Money is an Experience Good:

Competition and Trust in the Private Provision of Money*

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Abstract

We study the interplay between competition and trust as efficiency-enhancing mechanims in the private provision of money. With commitment, trust is automatically achieved and competition ensures efficiency. Without commitment, competition plays no role. Trust does play a role but requires a bound on efficiency. Stationary inflation must be non-negative and, therefore, the Friedman rule cannot be achieved.

The quality of money can only be observed after its purchasing capacity is realized. In that sense money is an experience good.

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> There could be no more effective check against the abuse of money by the government than if people were free to refuse any money they distrusted and to prefer money in which they had confidence. (...) Therefore, let us deprive governments (or their monetary authorities) of all the power to protect their money against competition: if they can no longer conceal that their money is becoming bad, they will have to restrict the issue. (F.A. Hayek, 1974 *Choice in Currency: A Way to Stop Inflation* p.18. The Institute of Economic Affairs, London.)

1 Introduction

Can currency be efficiently provided by competitive markets? A traditional *laissez-faire* view – as, for example, has been expressed by Hayek – based on 'Bertrand competition', argues that competition drives the price of money to its marginal cost. Therefore, if the marginal cost of producing currency is zero, competition drives nominal interest rates to zero and private provision of currency is efficient.

We show that there is a major flaw in this 'Bertrand competition' argument, when applied to fiat money: if suppliers of currency cannot commit to their future actions, then competition loses its bite. The reason for this is that, while currencies compete on their promised rates of return, once agents hold a particular currency there may be an incentive for the issuer to inflate the price of goods in terms of this currency, reducing, in this way, its outstanding liabilities. Current currency portfolios have been pre-specified, while there is full flexibility to choose tomorrow's portfolios. Currencies compete for tomorrow's portfolios. When choices are sequential, currencies are no longer perfect substitutes; in a sense, they are not substitutes at all. Does "Bertrand competition" still drive promised rates of return to the efficient level? Not if those promises are not credible, if issuers of currencies are not trusted.

Trust may solve the time inconsistency problem in the supply of money, since concern for the future circulation of money may deter currency issuers from creating inflation. Nevertheless, reputation concerns exist as long as currency suppliers expect sufficiently high future profits to refrain from capturing the short-term gains. Does competition, by driving down profits, enhance efficiency but also destroy the disciplinary properties of the 'trust mechanism'? We show that there is no such trade-off. Without commitment, competition plays no role in sustaining efficient outcomes.

We analyze a model of currency competition where goods are supplied in perfectly competitive markets, and consumers can buy these goods by using any of a continuum of differentiated currencies. Each currency is supplied by a profit maximizing firm. Even though the currencies are imperfect substitutes, by making the degree of substitutability arbitrarily large we can characterize the limiting economy of perfect substitution among currencies. With commitment, currency competition achieves the efficient (Friedman rule) monetary equilibrium, as Hayek envisioned. It does this in a remarkable way: because the cost of providing money is very low, even a very large mark up is associated with a very low price charged for the use of money. In the limit, as the cost of producing money converges to zero, the equilibrium is efficient whatever the elasticity of substitution across competing currencies is.

The Friedman rule condition of zero nominal interest rates implies that inflation will be negative on average, since real interest rates are on average positive. Currency issuers will have to withdraw money from circulation, which means that cash flows will be negative. Even if the total revenues from currency issuance, including the gains from the initial issuance, may be positive, in each period losses will be incurred. In order for this to be an equilibrium, currency issuers must be able to commit to future losses.

Without commitment, negative inflation cannot be sustained. But, as it turns out, every stationary positive inflation is an equilibrium outcome, and the degree of substitutability does not affect this characterization. These are the main results of this paper: *i)* the existence of a bound on efficiency defined by the need to 'sustain trust'; *ii)* that the bound of efficiency corresponds to inflation being non-negative and *iii)* there exists an indeterminacy of equilibria with positive inflation rates and competition playing no role.

These results apply to other markets where goods or services must be purchased before their quality can be observed. Those goods are called *experience goods*.[1] There is a sense in which money is also an experience good. We can think of the quality of money as the amount of goods that money can buy, the real value of money, which can only be observed ex-post. The provision of money and the provision of experience goods seem a priori very different problems (the former being a commitment problem and the latter

[1] See Nelson (1970).

an information problem), but they are indeed isomorphic regarding the interplay between competition and trust. While the elasticity of substitution for high quality goods can be quite high, once the goods have been purchased the elasticity is zero. A supplier who does not take into account reputational concerns will only consider this elasticity, and will not supply high quality goods or services. Still, in a dynamic economy, firms are concerned about their future market position, so that the need to maintain 'trust' in their products may be enough to discipline them to effectively provide high quality goods. The mechanism that can sustain high quality (and possibly low prices) is 'trust,' not 'competition.' This analogy is discussed in section 6.

The issue of currency competition has been the subject of an extensive academic debate. This debate has seen many supporters of free competition making an exception when it comes to money (Friedman, 1960), while advocates of free currency competition (notably, Hayek (1974 and 1978), and Rockoff, 1975) have been somewhat isolated. In spite of this, the relatively recent reappraisal of the self-regulating properties of free banking[2] has raised new interest in the study of currency competition.

The problem of time-inconsistency of monetary policies has been extensively studied since Calvo (1978),[3] but with the partial exceptions of Klein (1974) and Taub (1985), the currency competition argument has not been considered. Klein understood that the problem of currency competition could not be studied independently of the time inconsistency problem. Like Shapiro (1983), he postulated ad-hoc beliefs, so the way competition and reputation interplay in determining equilibrium outcomes is not analyzed. He raised some of the questions we address in this paper but without a full characterization as we do here. Similarly, Taub (1985) studies the interaction of commitment and competition using a different approach and obtaining different results; we discuss this in Section 5.

Marimon, Nicolini and Teles (2003) analyze the effects of electronic money, and other currency substitutes, on monetary policy, focusing on the case in which the central bank cannot commit to future policy. The suppliers of inside money must use an inefficient technology, relative to the provision of

[2]See, for example, Calomiris and Kahn (1996), Dowd (1992), King (1983), Rolnick and Weber (1983), Selgin (1987), Selgin & White (1987), Vaubel (1985), and, more generally, White (1989, 1993) . See also Schuler (1992), for an account of historical episodes of free banking, and Hayek (1974,1978), Dowd (1992) and White (1993).

[3]See, for example, Kehoe (1989), Chang (1998), Chari and Kehoe (1990), Ireland (1997) and Stokey (1991).

outside money. The main difference to the problem we study here is that the suppliers of inside money - banks - are assumed to behave competitively and to issue deposits in the same units of account as the outside money issued by the central bank. Thus, the banks are small and take prices as given and, as such, cannot manipulate the price level. It follows that they are not subject to the time inconsistency problem that the supplier of outside money faces. Competition from inside money does play a role in this context. Improvements in the technology to supply inside money do bring equilibrium inflation down. In this paper we are interested in analyzing competition in the provision of different currencies, and therefore the time inconsistency problem is shared by all the suppliers. The strategic interaction between money issuers and, more importantly, between each issuer and consumers is the main theme of this paper.[4]

An interesting application of the analysis in this paper is to competition in the supply of reserve currencies. For the issuer of a reserve currency with commitment there is a level of inflation that maximizes seigniorage revenues from nonresidents. The benevolent Ramsey planner will have to weigh those gains against the costs of distortionary inflation affecting resident agents. The resulting inflation rate could be reasonably high. Schmitt-Grohe and Uribe (2011) compute the optimal inflation rate for the US dollar and conclude that this could be the justification for the observed deviation from the Friedman rule. Taking our approach, we would add that competition with alternative providers of a reserve currency, such as the Euro, would imply different equilibrium outcomes. Under commitment, Bertrand competition would bring inflation back down to the Friedman rule. Without commitment, any positive inflation would be sustainable, as long as seigniorage revenues from non residents were the only objective of reserve currency issuers.

2 A model of currency competition

We consider an economy with a large number of identical households that draw utility from a single consumption good, c_t, and disutility from work

[4]Taub (1986) considers the problem of a monopolist that issues currency and can commit for a given number of periods. By varying the elasticity of money demand faced by the monopolist, Taub studies the interaction between the length of the commitment period and the implicit degree of competition.

effort, n_t. The utility function of the representative household is

$$\sum_{t=0}^{\infty} \beta^t \left[U(c_t) - \alpha n_t \right], \tag{1}$$

where U is increasing, concave and satisfies the Inada condition $\lim_{c \to 0} U'(c) = +\infty$; furthermore, $U(0) = 0$. α is a positive constant. The technology is linear in labour, with a unitary coefficient, so

$$c_t = n_t. \tag{2}$$

The consumption good is produced by perfectly competitive firms. Therefore the price of the consumption good in terms of labour will be one.

We assume that consumers must buy the consumption good with a composite of the continuum of all possible differentiated currencies. This composite money aggregate is defined as

$$m_t = \left[\int_0^1 m(i)_t^{1/\mu} di \right]^{\mu}, \ \mu > 1, \tag{3}$$

where $m(i)_t$ is the real value of type i money, used for transactions at time t. The currencies are imperfect substitutes but we consider imperfect substitutability only as a methodological device to study the limiting economy where substitutability is arbitrarily large. In the limit, each of the currencies has general purchasing power. This model is a natural framework for analyzing Hayek's conjecture that money can be supplied efficiently by the market, and, as such, it contains interesting implications for monetary theory.

The representative consumer maximizes utility subject to the following budget constraint:

$$b_{t+1} + \int_0^1 q(i)_t M(i)_{t+1} di + c_t \leq n_t + b_t(1 + r_t) + \int_0^1 q(i)_t M(i)_t di + \Pi_t, \ \ t \geq 0,$$

where $q(i)_t$ is the price of currency i in units of the consumption good and $M(i)_t$ is the quantity of money i, held from time $t-1$ to time t, and used for transactions at time t, so that $m(i)_t = q(i)_t M(i)_t$. $\Pi(i)_t$ are the current profits of the provider of currency i in units of the consumption good, $\Pi_t = \int_0^1 \Pi(i)_t di$. In every period t, the consumer purchases $M(i)_{t+1}$ of currency i

and real bonds b_{t+1} that pay the real interest rate r_{t+1} in period $t+1$. $M(i)_0$ and b_0 are given. This budget constraint can be written as

$$b_{t+1}+\int_0^1 m(i)_{t+1}\left(1+\pi(i)_{t+1}\right)di+c_t \leq n_t+b_t(1+r_t)+\int_0^1 m(i)_t di+\Pi_t,\ t\geq 0, \tag{4}$$

where $\pi(i)_{t+1}=\frac{q(i)_t}{q(i)_{t+1}}-1$.

The cash-in-advance constraint is

$$c_t \leq m_t = \left[\int_0^1 m(i)_t^{1/\mu} di\right]^{\mu}, t\geq 0. \tag{5}$$

Let $R(i)_{t+1}$ be the gross nominal interest rate from time t to $t+1$ on currency i, so that $R(i)_{t+1} \equiv (1+r_{t+1})(1+\pi(i)_{t+1})$, and let

$$R_{t+1}-1 \equiv \left[\int_0^1 \left(R(i)_{t+1}-1\right)^{\frac{1}{(1-\mu)}} di\right]^{1-\mu}.$$

Then, the first order conditions of the consumer's problem imply:

$$U'(c_{t+1}) = \alpha R_{t+1},\ t\geq 0,$$

$$m(i)_{t+1} = \left(\frac{R(i)_{t+1}-1}{R_{t+1}-1}\right)^{\frac{\mu}{1-\mu}} m_{t+1},\ t\geq 0, \tag{6}$$

$$r_{t+1} = \frac{1}{\beta}-1 \equiv \rho,\ t\geq 0,$$

together with (6), which is binding for $t\geq 1$, when $R_t>1$, for $t\geq 1$.

We now describe the problem of a currency issuer. The flow of funds condition for the issuer of currency i is given by

$$q(i)_t M(i)_{t+1} + d(i)_{t+1} = q(i)_t M(i)_t + d(i)_t(1+\rho) + \Pi(i)_t,$$

where $d(i)_{t+1}$ is the debt issued by the issuer of currency i at time t, in units of the consumption good, $\Pi(i)_t$ are the profits of the currency issuer in units of the consumption good, and $M(i)_0$ and $d(i)_0$ are both given. The issuer also faces a no-Ponzi game condition guaranteeing that the present value budget constraint is well defined. The present value of profits is

$$\sum_{t=0}^{\infty} \beta^t \Pi(i)_t = \sum_{t=1}^{\infty} \beta^t \left[R(i)_t - 1\right] m(i)_t - q(i)_0 M(i)_0 - \frac{d(i)_0}{\beta}. \qquad (7)$$

3 Equilibria with commitment

As in standard (single currency) monetary models, a monetary policy for the i-currency issuer consists of an initial currency price and a sequence of future nominal interest rates, $(q(i)_0, \{R(i)_t\}_{t=1}^{\infty})$.

In order to maximize the present value of profits (7), firms must choose $R(i)_t$ to maximize

$$\left[R(i)_t - 1\right] m(i)_t,$$

taking the demand for currency (6) as given. Optimality also requires that the real value of initial outstanding money holdings (liabilities for the issuer) become zero, $q(i)_0 M(i)_0 = 0$. As long as $M(i)_0 > 0$, this implies that $q(i)_0 = 0$, or that the initial price level is arbitrarily high. The price level must then be defined in the extended reals.[5]

The maximization of $\left[R(i)_t - 1\right] m(i)_t$ where $m(i)_t$ is given by (6), i. e.

$$\left[R(i)_t - 1\right] \left[\frac{R(i)_t - 1}{R_t - 1}\right]^{\frac{\mu}{1-\mu}} m_t, \qquad (8)$$

results in

$$R(i)_t = 1.$$

To see this, notice that the derivative of the function (8) above is

$$\frac{-1}{\mu - 1} \left[\frac{R_t - 1}{R(i)_t - 1}\right]^{\frac{\mu}{\mu-1}} m_t, \qquad (9)$$

which is always negative. Since the nominal interest rate cannot be negative, the solution is $R(i)_t = 1$. In equilibrium $R(i)_t = R_t = 1$. When $R_t = 1$, the cash-in-advance constraint does not have to hold with equality. But $c_t = m_t$, is still a solution of the households' problem. This corresponds to a stationary finite level of real money $m(i)_t = m$, such that

[5] This is a technical assumption that allows us to deal with infinite price levels, and also infinite growth rates of those prices.

$$\frac{U'(m)}{\alpha} = 1.$$

This equilibrium allocation, from $t \geq 1$, is the efficient one[6], since the allocation that maximizes utility (1) subject only to the production technology (2) is characterized by

$$\frac{U'(c_t)}{\alpha} = 1.$$

The equilibrium allocation from period one onwards is efficient independently of the elasticity of substitution across the competing currencies because money is costless to produce. If there were a cost of providing currency, δ, the flow of funds of the currency issuer were

$$\frac{1}{1+\delta} q(i)_t M(i)_{t+1} + d(i)_{t+1} = q(i)_t M(i)_t + d(i)_t(1+\rho) + \Pi(i)_t,$$

then the present value of profits would be

$$\sum_{t=0}^{\infty} \beta^t \Pi(i)_t = \sum_{t=1}^{\infty} \beta^t \left[\frac{R(i)_t}{1+\delta} - 1\right] m(i)_t - q(i)_0 M(i)_0 - \frac{d(i)_0}{\beta}.$$

Firms would then choose $R(i)_t$, $t \geq 1$, to maximize

$$\left[R(i)_t - 1 - \delta\right] m(i)_t$$

and the choice for the nominal interest rate would be

$$R(i)_t - 1 = \mu\delta.$$

The nominal interest rate, $R(i)_t - 1$, would be equal to the mark up μ times the marginal cost δ. The mark up μ is determined by the substitutability of the currencies. The closer μ is to one, the higher is the degree of substitutability. As currency substitution increases, i.e., $\mu \searrow 1$, nominal interest rates tend to δ, i.e. $R(i)_t - 1 \searrow \delta$, covering the production cost of real money.

As the cost of providing money is made arbitrarily close to zero, $\delta \searrow 0$, the price charged for it, being a constant markup over marginal cost, is also

[6] Notice that consumption in period $t = 0$ is zero, $c_0 = 0$, which obviously is not efficient.

close to zero. This is the case, regardless of the elasticity of substitution that determines the mark up. The nominal interest rate tends to zero, $R(i)_t - 1 \searrow 0$, i.e. the Friedman rule is implemented.

With full commitment, Hayek's conjecture, that efficient monetary equilibria can be achieved through currency competition, is verified[7]. But, as it turns out, the conjecture proves to be right in a particularly powerful way. The production cost of money is low; so low that it is usually assumed to be zero. The equilibrium is efficient because money is costless to produce even if there may be low elasticity of substitution across competing currencies.

The 'abuse of money by the government' Naturally, if there were a single supplier of a single money stock M_t in this economy the equilibrium would not be efficient. There would be monopoly profits, regardless of the cost of producing money.

The profits of the monopolist supplier of money are

$$\sum_{t=0}^{\infty} \beta^t \Pi_t = \sum_{t=1}^{\infty} \beta^t \left[R_t - 1 \right] m_t - q_0 M_0 - \frac{d_0}{\beta}, \tag{10}$$

which are the same as (7) without the i indexation. The monopolist takes into account that

$$U'(c_{t+1}) = \alpha R_{t+1},\ t \geq 0,$$

and the cash-in-advance constraint,

$$c_{t+1} \leq m_{t+1},\ t \geq 0,$$

which will hold with equality. Profits can be written as

$$\sum_{t=0}^{\infty} \beta^t \Pi_t = \sum_{t=1}^{\infty} \beta^t \left[\frac{U'(m_t)}{\alpha} - 1 \right] m_t - q_0 M_0 - \frac{d_0}{\beta}. \tag{11}$$

The optimal solution will be to set $q_0 M_0 = 0$, and choose a constant $m_t = m$, $t \geq 1$, such that

$$\frac{U'(m)}{\alpha} \left[\frac{U''(m)m}{U'(m)} + 1 \right] - 1 \leq 0.$$

[7] With the caveat that there is an inefficiency in period zero.

This inequality is required because there could be a corner solution where $m = 0$.

Let $\sigma(m) \equiv -\frac{U''(m)m}{U'(m)}$. Then, the expression can be written as

$$\frac{U'(m)}{\alpha}\left[1-\sigma(m)\right]-1 \leq 0.$$

Let $\sigma(m) = \sigma$, with $0 < \sigma < 1$.[8] Then, there is an interior solution described by

$$\frac{U'(m)}{\alpha} = \frac{1}{1-\sigma} = R,$$

so that there is a distortion even with $\delta = 0$, which is larger the lower the price elasticity $\frac{1}{\sigma}$ is.

Time consistency and intertemporal seigniorage accounting As in standard single currency monetary models, the full commitment policy is time inconsistent. This can easily be seen by considering how the present value of profits of a currency issuer evolves over time. At time t, this is

$$\sum_{j=t}^{\infty} \beta^{j-t}\Pi(i)_j = \sum_{j=t+1}^{\infty} \beta^{j-t}\left[R(i)_j - 1\right] m(i)_j - q(i)_t M(i)_t - \frac{d(i)_t}{\beta}. \qquad (12)$$

Thus, if given the option of changing plan at time t, which we rule out when assuming full commitment, the currency issuer will find it optimal to let $q(i)_t M(i)_t$ be zero. The reason is that, while the real money demand is decreasing in the nominal interest rate – i.e. in the expected future price level – once consumers have made their currency decisions, the nominal money demand is predetermined and therefore it is rigid with respect to the current price level.

The real value of the outstanding money balances $q(i)_t M(i)_t$ is set to zero through an initial big open market operation in which currency $M(i)_{t+1}$ is issued in an arbitrarily large amount and lent to the households. Each currency issuer takes a negative position in bond holdings in an amount equal to the real quantity of money. In this way the currency issuer is able to eliminate its outstanding liabilities and reissue the money stock.

[8] This is the case that is consistent with our assumption that $U(0) = 0$.

What is then the seigniorage revenue when the value of outstanding currency is set to zero? For a constant nominal interest rate $R(i)_j = R(i)$, $j \geq t+1$, the expression for seigniorage revenue is

$$\frac{\beta}{1-\beta}\left[R(i)-1\right]m(i) - q(i)_0 M(i)_0 = \frac{\beta}{1-\beta}\left[R(i)-1\right]m(i). \tag{13}$$

In every period, the issuer of currency receives the nominal interest rate times the real quantity of money. Suppose now that the value of outstanding currency is not set to zero, but that it is equal to the stationary level of real balances $m(i)$. Then, again for a constant nominal interest rate $R(i)_j = R(i)$, $j \geq t+1$, seigniorage revenue is

$$\frac{\beta}{1-\beta}\left[R(i)-1\right]m(i) - m(i) = \frac{1}{1-\beta}\pi(i)\, m(i). \tag{14}$$

In this case seigniorage revenue is zero when stationary inflation is zero; in the case above, if inflation is zero, seigniorage revenue is positive and equal to the present value of the real return on the money stock, i. e, the money stock itself. The full commitment equilibrium is time inconsistent because each currency issuer would want to reissue every period.

In an equilibrium with stationary positive inflation, seigniorage revenues are positive as of period zero, when the currency issuer takes into account the gains from the initial issuance, but they are also positive in all the future periods. Instead, when inflation is negative, the gains are still positive as of period zero, because the nominal interest rate is positive, but they are negative from there on.

The efficient equilibrium with full commitment is supported with negative inflation; i.e. $\pi(i)_t \searrow (\beta - 1)$. Stationary profits are therefore negative. This seigniorage accounting is at the core of the intertemporal incentives faced by a currency issuer deciding sequentially. We turn now to the analysis of the case without commitment.

4 Currency competition without commitment

With full commitment, there is no distinction between ex-ante and ex-post nominal interest rates. We were able to specify the decisions of the currency issuer in terms of the whole sequence of ex-ante nominal interest rates, $\{R(i)_t\}_{t=1}^{\infty}$, which depend on the realization of future prices. Without commitment, that cannot be done. We have to define the strategies of the currency issuer in terms of realized, ex-post nominal interest rates. We define these as $R^q(i)_t = (1+\rho)(1+\frac{q(i)_{t-1}}{q(i)_t})$, in the extended reals: $R^q(i)_t \in [1,+\infty) \cup \{+\infty\}$.

Firms maximize short-run profits by setting an arbitrarily large price, $P(i)_t$, corresponding to $q(i)_t = 0$, and to an arbitrarily large, ex-post nominal interest rate, $\frac{1}{R^q(i)_t} = 0$. This means that outstanding money holdings will be inflated away (making 'the quality of outstanding money' arbitrarily low). Consumers purchase currencies before they observe the real return they yield, and must form their expectations of future prices, based on past information and current prices. Reputation is the only thing that can prevent firms from 'flying-by-night.'

Currency issuers choose $R^q(i)_t = (1+\rho)(1+\frac{q(i)_{t-1}}{q(i)_t})$, except for the first period where $q(i)_0$ is chosen, since $q(i)_{-1}$ is not defined[9]. Histories are given by $h_{-1} = \{\emptyset\}$, $h_0 = \{h_{-1}, q(i)_0\}$ and $h_t = \left\{h_{t-1}, \frac{1}{R^q(i)_t}, \text{ all } i\right\}$, for $t \geq 1$. The i-currency issuer strategy is given by

$$\begin{aligned} \sigma^b_{i,0}(h_{-1}) &= q(i)_0, \text{ and} \\ \sigma^b_{i,t}(h_{t-1}) &= \lambda_{i,t}, \text{ for } t \geq 1, \end{aligned}$$

where $\lambda_{i,t}$ is a density function on R^+, such that $\lambda_{i,t}(h_{t-1}; \frac{1}{R^q(i)_t})$ is the density of $\frac{1}{R^q(i)_t}$, conditional on h_{t-1}.[10]

Consumers behave competitively, deciding according to the allocation rule $\sigma^c = \{\sigma^c_t(h_t)\}_{t=0}^{\infty}$, where $\sigma^c_t(h_t) = \{c_t, n_t, b_{t+1}, M(i)_{t+1}, \text{all } i\}$, for $t \geq 0$, based on υ^i_t – their beliefs about future decisions of the currency issuers – and the corresponding prices; where $\upsilon^i_t(h_t; \frac{1}{R^q(i)_{t+1}})$ denotes the assessed density of the ex-post interest rate $\frac{1}{R^q(i)_{t+1}}$. Rational expectations require that beliefs are consistent with currency issuers strategies,[11]

$$\upsilon^i_t(h_t; \frac{1}{R^q(i)_{t+1}}) = \lambda_{i,t+1}(h_t; \frac{1}{R^q(i)_{t+1}}).$$

[9] Note that given a history, choosing the price of the currency at time t, is equivalent to choosing the ex-post nominal interest rate.

[10] Since issuers decide on $q(i)_0$ before consumers make any decision, there is no need to introduce mixed strategies into that decision.

[11] Note that at time t consumers care about future monetary policy. That is why time t beliefs ought to be the same as firms' strategies at $t+1$.

A *Sustainable Currency Competition Equilibrium* (SCCE) consists of $\left((\sigma^c, \upsilon^i), (\sigma_i^b)\right)$, such that,

1. for every (t, h_t), $\sigma_{i,t}^b(h_{t-1})$ solves the maximization problem of the i-currency issuer;
2. $\sigma_t^c(h_t)$ solves the consumer's problem given consistent beliefs $\upsilon_t^i(h_t; \frac{1}{R^q(i)_{t+1}})$;
3. all markets clear.

A *Sustainable Currency Competitive Equilibrium* provides a natural framework within which to study the interactions between competition and trust. On the one hand, as long as μ is strictly larger than one, the economy exhibits monopoly power, and as μ gets close to one, the competition between issuers is increased. On the other hand, the beliefs of the consumers depend on the firms' actions. In this sense, the firms care about their reputation.

In what follows, we restrict our attention to *symmetric equilibria* in the sense that all firms behave the same way in equilibrium.

Let us consider an equilibrium where strategies do not depend on histories. If the current actions of the issuers of currency do not affect consumers' expectations about their future actions, then it is a dominant strategy for the issuer of each currency to choose $\frac{1}{R^q(i)_t} = 0$, for every $t \geq 1$. At $t = 0$, $q(i)_0 = 0$. It follows that the currency will not be held, $m(i)_{t+1} = 0$, $t \geq 0$. The resulting payoff for the issuer, as of any period $t \geq 0$, is $-\frac{d(i)_t}{\beta}$. The issuers can guarantee themselves this payoff independently of consumer beliefs. In fact, notice that the present value of profits can be written as

$$\sum_{j=t}^{\infty} \beta^{j-t} \Pi(i)_j = \sum_{j=t+1}^{\infty} \beta^{j-t} \left[R^q(i)_j - 1\right] m(i \mid \upsilon_{j-1}^i)_j - q(i)_t M(i)_t - \frac{d(i)_t}{\beta}. \quad (15)$$

where the demand for currency i, $m(i \mid \upsilon_{j-1}^i)_j$, depends on the beliefs υ_{j-1}^i. Given that $m(i \mid \upsilon_{j-1}^i)_j \geq 0$, the minimum value of profits is $-\frac{d(i)_t}{\beta}$. This is the case when $q(i)_j = 0$, $\frac{1}{R^q(i)_{j+1}} = 0$, and $m(i \mid \upsilon_{j-1}^i)_j = 0$, for all $j \geq t$. This equilibrium is, therefore, *the worst SCCE*. More formally,

Proposition 1 *There exists a* low quality SCCE, *supported by strategies* $q(i)_0 = 0$, *and* $\lambda_{i,t}(h_{t-1}; 0) = 1$, *and beliefs* $\upsilon_t^i(h_t, 0) = 1$. *Furthermore, there is no SCCE with lower payoffs for the currency issuers.*

Proof: Given the degenerate beliefs $v_t^i(h_t, 0) = 1$, for the households $R^q(i)_t = R(i)_t = R_t = +\infty$, $t \geq 1$, with probability one. From the money demand equation, $U'(c_{t+1}) = \alpha R_{t+1}$, and given the Inada condition and the cash-in-advance constraint: $c_{t+1} = m_{t+1} = m(i)_{t+1} = 0$. Given the demands are zero, the strategy of the issuers for $t \geq 1$ is a best reply. Furthermore, at $t = 0$, it is optimal to set $q(i)_0 = 0$. The consistency of beliefs condition is satisfied. Therefore, this is a SCCE. It is also the worst SCCE, with payoff $-\frac{d(i)_t}{\beta} = -\frac{d(i)_0}{\beta}$ for each period $t \geq 0$. Suppose there was a worse equilibrium. Then each currency issuer could deviate, follow the strategies above, and guarantee that payoff. Notice that the term $-\frac{d(i)_t}{\beta}$ in (15) cannot be affected, the first term is positive, $\sum_{j=t+1}^{\infty} \beta^{j-t} \left[R^q(i)_j - 1\right] m(i \mid v_{j-1}^i)_j \geq 0$, and the term $q(i)_t M(i)_t$ can be set to zero, independently of the beliefs.■

In this worst SCCE, no issuer is ever trusted to provide high-quality money. This would be the unique outcome if issuers were anonymous players, not accountable for their past decisions.

We now check whether a stationary gross nominal interest rate, $R = R(i)$, is sustainable as a SCCE. In order to check this, we consider the standard trigger strategies of reverting to the worst SCCE strategies, which in our context should be understood as a generalized loss of confidence in a currency when there is a deviation from an equilibrium path. Suppose that the i-currency issuer considers a deviation in period $t > 0$, letting $\frac{1}{R^q(i)_t} \to 0$, by printing an arbitrarily large quantity of money. Suppose that agents' expectations are such that, after observing that the *ex-post* rate differs from the equilibrium outcome R, they become $v_{t+s}^i(h_{t+s}; \frac{1}{R^q(i)_{t+1+s}} = 0) = 1$, for any h_{t+s}, $s \geq 0$. Given such beliefs, real money demand for that currency is zero from time t on, i.e., $m(i)_{t+s} = 0$, $s \geq 0$, which means that the newly issued pieces of paper are worthless.

The value of the outcome after the deviation is zero, except for the value of the outstanding real debt. The reason is that the deviation triggers a currency collapse for that currency, starting tomorrow. The demand for money, being an asset, depends on future prices. Thus, the expectations of the currency collapse make the newly injected money be worthless today. Therefore, the present value of the benefits following a deviation is obtained by replacing the real value of money from time t on by zeroes in the expression for profits (12)

$$V^D(i)_t = -\frac{d(i)_t}{\beta}.$$

On the other hand, if the issuer does not deviate, the present value of the profits are

$$\begin{aligned} V^C(i)_t &= \beta \frac{[R(i) - 1] \, m(i)}{1 - \beta} - q(i)_t M(i)_t - \frac{d(i)_t}{\beta} \\ &= \rho^{-1} [R(i) - 1] \, m(i) - m(i) - \frac{d(i)_t}{\beta}. \end{aligned}$$

The last equality follows from the fact that, in equilibrium, $m(i) = q(i)_t M(i)_t$. It follows that the i-currency issuer will choose not to deviate when

$$\rho^{-1} [R(i) - 1] - 1 \geq 0,$$
$$\text{i.e. } R(i) \geq 1 + \rho.$$

Since $R(i) = (1 + \rho)(1 + \pi(i))$, the condition is satisfied, whenever

$$\pi(i) \geq 0.$$

An equilibrium path with symmetric stationary policies is sustainable if and only if the corresponding inflation rates are non-negative. The reason why inflation must be non-negative is because of the timing of collection of revenues for the issuers.

A positive nominal interest rate guarantees that the seigniorage revenue is positive as of time 0, when the real value of the initial outstanding money stock is zero (recall equation (13)). The nominal interest rate is equal to the real interest rate, which is the period-by-period return on the initial issuance of money, plus the inflation rate. The issuers of currency lend the initial money balances to the households. Thus, they hold positive assets in an amount equal to the real value of those balances. From those assets they collect the real rate of interest, ρ. As of any period $t \geq 1$, the gains from the initial issuance of money are sunk. All that matters for the currency issuers is the additional revenue given by the depletion each period of the real quantity of money. Inflation must therefore be positive and the nominal interest rate must be higher than the real, to guarantee positive profits in each period t; therefore the inflation rate must be non-negative (equation (14)). More formally,

Proposition 2 $\pi(i) = \pi$ *is an outcome of a stationary symmetric SCCE if and only if* $\pi \geq 0$.

Proposition 2 has two implications. The first is that sustainable equilibria are inefficient. While with commitment it is necessary that the present value of profits at date zero is positive, without commitment profits must be non-negative in any period, and that implies that there must be strictly positive profits in period zero. The second implication is that competition plays no role in the absence of commitment, regardless of whether there are competing currencies or a single supplier of a single currency.[12] The set of sustainable equilibria is characterized by $\pi \geq 0$, independently of the elasticity of substitution. Notice that the set of equilibria would be the same if there were a single currency and a single supplier of it.

In summary, without full commitment, Hayek's conjecture that efficient monetary equilibria can be achieved through currency competition is not verified, as long as optimality requires deflation in equilibrium, as in Friedman's rule – of a zero nominal interest rate associated with deflation when $\rho > 0$.

The discount rate ρ does not affect the condition on inflation for sustainability. However it does affect the efficiency of the lowest inflation equilibrium. The lower ρ is, the closer is zero inflation to the efficient outcome. Now, does this mean that if the length of the time period were shortened, it would be possible to sustain more efficient outcomes? No, that should not be the case. In a monetary model, the currency issuer compares the gains from depleting the outstanding stock of money with the future flows from money issuance. The gains from the depletion of the initial stock should not be affected by the length of the time period, and neither should, the present value of future gains. The model does not distinguish between a direct change in ρ and a change in the length of the time period. In order to be able to establish that distinction, velocity needs to be variable. We have considered that velocity is one. By doing this we have pinned down the length of the time period. Because velocity relates the stock of money to the flow of consumption, the shorter the time period is, the lower is velocity. In the limit as the time period goes to zero, while the stock of money remains constant, the flow of consumption converges to zero, and so does velocity. At zero velocity, even a very small nominal interest rate would mean an arbitrarily large cost of using money. As the length of the time period goes down, velocity also goes down, in such a way that the future gains from money issuance are invariant to that change.

[12] With $\delta = 0$, increasing competition plays no role in the commitment case but there would be monopoly profits with a single monopolist.

5 Robustness

In the monetary model of currency competition that we have analyzed, in any time period, there are two relevant elasticities of substitution. On the one hand, the holder of currency will be considering alternative currencies to hold in the future. The opportunity cost of holding each currency is the future return on interest-bearing assets denominated in that currency. The elasticity of substitution could be quite high, possibly arbitrarily large. On the other hand, currency holders also hold outstanding money balances. Those balances are whatever they are: they cannot be changed. On these outstanding money balances, the elasticity is zero. For the currency issuer, the elasticity of substitution that is relevant for current decisions is zero, while the elasticity of substitution that is relevant for future decisions is positive; it could even be infinite.[13] With commitment, the issuer of currency will always want to exploit the initial period zero elasticity, and inflate away those initial liabilities. Commitment, precisely, is the capacity to credibly restrain from extracting these short-term rents. In addition, there would then be competition in nominal interest rates. As it turns out, because money is costless to produce competition will drive down the price of money to its marginal cost regardless of the elasticity of substitution across currencies. As seen in section 3, for a small cost of providing currencies, the outcome would depend on the elasticity of future money holdings. In particular, if this elasticity is arbitrarily large, then the equilibrium outcomes will be efficient, as the cost of production also converges to zero.

Instead, if the currency issuer is unable to commit to future decisions, then competition in nominal interest rates is meaningless. The relevant elasticity of substitution that it faces is zero, period after period. If reputational considerations are not taken into account, then the issuer will always want to act on the zero elasticity, and the only equilibrium is one where money has no value. Beliefs about future actions, because future profits can be high enough, may discipline the issuer of money, and there could be equilibria where actual inflation is not arbitrarily large. This mechanism is independent of the elasticity of substitution for future holdings, and therefore in our

[13] In a related literature (see Phelps and Winter (1970), Diamond (1971), Bils (1989), Nakamura and Steinsson (2009)) firms face different short-and long-run elasticities, possibly because of habits. In such a context, firms' decisions are also time inconsistent. However, because the short-run elasticity is not zero, as it is in our case, the short-run elasticity will matter for the characterization of equilibria without commitment.

framework, it is independent of competition.

We make these points in a version of the Dixit-Stiglitz model of monopolistic competition. It is clearly a very particular set-up.[14] Now, is it the case, that alternative models of competition would affect the results? How general are the results?

In the case of commitment, if money were costly to produce, then the particular model of competition would affect the results in all the usual ways. If the number of firms were finite, it would matter whether competition was Bertrand or Cournot, and the number of firms would matter. If the number of firms were endogenous, and there was free entry, as in the Salop (1979) circular-city model, this would also affect the commitment results. It turns out that because money is costless to produce, currency competition results, in our model, in an efficient outcome even if currencies are not perfect substitutes. This particular feature may not be true in alternative models of competition. An example is the model of Taub (1985). Taub studies a monetary model with Cournot competition across N currency issuers. He considers two distinct regimes: one with full commitment, and another in which there is partial commitment and polices are constrained to be Markov perfect. He shows that in the commitment case, the Friedman rule emerges as the equilibrium outcome only in the limiting case of perfect competition ($N \to \infty$).

Instead, without commitment, as it turns out, the results are quite general. Whatever is the form of competition, the elasticity of the outstanding money balances will always be zero, and the demands for future money holdings will be a function of today's actions according to arbitrary beliefs. That is, beliefs about the future returns of the different currencies fully determine the demands, not the underlying elasticities of substitution. We argue that these are general features of currency competition without commitment.

Regardless of future elasticities, or strategic interactions, there will always be an equilibrium where the issuers will take into account only the short-run gains, resulting in beliefs that will not sustain valued money. This will be the worst sustainable equilibrium. Alternative equilibrium outcomes will be sustained by a possible reversion to the worst sustainable equilibrium. Any deviation from an equilibrium outcome will trigger beliefs that the currency

[14] Clearly this model does not capture all the features that currency competition entails; for example, there are interesting issues regarding competing currencies as 'means of exchange.'

issuer will be inflating in the future. This will happen regardless of the elasticity of substitution or other firms' reactions. With unrestricted beliefs, this results in an indeterminacy of sustainable equilibria, where competition plays no role.

It should be noticed that Taub (1985) obtains different results. In particular, in his analysis with limited commitment competition plays a role. This is driven by two different assumptions. He assumes that there is at least one-period commitment and he considers only Markov perfect equilibria. The former implies that currency issuers can compete period by period, without being able to take advantage of the zero elasticity on outstanding balances. The latter means that beliefs are restricted to depend only on variables that directly affect current and next period payoffs. We do not impose any of these restrictions. In Taub (1985), in the case of partial commitment, increasing the degree of competition results in an inefficient outcome, implying vanishing real money balances.

In any sustainable equilibrium, the issuers must make positive profits out of currency issuance. In our model, the number of firms is exogenous, so this is not a problem in our set-up. However, in a model with many potential entrant firms ready to replace the incumbent firms, shouldn't there be a zero profit condition? There are equilibria with positive profits, because consumers may believe that new entry will result in bad quality money and, therefore, in a rational expectations equilibrium, these consumers' beliefs deter new firms from entering.

The indeterminacy of Sustainable Currency Competition Equilibria is not a special feature of our model, as long as beliefs are unrestricted. Restrictions on beliefs may reduce the set of SCCE. For example, if expectations about future returns are functions of current and past prices (of h_t) and, as in learning models, there is more structure on how agents form their expectations, competition may play a role in restricting the set of sustainable equilibria, since currency issuers will compete taking these forecasting functions as given. Decisions on current prices, $R^q(i)_t$, will have a predictable effect on expectations of future interest rates, $\upsilon_t^i(h_t; \frac{1}{R^q(i)_{t+1}})$, without being constrained to a specific interest rate, as in the beliefs supporting 'trigger strategies'. As a result, there can be an intertemporal effect which may restore a role for competition and, possibly, drive inflation rates to the zero lower bound of Proposition 2[15]. However, even if some of these restrictions

[15] For example, if agents' forecasting rules are such that trust is monotone with respect

are reasonable, restricting beliefs opens up a different set of issues that we do not pursue here.

There is an extensive literature on models of reputation with adverse selection (e.g. Tirole (1996), Cabral (2009), Levin (2009)); however, equilibrium selection arguments based on discrimination in adverse selection models do not apply to our currency competition model, where there are no reputational state variables about 'types' – say, 'good' or 'bad' currency issuers. All currency issuers face the same incentive problems and there is no room for discrimination among 'types'.

Finally, it should also be noticed that while we have only characterized stationary Sustainable Currency Competition Equilibria, our results generalize to non-stationary SCCE. The worst SCCE of Proposition 1 is an equilibrium that sustains non-stationary Currency Competition Equilibria. Furthermore, for a given path of interest rates to be sustainable as a currency competition equilibrium it is enough that, in every period and for every currency issuer, the expected future gains are higher than the value of the current currency holdings.

6 Money is an experience good

The private provision of currencies is by no means the only case where producers compete for promises and the standard 'Bertrand competition' argument does not apply. Competition in experience goods - those whose quality can only be revealed by consuming the good - has similar properties, since firms have an incentive to 'fly-by-night' and provide low quality products. 'Bertrand competition' can only affect market prices, but not qualities which are observed only *ex-post*[16].

To be more specific, suppose that, instead of being monopolistic competitive issuers of currency, firms supplied final goods also under monopolistic competition. Assume producers have, at any time, the option of producing either high quality goods – at some unitary cost – or 'fake' units of the consumption good that are costless to produce and deliver no utility to the

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to realized returns (i.e. $v_t^i(h_t; \frac{1}{R^q(i)_{t+1}}) \geq v_t^i(h_{t-1}; \frac{1}{R^q(i)_t})$ if $\frac{R^q(i)_t}{R_t^q} \leq \frac{R^q(i)_{t-1}}{R_{t-1}^q}$), issuers, taking this into account, will compete.

[16] Shapiro (1983) considers a model of monopolistic competition with experience goods. However, in his model consumers' expectations regarding quality follow an ad-hoc exogenous process. He does not study the trade-offs between competition and reputation.

buyer. A key assumption for the characterization of the equilibria is whether consumers can distinguish the high quality goods from the low quality ones before they buy them.

If the quality of the goods is perfectly observable before buying, the equilibrium is uniquely determined: The price chosen by each monopolist is determined by the elasticity of substitution. As goods become closer substitutes, the equilibrium outcome becomes more efficient. It is Pareto efficient in the limiting case of perfect substitution. In sum, the 'Bertrand competition' argument holds.

Imagine, instead, that the quality is only observed with a lag. In a dynamic economy, firms are concerned for their future market position and this may be enough to discipline them to effectively provide high quality goods. Given that the firm has the option of making a short-run profit by selling low quality goods, the equilibrium mark-up must be high enough for the firm to choose not to follow this path. The equilibrium mark-up is not determined by the elasticity of substitution, as in the case of perfect observability. Rather, it is determined by the need to guarantee enough future profits to ensure high quality. Increasing the degree of substitutability does not affect the set of equilibria, and competition plays no role.

Thus, while the provision of money and the provision of experience goods seem a priori very different problems, the former being a 'time inconsistency problem' and the latter a 'moral hazard problem' the ways in which competition and trust interact are strikingly similar. In both models firms compete on prices that are not observable or that they cannot commit to: in the quality-goods model, this is the price of the good per unit of quality; in the currency competition model it is the nominal interest rate, or the inflation rate. With perfect observability in the first model and with full commitment in the second, there is no distinction between set and realized prices. With unobservable quality in the first model and lack of commitment in the second, we have to consider off-equilibrium paths where the *ex-post* realized prices may differ from the *ex-ante* prices. In such cases, firms maximize short-run profits by setting an arbitrarily large realized price, which in the experience good model corresponds to choosing low quality and in the currency model corresponds to inflating away current money holdings (i.e. in making 'the quality of outstanding money' arbitrarily low). In both models, the timing is very important: Consumers purchase services before they observe the quality they yield in one, and they purchase currencies before they observe the real return they yield in the other; in both models consumers must form their expectations of realized prices on the basis of past information and current prices, and in both models reputation is what may prevent firms from 'flying-by-night.'.

There is, however, a difference in how short-run profits are made. In the standard experience good model they are made on the current production flow, while in the currency model they are made on the current money stock. This has implications. For example, shortening the period reduces the short-run gain in the case of experience goods but not in the case of currencies, while in neither case does it affect the present value of the future flow of profits. Therefore, shortening the time period makes it easier to sustain high quality in the experience good model but not in the currency model. Nevertheless, in both models reducing the rate of time preference for a fixed period length makes it possible to sustain more efficient outcomes: in the experience goods model by virtue of the standard 'Folk-Theorem' argument; in the currency model because a lower real interest rate reduces the value of depleting the current stock of money.

Finally, there are two more relevant differences between currencies and experience goods. One is that it is meaningless to consider costless experience goods. Another, making the 'time-inconsistency' currency problem more difficult to circumvent, is that with experience goods firms can implement a policy of replacing bad quality goods, a policy which is not available to a currency provider.

7 Conclusions

In this paper, we have addressed an old question in monetary theory: can currency be efficiently provided by competitive markets? We first show a flaw in the standard 'Bertrand competition' argument when suppliers compete on promises rather than on tangible deliveries. The key issue is whether promises can be 'automatically trusted', and expectations based on them always fulfilled. In the provision of currencies promised returns fulfill consumers' expectations when currency suppliers are fully committed to their promises. In this context, trust is automatically achieved and the competition mechanism results in an efficient allocation[17].

However, expectations based on promises may not be automatically fulfilled, because suppliers may not be able to commit to maintain future prices

[17] Subject to the caveat of footnote 6.

to achieve the promised returns. In this context, it must be in the interest of suppliers to be trustworthy: future rewards must compensate the temptation to renege on their promises. The need for such future rewards determines a lower bound on the degree of efficiency that can be achieved in these markets. In the market for the provision of money, the lower bound requires non-negative inflation and, therefore, positive nominal interest rates, away from the Friedman rule of zero nominal interest rates. A first corollary of this result is that Hayek's conjecture, that efficient monetary equilibria can be achieved through currency competition, is not verified if currency suppliers make sequential decisions.

There is a second, somewhat disturbing, corollary to the previous result. Once the 'trust mechanism' works it fully determines which equilibrium is achieved and, since beliefs sustaining trust are fairly arbitrary, there is an indeterminacy of such equilibria. That is, any positive inflation can be part of a stationary equilibrium outcome.

In summary, competition and trust are two disciplinary mechanisms that can enhance efficiency and one would think that they should be mutually reinforcing. We have seen that this may not be the case in a model of currency competition. With commitment, competition plays a role, but not trust (it is automatically satisfied); without commitment, trust plays a role, but not competition. In the former case, currency competition guarantees efficiency – independently of substitutability because currencies are costless to produce. In the latter, the trust mechanism sets a lower bound on inflation and the efficient outcome cannot be achieved. Competition and trust in currency markets is an old question; competition and the need for trust in financial markets is a timely one.

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