# Do cryptocurrencies matter?

B. Biais (HEC), J.C. Rochet (TSE), S. Villeneuve (TSE)

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**Abstract:**

We analyze a simple continuous-time, general equilibrium model, in which agents can invest their wealth in a production technology exposed to shocks and in fiat money issued by the government. The government relies on seigneurage and wealth taxation to fund public spending. If the government is non benevolent, in order to extract rents from agents it runs an expansionary monetary policy, which can lead to hyperinflation. When agents can also invest in a cryptocurrency, they can use it to buffer productivity shocks while avoiding public currency hyperinflation. This puts a cap on how much the government can inflate and extract rents. Thus, agents' welfare is larger with cryptocurrency than without.

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# 1 Introduction

Can cryptocurrencies be useful? With well functioning monetary and financial institutions, public currencies, such as the dollar or the euro, are likely to dominate cryptocurrencies, to the extent that they have lower transaction costs and lower volatility. But the situation might be different if institutions are dysfunctional. What if the government is predatory, there is hyperinflation, and political risk is large ? In that case, a cryptocurrency, shielded from institutions' dysfunctionality, could prove useful.

This may be the reason why ownership and use of cryptocurrencies has become very large in countries like Argentina, Egypt, Lebanon, Nigeria, Turkey, and Venezuela. In such countries, cryptocurrencies can be seen as a lifeline, a shield against hyperinflation and the depreciation of the official currency. According to some estimates, 50% of people in Turkey own cryptocurrency.[1] On February 23rd, a *Financial Times* article on Nigeria noted:[2]

> "Digital assets have gained popularity because many people lost trust in the naira as a reliable store of value. "

Similarly, on March 23rd, an article in Coin Telegraph noted:[3]

> "Argentines' efforts to preserve their savings amid the ongoing decline of their national currency, the Argentine peso, has resulted in the nation recently hitting its highest demand for Bitcoin in 20 months."

Large inflation is often attributed to the reliance on excessive money creation to fund large public spending.[4] This causal mechanism is emphasized, e.g., by Lopez and Mitchener (2020) in their study of hyperinflation in Europe after World War 1.[5] Similarly, Pittaluga, Seghezza and Morelli (2021) attribute the recent hyperinflation episode in Venezuela to inflationary financing of public spending.[6] In his essay entitled "Denationalisation of Money"Hayek (1976) argued that these problems could be avoided thanks to

> "the replacement of the government monopoly of money by competition in currency supplied by private issuers who, to preserve public confidence, will limit the quantity of their paper issue and thus maintain its value."

[1] See, e.g., https://www.binance.com/en/square/post/1131869

[2] "Nigeria blocks digital asset exchanges as naira plunges," *Financial Times*, 23rd of February, 2024.

[3] cointelegraph.com/news/bitcoin-demand-argentina-reaches-peak-argentine-peso

[4] The seminal paper on hyperinfation is Cagan (1956).

[5] On page 450 of their article, Lopez and Mitchener (2020, page 450) write "Why do hyperinflations begin? In a mechanical sense, economists have known the answer to this question at least since the monetarist revolution: money is printed in response to unsustainable fiscal policy."

[6] Pittaluga, Seghezza and Morelli (2021) write (pages 337 and 338): "When ... the financing of the existing level of public spending no longer could be sustained by domestic and oil-related taxes, inflationary financing was adopted and hyperinflation ensued. "

Cryptocurrencies are an interesting laboratory to test Hayek's proposition. Cryptocurrencies stand to offer privately supplied means of payment and store of value. Moreover, their issuance rate is determined by the protocol of the blockchain on which they rely, and this protocol is quite difficult to change. This creates the possibility to commit to a predetermined issuance rate, which helps maintain the value of a currency.

Against this backdrop, the goal of the present paper is to examine, within a formal model, whether cryptocurrencies can fulfill the role of the denationalised currencies called for by Hayek (1976). Can cryptocurrencies be used by private agents when the value of public currencies is undermined by non-benevolent governments' policies ? Can competition from cryptocurrencies discipline non-benevolent governments' monetary and fiscal policies?

To conduct this analysis, we rely on a theoretical model capturing some of the main characteristics of cryptocurrencies: The pace of cryptocurrency monetary creation is set in advance by the protocol of the blockchain on which ownership of the cryptocurrency is registered. This shields the cryptocurrency from the excessive inflation risk plaguing the official currency. Moreover, it is difficult for the government to tax cryptocurrency holdings. But the cryptocurrency is risky and may crash. As in Garratt and Wallace (2019), Rocheteau and Wang (2023), and Biais, Bisière, Bouvard, Casamatta and Menkveld (2023), the crash can reflect sunspot driven extrinsic uncertainty. It might also reflect a technology or cybersecurity problem, as in Pagnotta (2022).[7]

We analyze the consequences of these characteristics of cryptocurrencies in a simple general equilibrium model set in continuous time, featuring a government and a continuum of agents operating technologies with i.i.d productivity shocks. The government does not have the skills to operate these technologies and therefore must delegate operations to the agents. Because the technologies they operate are subject to random productivity shocks, the agents value the opportunity to hold a safe asset, helping them buffer productivity shocks. This is the reason why money is valuable in our setting, in spite of having no intrinsic value. In this context, agents make portfolio choices, deciding what fraction of their wealth to allocate to the risky asset and what fraction to allocate to the safe asset, i.e., money. The government chooses how much money to issue, and also how much agents' wealth should be taxed, as well as the level of public spending. The budget constraint of the government is that public spending equals tax proceeds plus seigneurage revenues. There is a conflict of interest between the government and the agents, as the government's preferences put more weight on public spending than the agents'. Our analysis proceeds as follows.

First, as a benchmark, we consider the case in which there is no cryptocurrency. In that case, we show that a non-benevolent government can rely on seigneurage to fund excessive public spending. When the government is highly

[7] As written by Garratt and Wallace (2019): "One interpretation is that the uncertainty is purely extrinsic... a publicly observed sunspot variable à la Cass and Shell (1983). The appearance of a sunspot triggers a change in beliefs that leaves bitcoin valueless. The other interpretation of the randomness underlying the equilibrium is that it represents intrinsic uncertainty."

non-benevolent, this leads to hyperinflation, which in our theoretical framework is defined as the situation in which agents are unwilling to hold the public currency, the value of which correspondingly goes to zero.

Second, we turn to the situation in which there is a cryptocurrency, and show that two cases can arise:

- If the government is rather benevolent, the presence of the cryptocurrency does not change outcomes: A benevolent government does not find it optimal to go for large inflation, so that agents are happy to hold public currency and, in equilibrium, don't hold cryptocurrency.

- In contrast, if the government is non-benevolent, it would like to go for large inflation. But this is prevented by competition from the cryptocurrency: if the inflation rate of the public currency were too large, agents would not want to hold it and would hold the cryptocurrency instead. Taking this reaction into account, the non-benevolent government finds it optimal to show restraint in its monetary policy. Thus, competition from the cryptocurrency effectively caps inflation in the public currency.

Our analysis thus shows that, while competition from cryptocurrency does not impact benevolent governments, it constrains non-benevolent governments, which makes agents better off. This is line line with Hayek (1976), and rationalizes the two following stylized facts:

- First, in many countries, governments and central banks oppose the development of cryptocurrencies, which is in line with the idea that competition from cryptocurrencies constrains governments and central banks.

- Second, ownership of cryptocurrencies is larger in countries in which government and central bank dysfunctionality gives rise to large inflation.

Our paper is related to the literature providing microfoundations for the usefulness of money (dating back to the seminal papers of Allais, 1947, Samuelson, 1958, Tirole, 1985, Weil, 1987, Kiyotaki and Wright, 1989 and 1993, and Lagos and Wright, 2005) and to the literature extending monetary theory to cryptocurrencies (see, e.g., Schilling and Uhlig, 2019, Benigno, Schilling, and Uhlig, 2022, and d'Avernas, Vandeweyer and Maurin, 2023). Within this literature, the papers to which our analysis is closest are those studying hyperinflation and those studying competition between currencies. Rocheteau (2024) offers an insightful analysis of equilibria in which the value of the currency progressively declines until it reaches zero. While in Rocheteau (2024) hyperinflation corresponds to a progressive erosion the value of money due to the self-fulfilling beliefs of the agents, in our analysis hyperinflation corresponds to an instantaneous erosion of the value of the money due to the unsustainability of the government policy. Kareken and Wallace (1981), Garatt and Wallace (2018), Fernandez-Villaverde and Sanches (2019), and Biais, Bisière, Bouvard, Casamatta and Menkveld (2023) and Rocheteau (2024) study competition between currencies. The main contribution of the present paper relative to that literature is to offer a microfoundation for the differences in usefulness between cryptocurrencies and public currencies, reflecting endogenous monetary and fiscal policy, and relate it to the conflict of interest between agents and non-benevolent governments.

Our paper is also related to the mechanism design analysis of Biais, Gersbach, Rochet, von Thadden, and Villeneuve (2023). They study the optimal dynamic mechanism designed by a principal facing many agents privately observing their outputs. Then they show how the optimal mechanism can be implemented with i) a market in which agents exchange goods for money issued by the principal, and ii) linear wealth taxation. The special case of our model in which there is no cryptocurrency corresponds to this implementation. The main contribution of the present paper relative to Biais, Gersbach, Rochet, von Thadden, and Villeneuve (2023) is to extend the analysis to the case in which there is a cryptocurrency competing with the currency issued by the principal. An additional contribution of the present paper relative to Biais et al (2023) is to analyze equilibrium hyperinflation, and trace it back to severe conflicts of interest between the government and the agents.

In our analysis, when inflation in the public currency is large, agents switch to the cryptocurrency. This is similar to Thiers' law, in Bernholz (1989) which states that when inflation is large agents switch from the domestic currency to foreign currency. Pittaluga, Seghezza and Morelli (2021) discuss this switch in the context of the recent hyperinflation crisis in Venezuela.

Our theoretical analysis is also related to empirical analyses of cryptocurrency markets. Luckner, Reinhart, and Rogoff (2023) provide empirical evidence that cryptocurrencies are used to conduct transactions and store value, not unlike in our model. In our model, as long as there is no crash, the demand for cryptocurrency trends up faster than its supply, so that the price of the cryptocurrency increases. This is not unlike the mechanism analyzed econometrically by Jermann (2021).

In the next section, we analyze the benchmark case in which there is no cryptocurrency. Section 3 then extends the analysis to the case in which there is a cryptocurrency. Section 4 offers a brief conclusion. Proofs not given in the main text are in the appendix.

# 2 The Case without Cryptocurrency

Our analysis of this benchmark case builds on Biais et al. (2023). In that paper, constrained optimal allocations can be implemented by appropriately chosen policy rates: a constant money growth rate and a constant wealth tax rate. If the government is self-interested, it distorts policy choices to extract rents from agents. In the next section, we show how competition from cryptocurrency limits government rent extraction and increases citizens' welfare.

## 2.1 Model

Consider a continuous time model with a government and a mass 1 continuum of agents, indexed by $i \in (0, 1)$. There is only one good, which is produced by the agents with a constant return to scale technology, and can be used for consumption or investment. Agents have discount rate $\rho$ and log utility. At date $t$, agent $i$ owns $k_t^i$ units of capital, and $m_t^i$ units of fiat money, issued by the government. Money is used by the agents to trade on the good market and to pay taxes to the government. Aggregate capital is denoted by $K_t$, that is

$$\int_0^1 k_t^i di = K_t. \tag{1}$$

The output of agent $i$ at date $t$ is

$$k_t^i(\mu dt + \sigma dZ_t^i), \tag{2}$$

where the $Z_t^i$ are independent Brownian motions that represent idiosyncratic risks.[8] When the allocation of capital is sufficiently regular,[9] these idiosyncratic risks wash away in aggregate, and total output is $\mu K_t$. In the absence of frictions, it would be optimal to eliminate idiosyncratic shocks by diversification. However, we assume that individual output is not publicly observable: Agents can secretly divert a fraction of their output and secretly consume it. Correspondingly, allocation rules must be incentive compatible, so that agents never divert output.

Biais, Gersbach, Rochet, von Thadden, and Villeneuve (2023) characterize constrained optimal allocations in this context and show that they can be implemented with appropriate (and constant) policy rates: a money supply growth rate ($g_m$), a wealth tax rate ($\tau$), and a public spending rate ($\gamma$). In the remainder of this section we revisit the results of Biais, Gersbach, Rochet, von Thadden, and Villeneuve (2023) and show that in their framework hyperinflation can arise in equilibrium when the government is highly non-benevolent. This sets a benchmark from which we depart in the next section, presenting the main contribution of this paper, which is to analyze the case in which the public currency competes with a cryptocurrency.

## 2.2 Agents' optimal decisions

The government issues $M_0$ units of fiat money at date $t = 0$ and distributes them to the agents. [10]. It commits to constant $\tau$ and $g_m$. Agents form expectations about the price $p_t$ of the good at all future dates and choose their consumption

[8]The rigorous formulation uses mean-field games techniques, explained in Biais, Gersbach, Rochet, von Thadden, and Villeneuve (2023).

[9]For example when, at each date $t$, the mapping $i \mapsto k_t^i$ is square-integrable.

[10]Because of log utilities, the way money and capital are distributed to the agents at date $t = 0$ is irrelevant for our analysis.

$c_t$, money holdings $m_t$ and investment $k_t$ to maximize[11]

$$E[\int_0^\infty e^{-\rho t} \log c_t dt]. \tag{3}$$

Since the model is stationary and the policy choices are constant, the equilibrium inflation rate $\pi$ and the growth rate of capital $g$ are constant and we have

$$p_t = p_0 exp(\pi t), K_t = K_0 exp(gt). \tag{4}$$

Agents' real wealth is the sum of their capital holdings and real balances:

$$e_t = k_t + \frac{m_t}{p_t}. \tag{5}$$

Since there are no transaction costs, the composition of agents' wealth can be instantaneously and costlessly adjusted at any time. Thus $e_t$ is the single state variable for the agent. The dynamics of $e_t$ is given by the state-equation:

$$de_t = k_t(\mu dt + \sigma dB_t) - (c_t + \tau e_t + \pi(e_t - k_t))\, dt, \tag{6}$$

expressing the change in real wealth as output minus consumption, fiscal tax, and inflation tax. Denoting by $u(e)$ is the value function of the agent, by Ito's Lemma the Bellman equation is

$$\rho u(e) = \max_{c,k \le e} \log c + u'(e)[\mu k - c - \tau e - \pi(e-k)] + \frac{\sigma^2}{2} k^2 u''(e), \tag{7}$$

subject to the constraint that money holdings cannot be negative, which is equivalent to $k \le e$. As in Merton (1969), the homogeneity of the agent's program and the logarithmic utility of consumption imply that $u(e)$ is also logarithmic:

$$u(e) = \frac{\log e}{\rho} + u(1),$$

so that

$$eu'(e) = -e^2 u''(e) = \frac{1}{\rho}. \tag{8}$$

The agent's decision problem therefore simplifies to

$$\max_{c,k \le e} \log c + \frac{1}{\rho}\left(\frac{(\mu + \pi)k}{e} - \frac{c}{e} - \tau - \pi\right) - \frac{\sigma^2 k^2}{2\rho e^2}.$$

The first order condition with respect to $c$ implies that optimal consumption is a constant fraction $\rho$ of agents' wealth:

$$c = \rho e.$$

[11]Hereafter, to avoid cumbersome notations, we omit the index $i$, but the reader should bear in mind that there are many agents, with different asset holdings and consumption.

The propensity to consume is thus constant and equal to $\rho$ : it increases with the impatience of the agent. Because agents have log utility, their propensity to consume is not affected by the tax rate or the inflation rate.

The first order condition with respect to $k$ implies that optimal investment in capital is a constant fraction $x$ of agents' wealth with:

$$x = \min\left[\frac{\mu+\pi}{\sigma^2}, 1\right] \tag{9}$$

So, when $\pi \leq \sigma^2 - \mu$, the agent chooses a capital investment share $x$, s.t.,

$$\mu + \pi = \sigma^2 x.$$

The left-hand side is the benefit of capital investment, equal to the return ($\mu$) plus the benefit of being shielded from inflation. Thus, $x$ increases with inflation, an important feature of optimal decisions in our setting to which we will return later. The right-hand side is the cost of capital investment, productivity risk. The larger this risk, the lower the propensity of the agent to invest in capital. Conversely, since the fraction of wealth invested by the agent in money is $1-x$, the equation states that money holdings decrease with inflation, but increase with productivity risk. The latter reflects the fact that money is valued by the agents because it is a safe asset. Finally, note that the agent's portfolio choice ($x$) does not depend on the tax rate ($\tau$) because money and capital are equally taxed.

## 2.3 Rational expectations equilibrium

Having characterized individual behaviour as a function of anticipated prices $p_t$, we now determine the rational expectations equilibrium for a given choice of policy instruments $(\tau, g_m, \gamma)$.

Equilibrium on the good market is characterized by the equality of savings and investment:

$$\frac{dK_t}{dt} = \mu K_t - C_t - \gamma K_t \tag{10}$$

Since there is no depreciation of capital, the growth of aggregate capital ($\frac{dK_t}{dt}$) is equal to investment. Market clearing implies that this is equal to savings, i.e., output ($\mu K_t$) minus agents' consumption $C_t$ and government spending $\gamma K_t$. Moreover, since the agent's optimality conditions imply that his consumption is $c_t = \rho e_t$ and his capital holdings are $k_t = x e_t$, the agent's consumption is $c_t = \rho \frac{k_t}{x}$. Aggregating across agents, we have that aggregate wealth is $E_t = \frac{K_t}{x}$, private consumption is $C_t = \frac{\rho}{x} K_t$. Hence, the growth rate of capital is:

$$g = \mu - \frac{\rho}{x} - \gamma. \tag{11}$$

The larger the investment $x$, the lower the consumption, and the larger the growth rate. Also, the larger $\rho$, the more impatient the agents, the larger their consumption and the lower their savings and therefore investment. Thus, the aggregate growth rate $g$ decreases with agents' discount rate $\rho$.

The second step is to write the government's budget balance stating that tax revenues ($\tau E_t$) plus seigneurage ($g_m(1-x)E_t$) equal public spending ($\gamma x E_t$), which implies

$$\tau = \gamma x - g_m(1-x). \tag{12}$$

The third step of our equilibrium analysis is to equalize money supply and money demand. We have seen that agents want to keep a constant fraction $(1-x)$ of their wealth in money and the rest in capital. Therefore aggregate money demand is proportional to the nominal value of the aggregate capital stock: $\frac{(1-x)}{x} p_t K_t$. Since money supply grows at rate $g_m$, the equality between money supply and money demand gives:

$$M_0.exp(g_m t) = \frac{(1-x)}{x} p_t K_t. \tag{13}$$

Condition (13) shows that there always exists a rational expectation equilibrium in which money has no value. When all agents anticipate that $p_t \equiv \infty$, they only invest in capital ($x = 1$) and money has indeed no value. But there can also exist a monetary equilibrium, i.e., an equilibrium in which money has a strictly positive value ($p_t$ is finite for all $t$) and the demand for money is strictly positive ($x < 1$). In a monetary equilibrium, market clearing in the money market is characterized by two conditions:

$$g_m = g + \pi, \tag{14}$$

expressing that nominal growth equals real growth plus the inflation rate, and

$$M_0 = \frac{(1-x)}{x} p_0, \tag{15}$$

which determines the initial level of prices $p_0$.

By (9), the demand for money is strictly positive ($x < 1$) only if inflation is not too large, i.e., $\pi < \sigma^2 - \mu$. Substituting (14) in this condition, the demand for money is strictly positive if

$$g_m + \gamma < \sigma^2 - \rho, \tag{16}$$

that is if the government does not follow too aggressive budget and monetary policies. If condition (16) does not hold, then the only equilibrium involves hyperinflation, which, in the context of our model, we define as a situation in which the demand for money is zero and money has no value. This yields our next proposition:

**Proposition 1** *When the government budget and monetary policies are not too aggressive, as (16) holds, there is a unique monetary equilibrium, characterized by an inflation rate $\pi = \sigma^2 x - \mu$, where $x < 1$ is the unique solution of*

$$\sigma^2 x - \frac{\rho}{x} = g_m + \gamma. \tag{17}$$

*Otherwise, if (16) does not hold, there is a unique equilibrium, characterized by hyperinflation, in which agents don't hold any money ($x = 1$).*

## 2.4 Agents' lifetime utility and optimal policies

Government policy involves three rates: the wealth tax rate $\tau$, the money supply growth rate $g_m$, and the public spending rate $\gamma$. By the government budget constraint, monetary policy ($g_m$) and budget policy ($\gamma$) fully determine fiscal policy ($\tau$). So we only need to consider the two rates $g_m$ and $\gamma$, or equivalently $\pi$ and $\gamma$. Now, in a monetary equilibrium, by (9), there is a one-to-one mapping between $\pi$ and $x$. So, in a monetary equilibrium, welfare depends only on $x$ and $\gamma$.

For simplicity, we assume agents only derive utility from their own consumption and don't derive any utility from government spending.[12] In this context, we first analyze agents' welfare when government is fully benevolent and public spending is zero. We then consider the case in which there is a conflict of interests between agents, who don't derive any utility from public spending, and government, who puts some weight on agents' utility but also derives utility from public spending.

### 2.4.1 Benevolent government

For simplicity and without affecting our qualitative results, we assume the government can redistribute capital at date 0 so that each agent starts with the same capital endowment $k_0 = K_0$.

When the government is fully benevolent it sets $\gamma = 0$, since agents don't derive any utility from public spending. In this case, the only policy instrument is monetary policy and, as explained above, inflation or monetary growth is equivalent in our model to $x$. So, to characterize the optimal policy of a benevolent government, we only need to determine the value of $x$ which maximizes agents' lifetime expected utility. Given that agents hold fraction $x$ of their wealth as capital and consume fraction $\frac{\rho}{x}$ of capital, their lifetime expected utility is $U$ such that

$$U = \frac{1}{\rho}[\log\left(\frac{\rho}{x}K_0\right) + \frac{g}{\rho} - \frac{\sigma^2 x^2}{2\rho}]. \tag{18}$$

This expression can be interpreted as follows. The right hand side is the expected present value of the agent's utility stream discounted at rate $\rho$ over an infinite horizon. The first term in brackets is the utility of consuming fraction $\frac{\rho}{x}$ of initial capital $K_0$. The second term reflects that the agent's capital grows on average at rate $g$. The third term reflects the risk premium corresponding to the residual risk left to the agent, which is increasing in $x$.

Substituting the growth rate (11) in (18), and putting together the terms in $x$, the objective of the benevolent government is

$$max_x[\log(\rho K_0) + \frac{\mu}{\rho}] - [\frac{1}{x} + log x + \frac{\sigma^2 x^2}{2\rho}],$$

[12] This simplifying assumption can be relaxed, by assuming agents derive some utility from public spending, without qualitatively changing our results, as long as we assume agents value public spending less than the government does.

underscoring that, because of log utility, the optimal risk exposure of agents ($x$) does not depend on their capital ($K_0$). The first order condition with respect to $x$ is

$$\frac{\sigma^2}{\rho}x^3 + x = 1. \tag{19}$$

Denote by $x^*$ the root of (19). Note that $x^* < 1$, i.e., hyperinflation is not beneficial for agents, and correspondingly not chosen by a benevolent government. While $x^*$ is the level of risk exposure that is optimal for the agents, the corresponding level of inflation is $\pi^* = \sigma^2 x^* - \mu$. By (17), and given that $\gamma = 0$ the corresponding optimal money supply growth rate is

$$g_m = \sigma^2 x^* - \frac{\rho}{x^*}. \tag{20}$$

Moreover, still using $\gamma = 0$, budget balance (12) implies

$$\tau = -g_m(1 - x^*). \tag{21}$$

We summarize the above analysis in our next proposition

**Proposition 2** *When the government is benevolent there is no hyperinflation and optimal money supply growth and optimal taxes are given by (20) and (21) respectively.*

Equation (20), shows that, depending on the value of $x^*$, optimal money supply growth can be positive of negative. If $x^*$ is relatively large, in the sense that

$$x^* \geq x_C \equiv \frac{\sqrt{\rho}}{\sigma}, \tag{22}$$

then optimal money supply growth is positive and, by (21), taxes are negative. In this regime, the benevolent government subdisizes agents ($\tau < 0$) by distributing them (helicopter) money. In contrast, when $x^* < x_C$, taxes are positive and money supply shrinks. As we will see in the following section, the link between $\tau$ and $g_m$ becomes more involved with a self-interested government, which also uses seigneurage and tax revenue to fund public spending.

### 2.4.2 Self-interested government

We now relax the assumption that the government is benevolent and assume instead that it derives utility from public spending, even if the latter don't benefit citizens. More precisely we assume that the objective of the government is

$$E[\int_0^\infty (\beta \log c_t + (1-\beta) log \gamma K_t) dt],$$

where $\beta$ is the weight placed by the government on the agents' expected utility and $(1-\beta)$ is the weight placed by the government on public spending. The objective of the government can be written as a function $U_G(x,\gamma)$ of $x$ and $\gamma$. It is such that:

$$\rho U_G(x,\gamma) = \beta[\log(\rho K_0) - \log x - \frac{\sigma^2 x^2}{2\rho}] + (1-\beta)\log \gamma K_0 + \frac{\mu - \gamma}{\rho} - \frac{1}{x}. \quad (23)$$

The first order condition with respect to $\gamma$ implies

$$\gamma = \rho(1-\beta). \quad (24)$$

Equation (24) implies that public spending increases with the rate of impatience of the government, $\rho$, and with the conflict of interest $(1-\beta)$ between the government and the agents.

The government maximizes its objective function (23) under the constraint that $x \leq 1$. When the optimal value of $x$ is strictly lower than one, the first order condition implies it is the unique root of

$$\frac{\sigma^2 x^3}{\rho} + x = \frac{1}{\beta}, \quad (25)$$

which we denote by $x^*(\beta)$. This root is lower than one when

$$\beta > \frac{\rho}{\sigma^2 + \rho}. \quad (26)$$

If (26) does not hold, then the government finds it optimal to set $x = 1$. The analysis above leads to our next proposition:

**Proposition 3** *A self interested government sets the public spending rate according to (24). Moreoever, if (26) holds, the government sets the monetary policy so that agents' risk exposure is given by (25). Otherwise there is hyperinflation, and agents don't hold any money ($x = 1$).*

The proposition states that hyperinflation occurs when the government puts a low weight on citizens' welfare, as (26) does not hold. The proposition also implies that, even if there is no hyperinflation, the inflation rate $\pi = \sigma^2 x - \mu$ is higher and the welfare of citizens lower than when the government is benevolent. in that case, the fraction $x^*(\beta)$ of their wealth that agents invest in capital is decreasing in the weight placed by the government on agents' welfare ($\beta$). This reflects that the government faces a trade-off. On the one hand a low value of $x$ implies low risk for the agents, which is valued by the government if the weight $\beta$ that it places on agents' welfare is large. On the other hand, a high value of $x$ implies large investment and thus large growth. In turn, this leads to large public spending, which are valued by the government if $\beta$ is low.

In our setting, monetary policy choices, and thus inflation, have a political economy interpretation. When the government is not benevolent (i.e., when $\beta$ is small), it wants to go for large spending . To fund this spending, the government needs high growth and correspondingly large investment. But agents may be reluctant to invest a lot in capital, because its output is risky. To ensure that agents still go for large investment, the non-benevolent government finds it optimal to go for high inflation.

If the government puts very little weight on agents' welfare(i.e., when $\beta$ is very small), we have that $x^*(\beta) > 1$, which means that agents only invest in capital and don't demand any money. They do so because inflation is so large that it is not worth holding money, i.e., there is hyperinflation. This leads to very low welfare for agents, as their risk exposure is very large, since they can't hold money to buffer productivity shocks. As we will see in the next section, in this context the ability to hold cryptocurrency can be valuable for agents.

# 3 Competition between public currency and cryptocurrency

## 3.1 Introducing a cryptocurrency in the model

Now turn to the case in which, at $t = 0$, $\hat{M}_0$ cryptocurrency tokens are issued and equally distributed to all agents. Ownership of the tokens is recorded on a blockchain, which, we assume, the government cannot tamper with. Cryptocurrency creation is set by the blockchain protocol. For simplicity, and without effect on our qualitative results, after the time 0 issuance the supply of cryptocurrency is kept constant through time.

To capture the risky nature of cryptocurrency, we assume it can crash. More precisely, we assume there is a Poisson process $N_t$ with intensity $\lambda$, which all agents observe. At the first jump of this process, cryptocurrency tokens become worthless, i.e., $\hat{p}_t$ goes to infinity. As in Garatt and Wallace (2018) and Biais et al (2023), there are two possible interpretations for the crash. The first interpretation is that the jump of the Poisson process is a sunspot: When they observe this sunspot, all agents expect the token to be valueless, and this expectation is self-fulfilling. This is because the cryptocurrency, just like the public currency, is a pure bubble, without any real counterpart or dividend, whose value stems from the belief that it is valuable. The second interpretation is that the Poisson process jumps when a major technological problem in the blockchain occurs, e.g., Byzantine nodes successfully attack the blockchain protocol (see, Pagnotta, 2022). We hereafter denote the time of the first jump of the Poisson process by $t^*$.

At any time $t < t^*$ an agent holds capital $k_t$, public currency $m_t$ (with price $p_t$), and cryptocurrency $\hat{m}_t$ (with $\hat{p}_t$). Correspondingly, an agent's real wealth is:

$$e_t = k_t + \frac{m_t}{p_t} + \frac{\hat{m}_t}{\hat{p}_t}.$$

As in the previous section, because utility is logarithmic and the environment is stationary (until the first jump of the Poisson process), portfolio shares are constant. We denote by $e_t$ the wealth of the agent, by $x$ the fraction of this wealth invested in capital, and by $b$ the fraction invested in public money. The share invested in cryptocurrency is $(1-b-x)$. So we have

$$k_t = xe_t, \frac{m_t}{p_t} = be_t, \frac{\hat{m}_t}{\hat{p}_t} = (1-b-x)e_t.$$

At the time of the cryptocurrency crash, the price of the public currency jumps from $p_t$ to $p_t^+$ (we use the superscript + to denote what happens after the crash.) Also, at the time of the crash the agent's wealth jumps to

$$e_t^+ = k_t + \frac{m_t}{p_t^+} = e_t(x + b\frac{p_t}{p_t^+}).$$

## 3.2 Agents' optimal decisions

As long as the cryptocurrency has not crashed, the environment is stationary: there exists a rational expectations equilibrium, characterized below, in which inflation is constant for both the public currency (whose inflation rate is denoted by $\pi$) and the cryptocurrency (whose inflation rate is denoted by $\hat{\pi}$), and the tax rate ($\tau$) also is constant. So the dynamics of an agent's wealth is given by:

$$\begin{aligned} \frac{de_t}{e_t} &= x(\mu dt + \sigma dB_t) - \left(\frac{c_t}{e_t} + \tau(b+x) + \pi b + \hat{\pi}(1-b-x)\right)dt \\ &\quad -dN_t(1-x-b\frac{p_t}{p_t^+}). \end{aligned}$$

The last term reflects that, when the Poisson process jumps so that $dN_t = 1$, the agent's wealth jumps from $e_t$ to $e_t^+ = e_t(x + b\frac{p_t}{p_t^+})$.

As in the previous section, because the utility function is logarithmic the value function also is logarithmic. Before the cryptocurrency crash there is a constant $\hat{u}(1)$ such that the value function of an agent is

$$\hat{u}(e) = \frac{\log(e)}{\rho} + \hat{u}(1).$$

Correspondingly, similarly to the previous section, the Bellman equation for the agent is

$$\rho\hat{u}(e) = \max_{c,x,b} \log c + \frac{1}{\rho}(\mu x - (\pi b + \tau(b+x) + \hat{\pi}(1-b-x))) + \frac{\sigma^2 x^2}{2\rho} + \lambda(log(x + b\frac{p}{p^+}))$$

The last term reflects the possibility of a cryptocurrency crash, a Poisson event with intensity $\lambda$. As in the case without cryptocurrency, the first order condition with respect to consumption yields

$$c = \rho e.$$

The portfolio choice problem of the agent is to choose $x$ and $b$, such that $x+b \leq 1$ to maximize

$$\mu x - (\tau(b+x) + \pi b + \hat{\pi}(1-b-x)) - \frac{\sigma^2 x^2}{2} + \lambda \log(x + b\frac{p_t}{p_t^+}).$$

Denoting by $\nu$ the multiplier of the constraint $b+x \leq 1$, the first order condition with respect to $x$ is

$$\tau + \sigma^2 x - \mu + \nu = \hat{\pi} + \frac{\lambda}{x + b\frac{p}{p^+}}.$$

This optimality condition states that at the optimum the marginal cost of holding capital is equal to the marginal cost of holding the cryptocurrency. The left-hand side of the equality is the marginal cost of holding capital, equal to the tax rate $\tau$, plus the penalty for risk net of the expected productivity $\sigma^2 x - \mu$, plus the shadow cost of the constraint that $x + b \leq 1$. The right-hand side is the marginal cost of holding the cryptocurrency, equal to the cryptocurrency inflation rate plus the risk premium associated with the risk of cryptocurrency crash. Similarly, the first order condition with respect to $b$ is

$$\pi + \tau + \nu = \hat{\pi} + \frac{\lambda\frac{p}{p^+}}{x + b\frac{p}{p^+}}, \tag{27}$$

where the left hand side is the marginal cost of holding the public currency, equal to inflation, plus tax, plus the shadow price of the constraint, and the right-hand side is the marginal cost of holding the cryptocurrency, equal to inflation plus the crash risk premium.

## 3.3 Without cryptocurrency crash

Before characterizing equilibrium in the general case, to build intuition we first consider the case in which there is no crash risk, i.e., $\lambda = 0$. In this case one could expect the cryptocurrency to crowd out the public currency, if only because it enables agents to avoid taxation. The arbitrage between the two currencies, however, is also affected by their relative inflation rates which are endogenous. This raises the possibility of an interior equilibrium in which agents are indifferent between the two currencies and hold both. When agents hold both currencies we have $\nu = 0$ and, for $\lambda = 0$, (27) becomes

$$\pi + \tau = \hat{\pi}. \tag{28}$$

This can be viewed as a no arbitrage condition, expressing that if both currencies are held they must have equal holding costs: inflation plus taxes for official money, and only inflation for the cryptocurrency which evades taxes. Since the equilibrium is stationary, the real value of the stock of each currency grows at the same rate as the capital stock. Therefore, since the growth rate of public currency supply is $g_m$, while that of the cryptocurrency is 0, we have

$$g = -\pi + g_m = -\hat{\pi}. \tag{29}$$

Combined with the no-arbitrage condition (28), condition (29) implies that

$$\tau = -g_m. \tag{30}$$

Equality (30) states that, if both currencies are to be held, public currency must be in scarce supply to remain attractive in spite of taxation.[13] Moreover, the budget constraint of the government writes:

$$\gamma x = g_m b + \tau(x + b). \tag{31}$$

Substituting (30) into (31), we have that

$$\gamma = \tau = -g_m. \tag{32}$$

Note that $\gamma = \tau$ means that public spending is entirely funded by taxes. Substituting the first order condition with respect to $x$:

$$\pi = \sigma^2 x - \mu, \tag{33}$$

the definition of $g$

$$g = \mu - \gamma - \frac{\rho}{x}, \tag{34}$$

and (32) into (29), we obtain that $x$ must be equal to $x_C$ (defined in equation (22).) So we can state our next proposition:

**Proposition 4** *When $\lambda = 0$ (the cryptocurrency never crashes) any interior equilibrium (in which agents hold both currencies) is such that $x = x_C$ and $\gamma = \tau$, i.e., public spending is entirely funded by taxes.*

Thus when the cryptocurrency competes with the public currency and there is no crash risk, i) agents don't hold public currency unless the inflation rate is limited to $\pi = \sigma^2 x_C - \mu$, and ii) the government must finance its expenditures solely by taxes: $\gamma = \tau$. So, when there is no crash risk, competition from the cryptocurrency exerts a strong disciplining effect on government policy. We show hereafter that, even when the cryptocurrency is subject to crash risk, it still has a disciplining effect.

## 3.4 Equilibrium when the cryptocurrency can crash

We now consider the general case, in which the cryptocurrency can crash. Denote by $E_t^+$ the aggregate wealth of the agents after the crash. After the crash, there is no cryptocurrency any more, so agents only can hold capital and public currency. In that context, government policy and agents' behaviour are as in the case without cryptocurrency, analyzed in the previous section. Correspondingly, when (26) holds, the government finds it optimal to conduct economic policies such that agents hold fraction $x^*(\beta)$ of their wealth in capital, and fraction $1 - x^*(\beta)$ in money, where $x^*(\beta)$ is defined just after equation (25). In this case, aggregate money demand is

$$M_t = (1 - x^*(\beta))E_t^+,$$

[13] That is when taxes are positive ($\tau > 0$), otherwise holdings of public currency are subsidized, which makes them attractive even if the supply of public currency grows.

while aggregate capital demand is

$$K_t = x^*(\beta)E_t^+.$$

Before the cryptocurrency crash, agents hold fraction $x$ of their wealth in capital. Noting that the stock of productive capital is unchanged by the crash, we obtain a "conservation of capital" equation

$$K_t = xE_t = x^*(\beta)E_t^+.$$

Bearing in mind that, at the time of the cryptocurrency crash, an agent's wealth jumps from $e_t$ to $e_t^+ = e_t(x + b\frac{p_t}{p_t^+})$, we have

$$\frac{E_t^+}{E_t} = x + b\frac{p_t}{p_t^+}.$$

Combining this equation with the conservation of capital equation we have

$$x + b\frac{p_t}{p_t^+} = \frac{x}{x^*(\beta)}. \tag{35}$$

Thus, the impact of the cryptocurrency crash on agents' wealth runs through the price change, which, by (35), is

$$\frac{p_t}{p_t^+} = \frac{x(1 - x^*(\beta))}{bx^*(\beta)}.$$

To characterize equilibrium in the economy with cryptocurrency, we also need to write the government budget constraint

$$(\gamma - \tau)\, x = (\tau + g_m)b,$$

the economy's growth rate, which takes the same form as in the previous section

$$g = \mu - \gamma - \frac{\rho}{x},$$

the cryptocurrency inflation rate, which is $\hat{\pi} = -g$, since the supply of cryptocurrency is constant while the economy grows at rate $g$, and finally the relation between money supply growth, inflation and economic growth

$$g_m = \pi + g.$$

Substituting these equalities in the first order conditions of the agent's portfolio problem, we obtain our next proposition (whose proof is in the appendix).

**Proposition 5** *Assume $\rho + \lambda \leq \sigma^2$ and (26) holds. When a cryptocurrency competes with the public currency, $x$ cannot be above*

$$x_C(\lambda) \equiv \frac{\sqrt{\rho + \lambda}}{\sigma}.$$

*Thus, government policy is either such that $x = x_C(\lambda)$, in which case, agents hold cryptocurrency, or such that $x < x_C(\lambda)$, in which case agents don't hold any cryptocurrency.*

When there is no cryptocurrency crash risk, i.e., $\lambda = 0$, the maximum level of risk exposure is $x_C(0) = x_C$, as in Proposition 4.

### 3.5 Government policy

The objective of the government is similar to its counterpart without cryptocurrency. The difference is that, when there initially is a cryptocurrency, the government must take into account that the fraction of their wealth which agents invest in capital is $x_t$ which varies with time. So we have

$$\rho U_G = E \int_{t=0}^{\infty} e^{-\rho t} \left[ \beta \left( \log \left( \frac{\rho}{x_t} K \right) - \frac{\sigma^2 x_t^2}{2\rho} \right) + (1-\beta) \log(\gamma K) + \frac{\mu - \gamma - \frac{\rho}{x_t}}{\rho} \right] dt,$$

subject to the constraint that $x_t = x \leq x_C(\lambda)$ for $t < t^*$, where $t^*$ denotes the (Poisson) time at which the cryptocurrency crashes. In this context, as shown in the appendix, the optimal policy of the government is as stated in our next proposition:

**Proposition 6** *When there is a cryptocurrency, government spending is the same as without the cryptocurrency, i.e., $\gamma = \rho(1-\beta)$. Moreover, after the crash of the cryptocurrency ($t > t^*$), the government follows the same monetary policy as that characterized above for the case without a cryptocurrency, leading, when (26) holds, to: $x_t = x^*(\beta)$. Finally, before $t^*$,*

- *if $x^*(\beta) \leq x_C(\lambda)$ the government finds it optimal to set monetary policy such that $x = x^*(\beta)$ and agents don't hold any cryptocurrency,*
- *if $x^*(\beta) > x_C(\lambda)$, the government finds it optimal to set monetary policy such that $x = x_C(\lambda)$, and agents hold cryptocurrency.*

When the government is rather benevolent (i.e., $\beta$ is high), it does not want to set inflation too high. Correspondingly, it does not want to set $x$ too high. This corresponds to a relatively low value of $x^*(\beta)$, below $x_C(\lambda)$. In that case, agents are satisfied with holding capital and the public currency, and don't find it optimal to hold cryptocurrency. So the government is not constrained in its monetary policy by competition from the cryptocurrency.

In contrast, when the government is quite non-benevolent (i.e., $\beta$ is lo¡), it would like to conduct monetary policy such that inflation would be high, and correspondingly $x$ would be high, as $x^*(\beta) > x_C(\lambda)$. In that case, competition from the cryptocurrency prevents the government from conducting such predatory policy. It curbs inflation and caps $x$ at $x_C(\lambda)$.

Note that $x_C(\lambda) = (\sqrt{\rho + \lambda})/\sigma$ is increasing in the risk of crash of the cryptocurrency ($\lambda$). If the cryptocurrency is very risky, agents are reluctant to hold it. Therefore the competitive pressure exerted by the cryptocurrency is weak, and does not constrain government very much.

The proposition also yields implications about the macroeconomic impact of the cryptocurrency. When the government is non benevolent and the cryptocurrency is not too risky, growth is lower and agents' consumption is larger with the cryptocurrency than without it. Moreover, agents bear less risk with the cryptocurrency than without it. Overall, when agents hold the cryptocurrency, its existence makes agents better off and the non benevolent government worse off.

# 4 Conclusion

In our model, money is valuable (although it has no intrinsic value and is not backed by any real asset) because it is a safe asset, useful for agents who seek to buffer their productivity shocks.

When there is no cryptocurrency, the government has monopoly power on the issuance of money. In that case, when the government is non benevolent, it runs an expansionary monetary policy, giving rise to high inflation, compelling agents to save by investing in risk real assets. Since these assets are productive, they generate large aggregate output, which the government can tax to indulge in large public spending. In the limit, when the government is very non-benevolent, this leads to hyperinflation, in which case money is valueless and agents only hold real and risky assets. The corresponding large risk exposure reduces the agents' welfare.

When there is a cryptocurrency, competing with the public currency, it prevents the government from running such an inflationary policy. Competition from the cryptocurrency caps how much inflation the government can go for. This raises agents' welfare relative to the situation in which there is no cryptocurrency, a resulting echoing Hayek's (1976) advocacy for the denationalisation of money.

## Appendix: Proofs

**Proof of Proposition 5:**

Since the supply of cryptocurrency is constant, while economy grows at rate $g$, the inflation rate for the cryptocurrency is

$$\hat{\pi} = -g = \gamma + \frac{\rho}{x} - \mu.$$

Substituting the value of $\hat{\pi}$ into the first-order condition with respect to $x$ we get:

$$\gamma - \tau = \sigma^2 x - \frac{\rho + \lambda x^*(\beta)}{x} + \nu.$$

Moreover, since $g_m = \pi + g$ we have:

$$\hat{\pi} - \pi = -g_m.$$

Substituting this equality into the first-order condition with respect to $b$ we have that

$$\tau + g_m = \lambda \frac{(1 - x^*(\beta))}{b} - \nu$$

Substituting into the government budget constraint

$$(\gamma - \tau)\, x = (\tau + g_m) b$$

the two first order conditions, we have

$$(\gamma - \tau)\, x = \sigma^2 x^2 - (\rho + \lambda x^*(\beta)) + \nu x, (\tau + g_m) b = \lambda(1 - x^*(\beta)) - \nu b.$$

Substituting the complementary slackness condition

$$\nu(x + b - 1) = 0,$$

we have $\sigma^2 x^2 = \rho + \lambda - \nu$. That is

$$x = \frac{\sqrt{\rho + \lambda - \nu}}{\sigma},$$

which establishes the first point in the proposition, that when there is a cryptocurrency competing with the public currency, $x$ cannot be above

$$x_c = \frac{\sqrt{\rho + \lambda}}{\sigma}.$$

The two other claims in the proposition stem from considering the case in which the constraint $x + b \leq 1$ binds and the case in which the constraint does not bnd.

QED

**Proof of Proposition 6:**

The objective is additive separable in $x_t$ and $\gamma$. So we can take the first order condition with respect to $\gamma$ and obtain the optimal budget policy of the government

$$\gamma = \rho(1-\beta),$$

which remains the same as without the cryptocurrency. The program of the government then simplifies to

$$\max_{x_t} E \int_{t=0}^{\infty} e^{-\rho t} \left[\beta\left(\log\left(\frac{1}{x_t}\right) - \frac{\sigma^2 x_t^2}{2\rho}\right) - \frac{1}{x_t}\right] dt,$$

subject to the constraint that $x_t = x \leq x_c$ for $t < t^*$. Separating the terms before the cryptocurrency crash from the terms following the crash, the objective of the government becomes

$$\max_{x_t} E \left( \int_0^{t^*} e^{-\rho t} \left[\beta\left(\log\left(\frac{1}{x_t}\right) - \frac{\sigma^2 x_t^2}{2\rho}\right) - \frac{1}{x_t}\right] dt + \int_{t^*}^{\infty} e^{-\rho t} \left[\beta\left(\log\left(\frac{1}{x_t}\right) - \frac{\sigma^2 x_t^2}{2\rho}\right) - \frac{1}{x_t}\right] dt \right),$$

subject to the constraint that $x_t = x \leq x_c$ for $t < t^*$. After the crash the government finds it optimal to set $x_t = x^*(\beta)$. So the program of the government simplifies to

$$\max_{x \leq xlc} E \left( \begin{array}{c} \left(\int_0^{t^*} e^{-\rho t} dt\right) \left[\beta\left(\log\left(\frac{1}{x}\right) - \frac{\sigma^2 x^2}{2\rho}\right) - \frac{1}{x}\right] \\ + \left(\int_{t^*}^{\infty} e^{-\rho t} dt\right) \left[\beta\left(\log\left(\frac{1}{x^*(\beta)}\right) - \frac{\sigma^2 x^*(\beta)^2}{2\rho}\right) - \frac{1}{x^*(\beta)}\right] \end{array} \right),$$

where the expectation is taken over the time at which the cryptocurrency crashes, $t^*$. So the program of the government is simply:

$$\max_{x \leq xlc} \frac{\rho}{\rho+\lambda} \left[\beta\left(\log\left(\frac{1}{x}\right) - \frac{\sigma^2 x^2}{2\rho}\right) - \frac{1}{x}\right] + \frac{\lambda}{\rho+\lambda} \left[\beta\left(\log\left(\frac{1}{x^*(\beta)}\right) - \frac{\sigma^2 x^*(\beta)^2}{2\rho}\right) - \frac{1}{x^*(\beta)}\right],$$

which yields the proposition.

QED

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