their value during global recessions. That is, the currencies of these countries tend to appreciate during a global downturn, and therefore have properties like fire insurance. While their expected return may be lower than returns on government bonds from other countries, investors are still willing to hold them for their insurance properties.

A complete theory of foreign exchange risk premiums would include the time-varying aversion to risk across countries, the effects of being net borrowers or net lenders to the rest of the world, and the relationship between exchange rate risk and inflation risk.

We can say that the equilibrium condition in global financial markets implies that the return on the home bond must equal the expected return on the foreign bond, adjusted for the expected capital gain, and corrected for the compensation for foreign exchange risk:

(2) $$i_{g,t} + v_{g,t} + rp_t = i^*_{g.t} + v^*_{g.t} + \frac{S^e_{t+1} - S_t}{S_t}$$

Here, rp_t is the foreign exchange risk premium. If rp_t is positive ($rp_t > 0$), then the foreign bond pays a return that is higher than the home bond: $i^*_{g.t} + v^*_{g.t} + \frac{S^e_{t+1} - S_t}{S_t} > i_{g,t} + v_{g,t}$. In this case, the expected return on the foreign bond compensates investors for foreign exchange risk. The home bond pays a lower expected return than the foreign bond, but investors are willing to hold that bond because it provides insurance against foreign exchange risk. It could be the other way around, so that $rp_t < 0$, and it is the home bond that pays a higher expected return because of how the market prices foreign exchange risk.

Basic model of exchange-rate determination

Equation (2) can be rearranged with a little bit of algebra to give us our basic model of foreign exchange rate determination:

$$(3) \qquad S_t = \frac{S^e_{t+1}}{\left(i_{g,t} - i^*_{g.t}\right) + \left(v_{g,t} - v^*_{g.t}\right) + rp_t + 1}.$$

Consider the determinants of exchange rates in equation (3). Interest rates play a role. When the home interest rate increases relative to the foreign interest rate, so $i_{g,t} - i^*_{g.t}$ increases, the exchange rate falls. The exchange rate, recall, is the home currency price of foreign currency, so a decrease in S_t is an appreciation of the home currency. For example, when U.S. interest rates rise relative to European interest rates, the dollar appreciates relative to the euro (holding all else constant.) That matches the that an increase in home interest rates increases the marginal return on home money, because $v_{m,t} = i_{g,t} + v_{g,t}$, which leads to an appreciation of the home currency.

The relative convenience yields play the same role as the relative interest rates, because the convenience yield is just another source of return on the bonds. When $v_{g,t} - v^*_{g,t}$ rises, the home currency appreciates.

If there is an increase in the riskiness of the foreign bond – that is, if the compensation to investors for foreign exchange risk on the foreign bond increases – the home currency appreciates. When rp_t rises, investors want to switch away from foreign bonds to home bonds. If interest rates do not change, the home currency must appreciate. Holding expectations of the future exchange rate level constant, an appreciation of the home currency today will imply an expectation of a depreciation between time t and $t+1$. That is, algebraically, if S_t falls, and S_{t+1}^e is held constant, than $\frac{S_{t+1}^e - S_t}{S_t}$ must rise. In order to compensate investors for the increased riskiness of the foreign bond, it must be expected to yield a capital gain in terms of home currency.

Finally, next period's expected exchange rate affects today's exchange rate. If the foreign currency is expected to have a higher level tomorrow, investors want to buy it today. A higher S_{t+1}^e makes S_t higher. But what determines expectations of next period's exchange rate? One possible answer is that investors are forward looking. They understand that in period $t+1$, the model given by equation (3) will determine the exchange rate:

$$S_{t+1} = \frac{S_{t+2}^e}{\left(i_{g,t+1} - i_{g.t+1}^*\right) + \left(v_{g,t+1} - v_{g.t+1}^*\right) + rp_{t+1} + 1}$$

Then their expectations of the future exchange rate are determined by their expectations of the determinants of the exchange rate that the model posits:

$$(4) \qquad S_{t+1}^e = \frac{S_{t+2}^e}{\left(i_{g,t+1}^e - i_{g.t+1}^{*e}\right) + \left(v_{g,t+1}^e - v_{g.t+1}^{*e}\right) + rp_{t+1}^e + 1}.$$

The superscript e represents the market's expectations. We can use this model of the expected exchange rate, S_{t+1}^e, and substitute into our exchange rate model, (3), to derive:

$$(5) \qquad S_t = \left(\frac{1}{\left(i_{g,t} - i_{g.t}^*\right) + \left(v_{g,t} - v_{g.t}^*\right) + rp_t + 1}\right) \times \left(\frac{1}{\left(i_{g,t+1}^e - i_{g.t+1}^{*e}\right) + \left(v_{g,t+1}^e - v_{g.t+1}^{*e}\right) + rp_{t+1}^e + 1}\right) \times S_{t+2}^e.$$

We can see from (5) that the current exchange rate is affected not only by current interest rates, convenience yields and the risk premium, but also expectations of those variables in the future.

Long-run expectations

Equation (5) does not fully decide the role of expectations, because it leaves undetermined the expectation of the exchange rate in period $t+2$. Let's use the letter f_t to denote the "fundamental" determinants of the exchange rate at time *t*. That is,

$$(6) \qquad f_t \equiv \frac{1}{\left(i_{g,t} - i_{g.t}^*\right) + \left(v_{g,t} - v_{g.t}^*\right) + rp_t + 1}.$$

Then we can write equation (5) as:

$$S_t = f_t \times f_{t+1}^e \times S_{t+2}^e.$$

We can repeatedly substitute for expectations as we did in deriving equation (4), to arrive at:

$$(7) \qquad S_t = f_t \times f_{t+1}^e \times \ldots f_{t+n}^e \times S_{t+n+1}^e$$

If period $n+1$ is far enough into the future, then S_{t+n+1}^e can be interpreted as the market's expectation of the long-run exchange rate.

What determines exchange rates in the long run? Note that for some commodities, such as oil, gold, copper, wheat, etc., the *law of one price* holds. That is, the price of the commodity in the home country, P_t^c, equals the price of the commodity in the foreign country when expressed in home currency units, $P_t^c = S_t P_t^{c*}$. In the long run, the price of commodities relative to the overall consumer price index will be determined by fundamentals of supply and demand in each country. That is, P_{t+n+1}^c / P_{t+n+1} and $P_{t+n+1}^{c*} / P_{t+n+1}^*$ are nailed down by factors that affect the supply and demand for the commodity relative to the overall consumption basket. P_{t+n+1} is the consumer price level in the home country and P^{*}_{t+n+1} the foreign consumer price level. Then in the long-run, if $P^{c}_{t+n+1} / P_{t+n+1} = P^{c*}_{t+n+1} / P^{*}_{t+n+1}$, we have $P_{t+n+1} = S_{t+n+1} P^{*}_{t+n+1}$, a relationship known as long-run *purchasing power parity*. It follows that if this relationship is expected to hold in the long-run, the model of the exchange rate in (7) can be finally rewritten as:

$$(8) \qquad S_t = f_t \times f^{e}_{t+1} \times \dots f^{e}_{t+n} \times \left(\frac{P^{e}_{t+n+1}}{P^{*e}_{t+n+1}} \right).$$

The equation says that the exchange rate is determined by the current economic fundamentals (the interest rates, the liquidity returns, and the risk premium), expectations of future fundamentals, and the long run expectations of nominal prices.

One simple generalization of this model recognizes that purchasing power parity may not hold exactly in the long run. It may be that in the long run (in period $n+1$), prices in the home country and foreign country are not equal, but instead differ by a factor *k*: $kP_{t+n+1} = S_{t+n+1} P^{*}_{t+n+1}$. In this equation, if $k > 1$, prices are higher in the foreign country than the home country in the long run (when both are expressed in units of the home currency.) For example, high income countries or urbanized countries might have higher consumer prices than low-income or rural countries. Economic models allow us to estimate this factor, but a simple way to measure it is using historical data. According to the equation, $k = \frac{S_{t+n+1} P^{*}_{t+n+1}}{P_{t+n+1}}$, and we can estimate *k* by looking at the average value of $\frac{S_t P^{*}_t}{P_t}$ over a long period of time such as the past thirty or forty years. We can modify the above model, then, using $S^{e}_{t+n+1} = \frac{kP^{e}_{t+n+1}}{P^{*e}_{t+n+1}}$.

Monetary policy can influence the exchange rate through perhaps four channels. First, if the home country tightens policy by increasing the current interest rate or is expected to increase the interest rate in the near future, the exchange rate will fall – a home appreciation. Second, monetary policy that consistently keeps inflation in check will lead to lower expected nominal prices in the long run, which will imply a stronger currency. Monetary policy could also affect the convenience yield and the foreign exchange risk premium. If policy can stabilize inflation and maintain the value of the currency, more investors will want to hold the country's government bonds. When the market is deep for an asset, it becomes more liquid, and then the third channel of influence of monetary policy is at work through its effect on the convenience yield. Fourth, if monetary policy is successful in preserving the value of the currency during global recessions, the currency will have lower foreign exchange risk, and therefore strengthen. A "safe haven" currency such as the U.S. dollar, Swiss franc or Japanese yen is one that has a high convenience yield and a low, or negative, foreign exchange risk premium.

"Bubbles" in the exchange rate

The model of exchange rates summarized by equation (8) is built on economic fundamentals. Expectations are "rational", in the sense that the model assumes that participants in the foreign exchange market form their expectations in a way that is consistent with the model. This formulation does not permit a role for "bubbles". The foundation of the model, given in (3), allows for the possibility that the exchange rate is driven by expectations of future exchange rates. The additional assumption that the long-run expectations are tied down by purchasing power parity rules out a bubble in the exchange rate. From (3), we see that the current exchange rate, S_t, moves one-for-one with expectations of the period $t+1$ exchange rate, S_{t+1}^e. In turn, equation (4) shows us that S_{t+1}^e moves in tandem with S_{t+2}^e. If the market believes the exchange rate will be higher in some future period, it will translate into a higher exchange rate today. If markets' long-run expectations are not tied down, the possibility arises that the exchange rate is entirely driven by expectations, untethered from any economic fundamentals. The price of foreign currency could increase simply because the market expects it to increase.

However, it seems likely that there is a miscalculation by markets if the exchange rate is driven by expectations that are not ever tied to long-run economic conditions. If the exchange rate drifts very far from its long-run purchasing power parity value, economic forces would tend to push it back in line with the PPP value. If foreign prices were much lower than home prices, so $P_t > S_t P_t^*$, businesses and households would find it cheaper to buy goods in the foreign country. If this difference persisted, there would be increasing pressure to buy the foreign currency, pushing up S_t toward its purchasing power parity value. If the exchange rate reverts to the long-run purchasing power parity level, any bubble in the exchange rate must eventually burst. Forward looking agents should recognize this, and if they do, the bubble will never start. That does not mean that bubbles are impossible in foreign exchange markets – but if they exist, it suggests some lack of foresight by the market.

Fixed exchange rates

Finally, it may be worthwhile to consider how an exchange rate could be fixed (to the dollar or another currency) in the context of the model given in equations (6) and (8). Suppose that the monetary policy authority of the foreign country would like to keep its exchange rate fixed (for example, at a rate of one-to-one) to the home currency. There may be forces that would work to change the exchange rate that are not directly controlled by the policymaker – changes in the current or expected future liquidity value of short-term government bonds, or there could be influences that arise because markets are not entirely convinced that the exchange rate will be fixed indefinitely. In that case, events might alter the market's expectations of future interest rates, or future risk premiums, or the long-run price level. For example, if the exchange rate were credibly fixed, then the risk premium, rp_t would be zero since there is no foreign exchange risk under a permanent foreign exchange peg. But if markets believe the peg will not last forever, then markets might expect an increase in the risk premium in some future period, $t+k$, so rp^e_{t+k} would increase. If the monetary authority can control the short-term interest rate, it can always use that instrument to offset any of these changes in demand for its currency and stabilize the exchange rate. Clearly, monetary policy must be entirely devoted to the goal of fixing the exchange rate, to the exclusion of other objectives if the exchange rate peg is to be successful.

For example, suppose that because of some lack of credibility, markets expect higher inflation in the foreign country, leading to a higher expected long-run price level, P^{*e}_{t+n+1}. In the absence of any action by the monetary authority, the foreign currency would depreciate, so S_t would fall. In equation (3), the current exchange rate falls because of a decrease in the expected exchange rate, S^e_{t+1}. The foreign policymaker can stabilize the exchange rate by increasing $i^*_{g,t}$ - the decrease in demand for the currency caused by the change in expectations can be offset by making the currency more attractive with a higher interest rate.

It is helpful to consider how the currency could be fixed if the interest rate fell to the zero or to the effective lower bound. Perhaps the monetary policymaker could influence the demand for its currency by effectively communicating about future monetary policy, thus impacting the market's expectations of future interest rates. However, this channel seems difficult to control. Another case would arise with a currency board. Suppose the currency board in the foreign country held one unit of home currency for every unit of foreign currency that it issued. How would the currency board react to changes in $v_{g.t}^{*}$, $v_{g.t+k}^{*e}$, rp_{t+k}^{e} or P_{t+n+1}^{*e} that led to an incipient depreciation of the foreign currency? It could buy its own currency using its reserves of the home currency. That ought to stabilize the value of the currency, perhaps by increasing its liquidity return, by lowering any expectation of a future foreign exchange risk premium, or, at the very least, by lowering the expected future nominal price level in the foreign country relative to the home country.

Is it possible for the currency board to always effectively stabilize the exchange rate? Yes and no. Yes, in that it can always sell one unit of home currency for one unit of foreign currency, so any agent that holds the foreign currency can always be assured that the currency is backed by the home currency. But the currency board cannot prevent runs that cause it to entirely deplete its holdings of reserves of the home currency. If markets become convinced that the currency peg will not last, they will no longer be complacent about the long-run value of the currency, represented by its expectations of the nominal price level in equation (8). That equation tells us that if P_{t+n+1}^{*e} rises enough, then the expected future exchange rate would fall, and the market value of the foreign currency may drop so much that the currency board expends all its reserves defending the currency. If that happens, the original holders of the foreign currency are repaid with one unit of home currency, but the country must create a new currency. More likely, at some point prior to all of its reserves disappearing, the country would abandon the currency board, as Argentina did in 2002. Then the market's expectation of a depreciation would be self-fulfilling. Only a hard-to-define "confidence" in the currency board – like the confidence that markets apparently have in Hong Kong's currency board - can indefinitely stave off a self-fulfilling currency crisis.

In section 2, we use the model of foreign exchange rates to assess the pricing of a cryptocurrency. We draw parallels between the fundamentals of national currencies such as the dollar or yen, and the fundamentals of virtual currencies such as Bitcoin or Ethereum.

2. Cryptocurrency Exchange Rates

If we treat cryptocurrencies like national currencies, then their price (in terms of U.S. dollars or some other national currency) should be determined by the interest or dividend they pay (if any), their liquidity value, their foreign exchange risk premium, and their expected long-run value. We consider each of these factors in turn. It is useful to keep in mind conventional currency (hundred-dollar bills, for example) and gold as analogs to which we can compare cybercurrencies. A third comparison is to a liquid account, such as a checking account, held at a bank or other financial institution.

To keep the analysis simplified, we will examine the typical case in which the cryptocurrency does not pay any interest or dividend. The payoff to the investor comes from the liquidity return, the risk premium and/or the capital gain.

Cryptocurrencies as Medium of Exchange

Cryptocurrencies can be used to make transactions, but in most cases, at least currently, it is easier and less costly to use traditional money to make payments. For transactions of small amounts, physical currency is quite convenient. For larger amounts, debits to electronic accounts (such as checking accounts in the U.S., or WeChat in China) work well. In many countries (especially the U.S.), a credit card is a very efficient means of payment. In comparison, payment with cryptocurrencies is not even possible for most transactions and most digital currencies. Even when it can be done, it is slower and more cumbersome than more traditional means of payment.

More importantly, goods and services are not priced in cybercurrencies. Instead, prices are quoted in traditional national currencies, so using digital cash for payments requires conversion into the traditional currency. That is, paying for something with Bitcoin that is priced in U.S. dollars is akin to paying with euros. As noted above, a currency that is used as a unit of account is most useful as a medium of exchange. A traditional currency is a good medium of exchange when we can be certain that prices in units of the currency are pretty stable. Prices are not nearly as stable if we are using euros to pay for goods priced in dollars then if we are using dollars, because the euro per dollar exchange rate is much more volatile than dollar prices of goods. The digital currency price of dollars is far more unstable than the euro price, and so those digital moneys are much less useful as a medium of exchange.

Some proponents of gold as an alternative investment, and as an alternative to holding money, make the point that gold maintains its real value even in the face of high and volatile inflation. But that argument seems antiquated. Figure 1 plots U.S. consumer price inflation, 1871-2018.

Figure 1 shows that U.S. inflation has been tamed and very stable since the mid-1980s. For a period of nearly 40 years, inflation has been low and predictable. The real value of U.S. dollars has not been eroded greatly by inflation, so it seems like dollars are a good vehicle for transactions to buy goods, services and assets priced in dollars. Figure 2 plots inflation in the U.K. since the year 1200. Again, it shows that in recent history, the pound sterling has a very stable value in real purchasing power terms.

Figure 1

Consumer price inflation in the U.S., 1871-2018

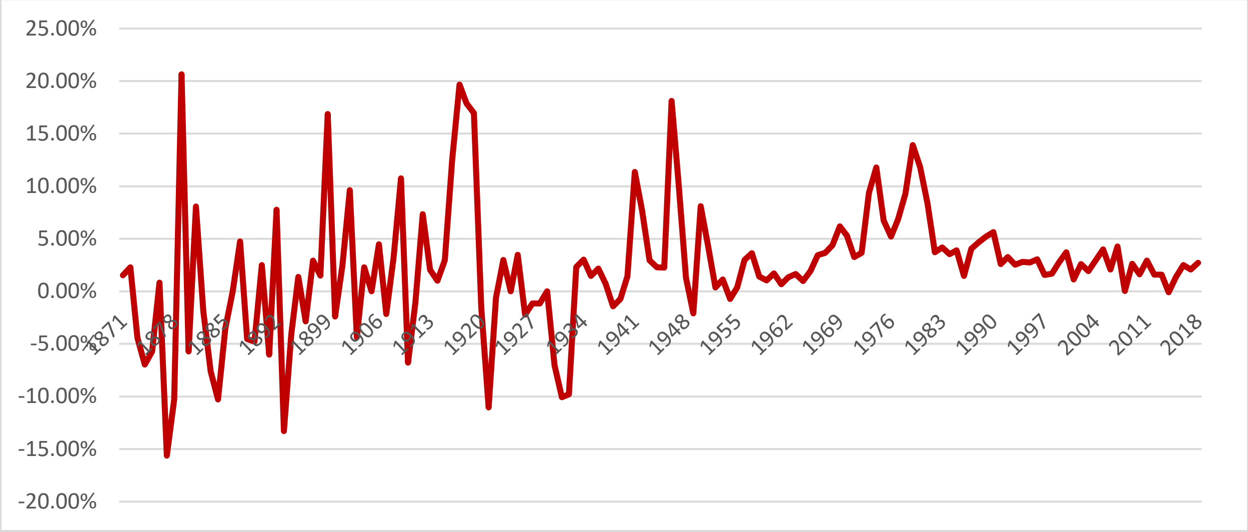
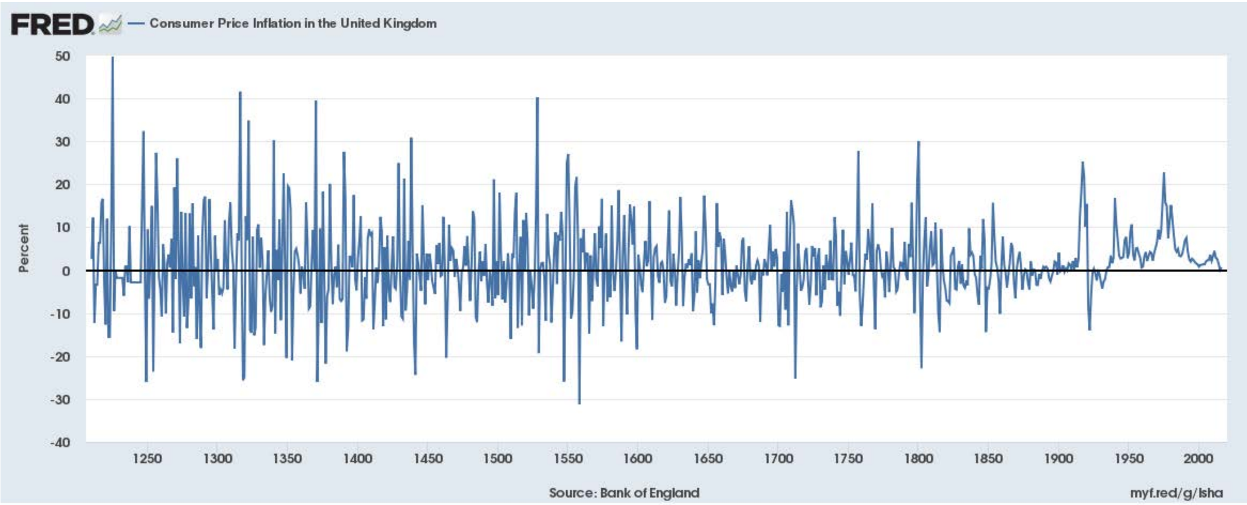


Figure 2

Consumer Price Inflation in the U.K. since 1200



In short, the case for using cybercurrencies on the grounds that they provide more stable purchasing power than traditional currencies is weak. It appears that independent entral banks that target inflation do a good job of preserving the purchasing power of the currency.

Security and Anonymity

One potential desirable feature of cryptocurrencies compared to checking accounts is that the digital currency is not held at a bank or other financial institution. They share the property of physical currency that the holder is not subject to the risk of bank failure. But while that is an advantage in principle, in practice it does not seem to work that way. In the first place, even when banks fail, deposits have been secure. Up to a limit, deposits are insured in many countries. Moreover, depositors generally are more senior to other creditors under bank default. On the other hand, there are cases of cryptocurrencies collapsing, or cryptocurrency exchanges failing, and even elaborate theft schemes that have inflicted damage on holders of cybercurrencies.

The main attractiveness of cryptocurrencies appears to be anonymity. They are like souped-up one-hundred-dollar bills. It is hard to trace transactions made with digital cash, and digital money is much more convenient for very large transactions than physical currency. In the context of the exchange rate model laid out in equation (3) and subsequent equations, the "convenience yield" of cryptocurrencies does not arise from their liquidity or safety, but from their anonymity.

The instability of cybercurrency prices arises in part because of the difficulty of assessing this fundamental value. Who wants anonymity? How much are these agents willing to pay for cybercash that pays no interest, that has a volatile price, that is clumsy for transactions, and whose long-run value is uncertain (a point addressed below)?

There are, of course, many legal and legitimate reasons for agents in the economy to desire anonymity, secrecy and privacy in their transactions. Households may not want to reveal private information to other households or businesses, and businesses may desire anonymity to protect trade secrets. Strong laws that protect privacy in the traditional financial sector may not be enough. There is a perception that cryptocurrencies provide greater *de facto* protection.

However, it is also the case that there are many illegal activities that are facilitated using cybercurrencies. These include evasion of capital flow management policies, the financing of illegal trade in arms, drugs, terrorist activity, and, money laundering to hide earnings from criminal activities.

Economists are split on the desirability of capital controls as a tool of prudential management. There is not any dispute about the importance of curbing money laundering and terrorist financing. But in the context here, the question is not whether these activities are good or bad, but how they impact the pricing of cryptocurrencies. There is clearly a demand for anonymous means of payment to facilitate illegal activity. A recent blog on the IMF website offers some anecdotal insight.[2] For decades, until 2016, the one-dollar bill had the greatest volume in circulation of all currency notes printed by the U.S. However, now it has been overtaken by the one-hundred-dollar bill. To be clear, this is not a statement about the value of the bills in circulation – the actual number of $100 bills in circulation is greater than the number of $1 bills. Most households in the U.S. use currency to make smaller transactions. It is unusual to use $100 bills for everyday expenses. According to the blog, there are over 13 billion one-hundred-dollar bills in circulation globally - $130 billion's worth – and it is likely that much of

[2] "US$100 Bill on the Rise" https://blogs.imf.org/2019/07/25/us100-bill-on-the-rise/ July 25, 2019

that finances illegal activities. For comparison purposes, this amount is roughly half of the total market capitalization of all cryptocurrencies as of August, 2019.[3] The demand for these $100 bills is evidence of a sizable worldwide demand for secret means of payment to finance illicit transactions. That demand extends also to cryptocurrencies. A recent study estimates that 46% of Bitcoin transactions involved unlawful business.[4]

The Difficulty in Valuing Cryptocurrencies

If in fact much of the demand for cryptocurrencies arises from funding of illegal activities (including evasion of capital controls), there are great difficulties in evaluating their economic value. In the model of equation (6) and (7), the valuation of the currency depends on the convenience yield offered by the digital cash, $v_{g,t}$, but given the uncertainty about who is buying the cryptocurrency and for what reason, this valuation is nearly impossible. Moreover, because the pricing depends not only on the current services offered but also expected future services, markets must form some expectations about how regulations and enforcement will impinge on the value of the digital currency. If governments crack down on the use of cybercurrencies, the value of the currency is affected directly because demand arising from criminal activities would decline, and indirectly because such regulations may reduce the anonymity of cybercurrency transactions, which is valued even by users that desire privacy for legal business.

The long-run fundamental value of the cryptocurrency is also hard to measure. With conventional currencies, as described above, investors can take advantage of measures of deviations from purchasing power parity to assess the long-run direction of changes in the exchange rate. When the exchange rate is greater than its purchasing power parity level (adjusted for some constant *k* to account for permanent differences in the cost of living between locations), we can forecast that the exchange rate will fall. That is, if $S_t > S^e_{t+n+1} = \frac{kP^e_{t+n+1}}{P^{*e}_{t+n+1}}$, then the foreign currency is overvalued in the short run, and we can forecast an eventual decline in the exchange rate. But this avenue for assessing the long run value of the currency is not available for cryptocurrencies because, for the most part, goods and services are not priced in

[3] See coinmarketcap.com

[4] Foley, Sean; Jonathan R. Karlsen; and, Talis J. Putnins. 2019. "Sex, Drugs and Bitcoin: How Much Illegal Activity is Financed through Cryptocurrencies?" The Review of Financial Studies 32, 1798-1853.

cryptocurrencies. That is, usually even when a purchaser can buy goods, services or assets with Bitcoin (for example), the price is set in dollars or euros or some other conventional currency. There is no consumer price index in Bitcoin, and so there is no way to measure the misalignment of the current Bitcoin price relative to its purchasing power parity level.

A common fallacy is that limiting the supply of the currency – a fixed amount in the case of Bitcoin, for example – stabilizes the long-run value of the currency (in terms of dollars, perhaps.) This is not true because the value depends not only on the supply, but also the demand for the currency. It is the components of demand that are uncertain and difficult to measure. Here is a trivial analogy: I can offer a currency called a “charles” which is entirely anonymous. There is only one unit of this currency – its supply is fixed. It is anonymous because payment is made directly with the charles, just as if it were a one-hundred-dollar bill. I personally will create the one unit. (Let’s also assume that my artwork is so good that it cannot be counterfeited.) What would somebody be willing to pay me for this cryptocurrency? The supply is fixed, but it can only have value to the extent that people find it a useful store of value or medium of exchange. A less trivial analogy is to monetary policy as it has been practiced in the past thirty years, especially in advanced economies. There was a time when economists believed that demand for money was very stable, and so a good policy rule was one that set a path for the growth rate of the money stock. Those policies faltered precisely because the demand for money was not stable. More accurately, the demand for whatever measure of money that policy was targeting – M1, M2, or some other measure – was not stable. When policymakers began instead to adopt policies that targeted outcomes, particularly inflation targeting, then the purchasing power of the currencies stabilized. In essence, to stabilize nominal prices, policymakers implicitly alter the supply of money in response to fluctuations in demand for money.

Cryptocurrencies and Bubbles

Some economists maintain that cryptocurrencies are purely a bubble that offer no fundamental return. If a currency is a pure bubble, investors value it only because they expect the price to rise. In this view, the bubble is bound to burst at some point because the price cannot rise forever relative to other assets – some sort of balance sheet constraint, or a change in expectations, will lead to the demise of the currency. That is not the view taken here. We have argued that the cybercurrency’s fundamental value arises from its relative anonymity for transactions (and possibly its protection from bank failure.) However, we have also contended that it is nearly impossible to assess the fundamental value of the currency. Under these circumstances, it is easy for asset price bubbles to arise. Consider equation (7). The exchange rate today may change, even when current and expected future fundamental determinants are held constant, if the long-run expected exchange rate changes. That is the essence of a bubble, because movements in the current value of the currency are caused only by changes in the expected future value. However, because it is difficult to measure the fundamentals and the market's expectations of future fundamentals (that is, it is hard to measure f_t, f_{t+1}^e, f_{t+2}^e, …), an investor would not be able to tell whether the exchange rate fluctuation is being caused purely by an expectation-driven bubble, or by changes in expectations about future fundamental determinants. In the case of conventional currencies, a bubble will not last long because knowledgeable investors will be able to ascertain when the currency is far out of line with the value pinned down by economic forces (as in equation (8)). Those bubble-bursting, fundamentals-trading investors must have a smaller role in pricing cryptocurrencies given the ambiguity about fundamental values. The pricing of these cyber assets then is amorphous both because it is hard to assess the value of fundamentals and because it is easy for bubbles to at least temporarily drive the price.

Another possible fundamental value to a cryptocurrency is as a hedge against global risks. Gold is said to have that property. During a crisis many assets lose value, and even conventional currencies lose value if inflation spikes up during a global downturn. Since gold is a real commodity, gold investors believe that it will maintain its value during such times, and so it serves as a hedge against fluctuations in the value of the investor's portfolio. A difference between gold and cryptocurrencies is that the fundamental long-run price of gold is connected to real demand from its usage in industry and fine art, while the real long-run value of cryptocurrencies is harder to pin down. Cryptocurrency prices have been very volatile over both day-to-day and longer-run horizons and have not proven to be a good portfolio hedge.

To summarize, while exchange rate models are far from perfect in accounting for the level and movement of conventional currency prices, they offer some guidance on measurable economic factors that affect these prices. Short-run movements are more difficult to account for, but long-run values are tethered by purchasing power parity (or some variant of that long-run model.) Cryptocurrencies are nearly impossible to price both because we cannot assess the value of its principle attribute, anonymity, and because there is no clear long-run anchor.

Stable Coins and Fixed Exchange Rates

Speaking of tethering, the application of the model in section 1 to pegged currencies is also helpful in the consideration of "stable currencies". "Stable coins" share many characteristics of traditional currencies that have an exchange rate fixed to another currency. In fact, the most successful (so far) of the stable coins, Tether, is operated much like a currency board. Tether claims to back each of its coins by one U.S. dollar.

There are a few interesting properties of stable coins that relate to traditional currencies and currency boards. Exactly as the discussion above of currency boards highlights, stable coins are subject to runs that are precipitated by a lack of confidence. Even if a coin pegged to the U.S. truly is backed 100 percent by very liquid dollar assets, there could be a run on the coin if investors have doubts about the future backing of the coin.

Coins that are not backed 100 percent by liquid, riskless assets are even more vulnerable to a run. In fact, the business model for most stable coins involves holding assets that have some risk but pay an expected return that compensates for that risk. Certainly stable coins are not backed by 100-dollar bills kept in a safe somewhere. When these risky assets lose value, investors in the stable coin may doubt the soundness of the backing, and a run could occur.

What are the advantages of a stable coin? Usually this question is answered comparing stable coins to other digital cash, and the answer is obvious: as long as a run does not occur, the value in terms of dollars (or whatever currency the stable coin is pegged to) is much less volatile. Since ultimately investors value wealth for what it can buy, and the goods and services they buy are priced in dollars or other traditional currencies, then this stability is desirable. A different comparison is to a liquid account denominated in a traditional currency. Why hold Tether (which is pegged to the U.S. dollar) when one can hold a liquid account in U.S. dollars at a bank? As we have noted, one potential advantage of any cybercurrency compared to bank deposits is the immunity from bank failure. The main advantage might be the higher security, anonymity and privacy offered by digital currencies relative to bank accounts. If the digital cash value is credibly fixed to the dollar, then the investor can balance his portfolio of liquid assets between those that are widely accepted, convenient, and subject to consumer regulatory protection with those that offer greater anonymity. Until now, the demand for stable coins is small relative to other liquid assets.

3. Policy Implications and Conclusions

Because cybercurrency holdings are small relative to other forms of liquid assets (in August, 2019, the market capitalization of digital currencies was approximately $260 billion, which by comparison is less than 2 percent of U.S. Treasury debt held by the public, which measured around $16.17 trillion[5]), the digital currency market is not a major concern for monetary policy currently. Regulatory issues should be the focus of policymakers at central banks.

Price stability is the primary concern of central bank monetary policymakers. As long as goods and services are priced in traditional national currencies, the existence of the cybercurrency market should not impede the achievement of an inflation target. A concern would be if "currency substitution" occurred. Currency substitution refers to the situation in which a national currency is replaced by a different currency. Consumer prices are set in the new currency, and transactions take place using the new currency. Examples of currency substitution have arisen in countries when prices in the national currency experience high and volatile inflation. Many central banks around the world have adopted inflation targeting practices, and no countries – with the exception of Venezuela – appear to be susceptible to currency substitution. If currency substitution occurs, then the national central bank no longer can control inflation, but this only occurs when the policymaker has lost control in the first place.

Another concern of monetary policymakers is to insure liquidity in the market for loans to households and businesses. A potential looming problem arises from loans denominated in cryptocurrencies. However, this problem is a mere speck currently – the market for such loans is tiny. The problem such loans raise is exactly analogous to foreign-currency loans using traditional currencies. A business whose revenue is in pesos may find it very difficult to repay a dollar-denominated loan if there is an unexpected peso depreciation, just as a household that earns income Polish zloty is taking on risk with a mortgage denominated in euros. Financial

[5] See coinmarketcap.com for the cryptocurrency figures and treasurydirect.gov for the U.S. government debt numbers.

stability could be threatened if a large market evolved with unsophisticated agents amassing debt in some cybercurrency. This is a possible macroprudential concern, but it must be far down the list of financial stability concerns at this point.

Monetary policymakers are sometimes concerned about exchange-rate stability. Emerging markets in which households and businesses hold a lot of dollar debt may be fragile if the exchange rate is volatile. It is hard to imagine a point at which any monetary policymaker would begin to worry about the stability of its exchange rate with a cryptocurrency. At the present time, it is the creators of these currencies that are working on different ways to insure greater exchange rate stability.

It is likely that if the crypto market grows, regulators will impose greater restrictions and tighter control on the buying and selling of these currencies. One concern is unsophisticated investors that are insufficiently aware of the risks of investing in digital currencies. Perhaps more important is the use of these assets to launder money and conduct illegal operations. However, increased regulation is likely to make these assets less valuable to investors that desire the properties of cryptocurrencies – their anonymity and their independence from the traditional financial system. They will constitute a strong lobby opposed to stricter rules.

There are at least a couple of things that can be done to ease the path toward tighter regulation. The first is education. Regulators should forewarn the public of their concerns about cryptocurrencies, and why they might require stronger controls. Legitimate investors stand to suffer large losses if major regulations are imposed without much warning. Second, governments can step up efforts to increase the safety, security, and privacy of the traditional sector – banks, credit cards, and other financial institutions. Such a step may reduce the demand for alternatives to the traditional financial system.

We have maintained that cryptocurrencies do have a fundamental value, arising principally from their ability to potentially provide greater privacy and anonymity compared to the conventional banking system. But that feature is difficult to value, which makes cryptocurrency exchange rates volatile and subject to bubbles. In addition, that very feature makes these assets desirable for the conduct of illegal activities, which is likely to invite increasing surveillance and regulation. In turn, those controls will work to reduce the value of cryptocurrencies, not only for use in illicit transactions, but for legitimate users as well.