19249v1 Updated 28 January, 2003

E-Barter vs. Fiat Money: Will Central Banks Survive?♦

By

F.H. Capie♣

Dimitrios P. Tsomocos♥

Geoffrey E. Wood♠

♣ City University

♥ Bank of England, FMG and Said Business School and St. Edmund Hall of University of Oxford.

♠ Bank of England and City University

♦ The views expressed here are those of the authors and do not necessarily reflect those of the Bank of England or the, or the City University, or the LSE or the University of Oxford.

The authors are grateful to Willem Buiter, Charles Goodhart, Mervyn King, Andrew Lilico, Stefan Schmitz, Martin Shubik, seminar participants at the Bank of England, the European Central Bank, the 2003 International Conference of Game Theory and to two anonymous referees for helpful comments and remarks. All remaining errors are ours.

Abstract

New technology in computing has led some to suggest that the ability to settle transactions electronically will develop to such an extent that money disappears from use. Two versions of this belief exist. One maintains that there will be "e-money", issued conceivably by many organisations, and that this will replace central bank money. The other suggests a still further development – that the very concept of a medium of exchange may become redundant, as assets or goods can be exchanged directly for other assets or goods through use of computing. In this paper we argue that the information-economising properties which allowed money to develop will also allow it to survive, despite actual and hypothesised technical progress.

JEL classification: E42

"Is it possible that advances in technology will mean that the arbitrary assumptions necessary to introduce money into rigorous theoretical models will become redundant, and that the world will come to resemble a pure exchange economy? Electronic settlements in real time hold out that possibility." (King 1999)

I Introduction

The development of electronic, and in particular of computer, technology has led to speculation that it will replace fiat money in facilitating exchange. Just as barter was supplanted first by commodity money and then by fiat money because these were superior transactions technologies, so, it is argued, information storage and transmission will be so facilitated by computer technology that in its turn fiat money will be displaced.

It must be emphasised that this claim, articulated by, for example, King (op.cit) is not just that electronic technologies will provide people with easier access to their bank accounts, and thus make carrying notes and coins redundant - that emoney will replace fiat money. "emoney" using schemes have already been tried: for surveys of them, see Gomez (2001) and Capie and Gomez (2002). Rather the claim is that fiat money will disappear, and that with it will disappear also the notion of goods having prices quoted in terms of some unit of account which has something called purchasing power; we shall, in other words, return to barter. But it will be barter rendered so efficient by technology as to be superior to exchange through an intermediary commodity. This is the claim we are examining.

Central to analysis of this proposition is the medium-of-exchange function of money. The crucial distinction between a money using economy and a barter economy, whether it be one of primitive or of electronic barter, is that in the former a medium of exchange is used. Our aim in this paper is to establish a simple formal framework which will let us examine the crucial determinants of whether or not a medium of exchange will be used. To do this, we construct a model of exchange with costs of transacting an intrinsic part of it; for if there are no costs of transacting then there are no transactions costs on which a medium of exchange can economise.

The next part of this paper (section II) comprises the intuition of and historical background to our model. The model (set out in section III) is of an exchange economy; introducing production would be an unnecessary elaboration as we wish to analyse an exchange process. We base our analysis on

the model developed by Shubik and Tsomocos (2002). Within the model formal definitions of exchange by use of fiat money and exchange by electronic barter are provided and we derive the costs of exchange with fiat money and by electronic barter. We take as given that fiat money dominates commodity money. We derive the condition such that the cost of transacting with fiat money is lower than that of electronic barter (proposition 1) and also the condition under which the two mechanisms of trade become equivalent (proposition 2).

Section IV sets out why in our model the issuer of fiat money (which we assume will be a central bank) will retain control of a concept called the price level. A formal demonstration of this point, in the framework of the model of section III, is also provided.

Section V summarises, and reiterates our main conclusions.

II The Role of Money

As was observed some years ago by George Stigler (1972), a world without transactions costs would seem a very strange place. There would be no firms – and therefore no banks, insurance companies, or other financial institutions. And further, there would be no money. The essence of our argument is that so long as there are transactions costs there will be money, and that even electronic barter will not, except under very special circumstances which we set out below, be able to replace "fiat" money because it will not be as effective in reducing transactions costs. To develop the economic intuition underlying our model we first argue informally why some form of money to mediate trade in mass anonymous markets evolved as a device to reduce the costs of transacting. Then we go on to show that once the concept of using money had developed, still further cost reductions were achieved by a further development – convergence to a very small number of commodities which were used as money. Indeed, a single money is, subject to certain constraints on its issuance, the optimal outcome.

Just how useful money is in reducing the costs of transacting is highlighted by the fact that societies continue to use money even when inflation, and thus the cost of holding money, is very high. Although under these circumstances barter does eventually replace money, money has been used even when prices are rising by as much as 1000% pa.[1] Why is the alternative, barter, so costly, and how does money reduce these costs?

Barter involves the double coincidence of wants. The buyer must want what the seller is selling – and vice versa. That could be eliminated by what Meltzer (1998) calls "barter credit" – supplying goods now in exchange for a promise of goods later. But such transactions are rare even in economies with developed and reliable legal systems. Why? The reason is that there is a superior – a cheaper – way of transacting. Credit, whether barter credit or not, requires the seller to know about the buyer – about his or her creditworthiness, and the features (such as income) which contribute to that. If a money which is widely accepted and recognised is available, then the personal attributes of the buyer are irrelevant. All that matters is what he is offering. Less information has to be gathered, so trade becomes cheaper. This expands the possibilities for trade, so both buyer and seller gain. (The analogy with a tariff reduction is clear.)

For something to evolve as the sole money of a society, rather than be imposed as such, two conditions have to be satisfied. These are as follows. First, not all goods are equally suitable for use as money; the costs of acquiring information must depend on the good selected. Second, the marginal cost of acquiring information about whatever is used in exchange falls the more frequently it is used. These two features let us explain the once widespread use of precious metals as a means of payment. Such metals can be assayed for fineness, are divisible, can be readily quantified by weighing, and are homogeneous – an ounce of gold of a certain fineness is identical to another ounce of that fineness. Alternative moneys – cattle, stones, tablets of salt – did not possess these attributes

[1] We show formally below (p14) the condition which has to be satisfied for barter to drive out money.

to anything like the same extent. These are the attributes that guide us towards the monetary commodity. But, it should be emphasised, the information–economising attribute is crucial. Precious metals are not always available. If they are not, something else is used. Cigarettes were used as money in German prisoner-of-war camps in the Second World War. (Radford, 1945). They were used because everyone could recognise them, and knew that everyone would accept them in any exchange. As that knowledge spreads about some good, that good becomes a medium of exchange. It might then acquire other roles – prices are likely to be quoted in it and it is likely to be used as a unit of account (McCallum 1989), and the government may require taxes to be paid in it.

We can thus see that a society will tend to evolve towards the use of a very few commodities as money, given our assumption that not all commodities are equally good at satisfying the medium of exchange function; and that one good will come to dominate if the marginal cost of acquiring information about that good falls the more it is used.

Not only does the use of money eliminate the need to know about the buyer in a transaction. When it has evolved into use as a unit of account, another saving is achieved.[2] Without a unit of account, any transactor must know the bilateral exchange value of each commodity for every other commodity. "If there are n commodities, there are at least $(n(n\text{-}1))/2$ separate values. The number of bilateral exchange ratios (prices) rises quickly. With $n = 100$ commodities, there are at least 4950 prices to know. At $n = 500$, the number if 124750, and with 1000 commodities there are at least 499 500 prices. Without a unit of account, trade would be very limited by costs of information. Use of a unit of account to express value reduces the number of prices from $(n(n\text{-}1)/ 2$ to n." (Meltzer, 1998).

[2] It is not essential although it is probable that the medium of exchange also serve as unit of account. It would be possible for prices to be quoted in one thing – ounces of gold, say – while a national currency served as the medium of exchange. But each transaction would then need to be accompanied by a calculation converting the price (quoted in gold) into the national currency before payment could be made. There is thus a saving in having the medium of

So far we have argued that evolution to the use of a few commodities, and subsequently to one commodity, as money, is beneficial. Subject to certain constraints going beyond that brings still further benefits. Paper money, so long as there is not overissue that leads to inflation, brings a resource saving if it substitutes in whole or in part for the commodities which heretofore had served as money.

To summarise so far, we have argued that the concept and use of money emerged through a process of search and discovery. Its advantage over barter credit, which has some advantages over simple barter, is that it reduces transactions costs still further by shifting attention from the qualities of the prospective purchaser of a good to the qualities of what he is offering to pay for it. From (in Allen Meltzer's words, op.cit.) "a unique and possibly obscure set of attributes to a common and widely known set of attributes". A money-using society requires less information than a bartering society.

Before going on to develop a formal demonstration of the above conclusions, and then to show their relevance to the future of electronic barter and paper money, it is useful to place the above arguments in their historical context, for the view of the development and role of money set out above is not new. A thorough exposition of it was provided over 100 years ago, by Carl Menger (1892)[3]. He maintained that money was a 'social' creation, a product of the invisible hand. His was an example of an invisible hand explanation - in contrast to a government based explanation – of a social institution. (See Latzer and Schmitz, (2002).) The basic point was not original to Menger, either. (It is a bold writer who asserts that he has found the original inventor of any economic concept!) Adam Smith had m[4]ade the point in the Wealth of Nations.

---

exchange and unit of account coincide. This can, however, be outweighed if the medium of exchange is changing value sufficiently rapidly.

[3] The complete text of this paper has recently been translated into English and is available in M. Latzer and S.W. Schmitz (2002).

[4]

"In order to avoid the inconvenience of such situations [where the would-be seller of a good does not want what the would-be buyer offers] every prudent man in every period of society, after the first establishment of the division of labour, must naturally have endeavoured to manage his affairs in such a manner, as to have at all times by him, besides the peculiar product of his own industry, a certain quantity of some one commodity or other, such as he imagined few people would be likely to refuse in exchange for the product of their industry." (1981 edn. Pp 37-38)

And that money was originally a social institution, although it had subsequently become a government one, was also noted by Keynes (1935, pp 4-5).

"Thus the Age of Money had succeeded to the Age of Barter as soon as men had adopted a money-of-account. And the Age of State money was reached when the state claimed the right to declare what thing should answer as money to the current money of account – when it claimed the right not only to enforce the dictionary but also to write the dictionary."[5]

[5] The most fully developed modern statement of the "transactions cost" theory of money can be found in the work of Karl Brunner and Alan Meltzer. The most detailed statement of their view is given in Brunner and Meltzer (1971). Alchian (1977) also develops the argument and Yeager (1968) draws out the implications of it for the behaviour of the macroeconomy. The argument that money evolved as a result of private initiative of course leaves unexplained why all money is now state money. Some scholars (e.g. Goodhart, 2000) argue that state money is an inherently superior "institutional symbol of trust" (to use Shubik's definition of money), while others (e.g. Glasser, 1989) point to the successful existence of private mints until they were extinguished by law and maintain the opposite. A formal model of an explanation for the dominance of state money can be found in Monnet (2002). An additional factor which may predispose a society to state rather than private fiat money is the comparative irrelevance of the solvency of the state. See also footnote 14.

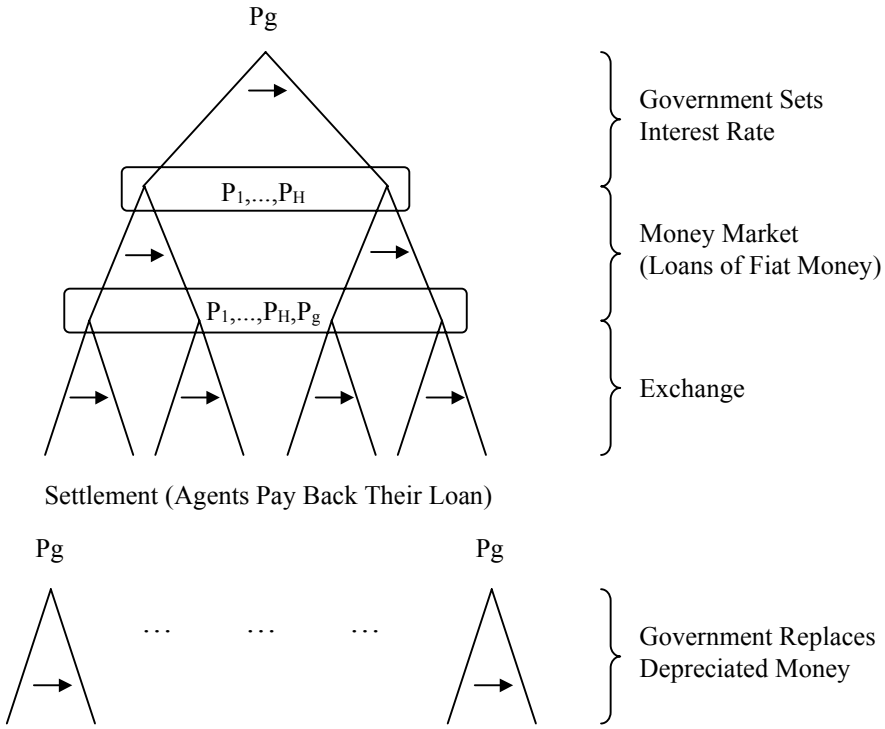

Fig. 1
Trade with seigniorage cost of fiat money
(Note that the labeling $P_1,\ldots,P_H$ and similarly $P_1,\ldots,P_H$, P_g indicate that all agents move simultaneously. Also, the arrows indicate that there is a continuum of their respective strategies).

III. The Model

We use the strategic market game developed in Shubik and Tsomocos (2002). Money depreciates (ie it wears out through deterioration of notes and coins' quality) when used in exchange, and its replacement is costly[6]. The stipulated means of exchange is fiat money and all transactions need cash in advance (see footnote 11 for the motivation of this constraint). We assume that the money supply enters exogenously. Figure 1 shows the extensive form of the game. The exchange game is a one period game with four subperiods. At each subperiod, as we explain below, an agent or a group of agents move. We first modify the game to admit both fiat money and electronic barter. We conceptualise electronic barter mediated as through a giant clearing house run by an institution, perhaps the government. We then analyze the condition under which fiat money dominates electronic barter.

At the first move the government P_g, determines the interest rate. At the second move, individuals, $P_1,\ldots,P_H$, obtain fiat money in the money market at the predetermined interest rate. At the third move, individuals exchange commodities and the government buys inputs of production to be used in the replacement of depreciated fiat money. We maintain simplicity of strategy sets by assuming a continuum of traders, simultaneous moves, and a minimum of information at the second and the third stage. Then traders pay back their loans, and finally the government replaces depreciated money. The government levies seigniorage costs to replenish depreciated money and also participates in exchange.[7]

Let $h \in H = \{1,...,H\}$ be the set of agents and $l \in L = \{1,...,L\}$ be the set of tradable commodities. Each agent is endowed with a vector of commodities $e^h \in \Re^L_+$.

The utility functions of agents are of the form $u^h : \Re^L \to \Re$.

The following assumptions hold:

(i) $\sum_{h\in H} e^h >> 0$

(ie every commodity is present in the economy.)

(ii) $e^h \neq 0, \forall \quad h \in H$

(ie no agent has the null endowment of commodities.)

(iii) u^h is continuous, concave and strictly monotonic $\forall \quad h \in H$.

(ie the more consumption the better.)

Agents maximize their utility of consumption subject to the following constraints:

$$\sum_{l\in L} b_l^h \leq v^h \qquad (1)$$

---

[6] Calculations of the rate of depreciation of various types of money can be found in Shubik and Tsomocos (op.cit.) The interest rate is set to finance seigniorage cost of replacing worn out fiat money.

(ie expenditures in commodities ≤ borroed money.)

$$q_l^h \le e_l^h \quad , \quad \forall \quad l \in L \qquad (2)$$

(ie sales of commodities ≤ endowment of commodities.)

$$(1+r)\, v^h \le \sum_{l \in L} p_l q_l^h + \Delta(1) \qquad (3)$$

(ie loan repayment ≤ receipts from sales of commodities + money at hand.)

where, $b_l^h \equiv$ money bid of h for the purchase of commodity $l \in L$,

$m^h \equiv$ private monetary endowments,

$q_l^h \equiv$ quantity of commodity $l \in L$ offered by h,

$v^h \equiv$ loans contracted by h,

$r \equiv$ loan interest rate,

$p_l \equiv$ commodity price of $l \in L$ and

$\Delta(1)$ is the difference between the right and left hand sides of equation (1).

As can be seen from the budget constraints (1) and (3) receipts from sales of commodities can not be used contemporaneously for financing purchases of other commodities. This is the essence of the cash in advance constraint which can also be thought as a liquidity constraint.)

The exogenously fixed money supply M depreciates at a rate η. Thus, if the total amount of fiat money borrowed by the agents from the government (or central bank) is $\sum_{h \in H} v^h = \bar{\mu}$ and the expenditure of the government for the purchase of inputs of production is $\bar{g}$ then $\eta\left(\bar{\mu} + \bar{g}\right)$ is the depreciated amount of money, since $\left(\bar{\mu} + \bar{g}\right)$ is the total amount of money in circulation.

[7] A more extensive presentation and discussion can be found in M. Shubik and D.P.Tsomocos (2002).

The government's production function for money exhibits decreasing returns to scale in order to generate a unique optimum.[8]

$$z_{L+1} = F\left(x_1^g, ..., x_L^g\right) \qquad (4)$$

with

$z_{L+1} \equiv$ amount of fiat money produced,

$x_t^g \equiv$ inputs of production.

We impose the standard technical assumptions on the government's production set, $y^g \in \Re^L$, these guarantee feasibility and the existence of a solution to the governments's maximisation problem.

(iv) $0 \in y^g$,

(v) y^g is convex and closed

(vi) $\exists \; B > 0 \ni$ if $\left(x_1^g, ..., x_L^g; z_{L+1}\right) \in y^g$ then $x_l^g \in B, \; \forall \; l \in L$ and $z_{L+1} \leq B$.

Thus the government's optimization problem becomes[9],

$$\max_{r, b_l^g, l \in L}{}^{10} \qquad -r$$

$$\text{s.t} \qquad z_{L+1} = \eta\left[\sum_{h \in H} v^h + \sum_{l \in L} b_l^g\right]. \qquad (5)$$

[8] For example, a Leontief production technology with coefficients γ_l, $\forall \, l \in L, z_{L+1} = \min[\gamma_1 x_1^g, ..., \gamma_L x_L^g]$. If another technology were chosen, a unique equilibrium could be guaranteed by an exogenous institutional constraint, such as a price level target.

[9] Government purchases are all used in the production process, ie government does not obtain utility from consumption.

$$\sum_{l\in L} b_l^g = r\sum_{h\in H} v^h. \qquad (6)$$

Where (5) is the amount of depreciated money that needs to be replaced, and (6) is the budget constraint of the government. (ie its expenditures to finance the cost of production come from seigniorage).

The final allocations for the agents and the government are:

$$x_l^h = e_l^h - q_l^h + \frac{b_l^h}{p_l} \quad , \quad \forall \quad \mathrm{l} \in \mathrm{L} \qquad (7)$$

(ie consumption = initial endowment – sales + purchases.)

and

$$x_l^g = \frac{b_l^g}{p_l} \qquad (8)$$

government's inputs of production = money offered / prices.)

Note that the relation between η and r is a complicated one and depends on gains from trade that in turn determine the volume of transactions. The interest rate r is set by the government to raise seigniorage revenue for the financing of fiat money production so as the replace depreciated money.

Finally, a Nash equilibrium (NE) or $\Gamma\left(H, u^h, e^h, \eta, M, x^h, x^g\right)$ is a set of strategy choices,

$s = \left(s^h, s^g\right) = \left(b_l^h, q_l^h, x_l^h; b_l^g, p\right)$; $\forall$ $\mathrm{h} \in \mathrm{H}$ and the government, and

$\alpha = \left(\alpha^h, \alpha^g\right) \in \sum = \underset{h\in H}{\mathrm{X}} B^h \times B^g$, э

$$\Pi\left(\mathrm{s}/\alpha\right) \leq \Pi\left(\mathrm{s}\right) \qquad (9)$$

where $\mathrm{B}^h, \mathrm{B}^g$ are the choice sets of the agents and the government (ie

$B^h = \langle (b_l^h, q_l^h, v^h)_{l\in L} : (1) - (2) \text{ hold} \rangle$ and $\mathrm{B}^g = \langle (r, b_l^g)_{l\in L} : (5) - (6) \text{ hold} \rangle$), and $\left(\mathrm{s}/\alpha\right)$ is s with either

---

[10] Mathematically, minimisation of r is equivalent to maximise –r.

s^t or s^g replaced by any other strategy choice α^t or α^g [11]. Also, $\Pi(\cdot)$ represents the payoff functions of agents ($\Pi^h(\cdot) = u^h$) and of the government ($\Pi^g(\cdot) = -r$) .

Prices are formed using the Dubey and Shubik (1978) price formation mechanism. Prices are by that mechanism formed as the ratio of the aggregate cash bid in a particular market to the aggregate quantity of commodities offered for sale. This is equivalent to an equilibrium condition; its accounting clarity allows for cash flows in the economy to be traced precisely.

$$\text{Thus,} \quad p_l = \begin{cases} \dfrac{\sum_{h\in H} b_l^h + b_l^g}{\sum_{h\in H} q_l^h}, & if \sum_{h\in H} b_l^h + b_l^g ; \sum_{h\in H} q_l^h > 0 \\ 0 \quad , & otherwise \end{cases} \qquad (10)$$

The existence and inefficiency theorems for these outcomes are stated and proved in Shubik and Tsomocos (2002). Here we will focus our attention on the relative efficiency of using alternative means of payments (on fiat money versus electronic barter).

III. <u>Trade with Fiat Money vs. Electronic Barter</u>

We conceptualise exchange using fiat money as follows. Consider a simple case in which L=4. Fiat money can be exchanged against every commodity but commodities cannot be exchanged with each other. Figure 2 describes the situation. The arcs connecting m with commodities 1, 2, 3, and 4 indicate that money can be exchanged against all commodities. On the other hand, commodities cannot be exchanged with each other (ie there are no arcs connecting them).[12]

[11] Without loss of generality, we consider the case of perfect competition (ie, a continuum of agents). Thus, agents regard prices as fixed in the optimisation problems.

[12] Note that the constraint that goods cannot be directly exchanged for goods is not imposed but naturally emerges as a consequence of our prior argument that trade with money dominates primitive barter.

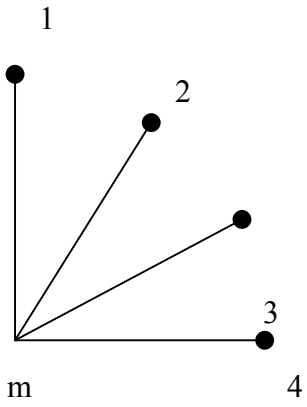

Fig. 2

Trade with fiat money

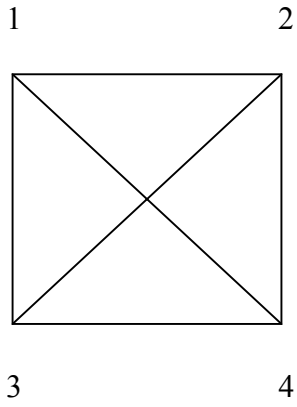

Fig. 3

Trade via electronic barter

Thus, there exist 4 markets. If on the other hand we want to conceptualize "electronic barter" we assume that commodities can be exchanged with each other, perhaps via an accounting device of e-barter, which now becomes the stipulated means of exchange, through a clearing house that matches demand and supply. In this case there will be $\frac{L(L-1)}{2}$ markets, ie, 6 markets altogether.[13]

Thus, in figure 3 arcs connect all commodities with each other indicating that exchange occurs without fiat money.

Let us assume that the combined cost of gathering and then processing information on each transaction is c. On the other hand trade with fiat money, by virtue of its anonymity, divisibility, fungibility and its other properties does not require any additional costs except its production and replacement costs. These are covered in its production process as described in (4). Also, information costs concerning the creditworthiness of borrowers using fiat money are dealt with by commercial banks and not by the original issuers of money (ie central banks) or by those who accept money in exchange for goods or services. These costs cannot be avoided by the operators of the central clearing house (or a similar transactions institution) that implements electronic barter. Then the total cost of exchange with e-money is:

[13] Extensive discussion on various market structures and how these affect exchange is contained in Cubic (1999).

$$\overline{C} = \frac{cL(L-1)}{2}(H+1)^{14} \qquad (11)$$

We note that each agent participates in only one side of the market since wash sales (ie the same individual participating in both sides of a particular market) are not profitable in a strategic market game without oligopolistic effects. If we assume that set up costs for establishing either of the two market structures are negligible we have proposition one. We also note that the total cost of fiat money and of electronic barter is endogenously determined; both depend on the volume of transactions; see equations (6) and (11).

Proposition 1:

The cost of exchange with fiat money is lower than exchange with e-money provided that,

$\frac{L(L-1)}{2} c\,(H+1) - r\,M > 0$, where $M = \sum_{h \in H} v^{h}$.

One point can usefully be made here about this relationship. If we imagine technical progress lowering c, the very same process is likely to increase the number of commodities, L. Indeed, over time we have seen a proliferation of traded commodities, most of them being associated with technical progress. Note also that while the lower bound of r is zero, that of c is inevitably above zero[15].

Proof:

The cost of exchange with fiat money is $r\sum_{h \in H} v^{h}$ (∗), since replacement of depreciated money is financed by seigniorage which is levied by interest rates.

[14] We implicitly assume that we are in an equilibrium such that agents participate in all markets.

Hence, $(11)-(*)=\frac{L(L-1)}{2}c\,(H+1)-r\sum_{h\in H}v^{\mathrm{h}}$ represents the cost difference of exchange with electronic barter vs. fiat money.

□

Proposition 1 underlines the fact that fiat money is a decoupling device that economises on transaction costs regardless from where they emanate (ie processing, information acquisition etc). On the other hand, electronic barter is a centralised accounting mechanism that requires detailed knowledge of every transaction. Thus, it entails higher aggregate costs in complicated market systems with multiple markets and commodities. It is not a coincidence that the advent of money (or equivalently the decline of barter) occurred contemporaneously with the development of the market system.

Proposition 2:

The equilibria of $\Gamma\left(H,u^{h},e^{h},\eta,x^{h},x^{g}\right)$ with trade with fiat money coincide with those of the corresponding game with e-barter only if r=0 and c=0.

Proof:

If $\mathrm{r}=0$ and $\mathrm{c}=0$ the two alternative methods of financing trade produce same commodity allocations. To get the same prices and allocations set

$$\frac{\sum_{\mathrm{h}\in\mathrm{H}}\mathrm{b}_{\mathrm{l}}^{\mathrm{h}}}{\sum_{\mathrm{h}\in\mathrm{H}}\mathrm{q}_{\mathrm{l}}^{\mathrm{h}}}=\mathrm{p}_{\mathrm{l}}\ \text{and}\ x_{l}^{h}=e_{l}^{h}-q_{l}^{h}+\frac{b_{l}^{h}}{p_{l}}\qquad\forall\ l\in L,\ \ h\in H.$$

---

[15] Why money is replaced by barter as a result of hyperinflation is summarised in the above relationship. In hyperinflation, the nominal interest rate rises enormously. See Capie (1986) for a review of some such episodes.

Then regardless whether trade is conducted with fiat or through electronic barter the same equilibrium obtains.

□

Proposition 2 underlines the fact that alternative methods of financing become distinct only when transactions costs are present in the economy. Unless one introduces process and the organisational details of market transactions, it is difficult to delineate the differences between alternative media of exchange. Both ofr them, without transactions costs, are identical units of account. Money is both neutral and super-neutral. Trade, no matter how organised, generates the same allocations. Whenever $r = 0$ and $c = 0$ then money is a 'veil'. For more on this see Shubik and Tsomocos (2002) and Tsomocos (1996), (2002). Even in the case of bimetallism or multiple means of exchange as long as there are determinate conversion rates among the media of exchange the analysis can be conducted in terms of a 'primary' means of payment. However, the allocations generated by the two methods of financing trade are not unambigiously Pareto ranked whenever $r, c \neq 0$. It remains an open question to determine the conditions on r and c that allow one method to generate Pareto superior allocations over the other.

A natural question that emerges from this analysis is whether it is possible for fiat money and electronic barter to coexist in equilibrium. In particular, can fiat money can be used for a subset of commodities and electronic barter for the rest? This issue is complicated and beyond the scope of our present analysis, since the volume of transactions with with each medium of exchange is endogenously determined and in turn determines the subset of commodities whose trade might occur with each medium of exchange. Also, the gains from trade of each commodity influence the marginal benefit and cost using different methods of financing trade. For example, if there exist big gains from trade in a specific commodity, the government may reduce the marginal cost of trading in that market by introducing electronic barter and thus avoiding depreciation of fiat money used in this particular very liquid market. We plan to explore this question in future research.

IV The Price Level – Meaningful and Determinate

The intrinsic informational superiority of central bank issued base money will ensure that demand for it is not extinguished by the growth of e-barter. Demand will remain from the non-bank public, and, because of that, derived demand will remain from the banking sector. The central bank will thus retain control of short-term interest rates.[16] This might seem at first glance sufficient for it to retain control of the price level; for in many models a short rate is the sole transmitter of monetary policy actions. For example, much recent work on monetary policy uses small macroeconomic models which include an IS function analogous to that in a basic IS-LM model. These can be backward looking, and thus very close to the traditional specification (eg Fuhrer and Moore, 1995), or forward looking, embodying rational expectations (eg McCallum and Nelson, 1999a). But whatever the specification, a common feature is that demand for current output is a function of the real rate of interest. Monetary policy in such models therefore affects output and inflation only through its effects on the real rate of interest; the money supply has no direct role. As we have shown, however, that a demand for base money will survive competition from electronic barter, it is useful briefly at this point to review some aspects of the work which suggests that focusing on a short term interest rate as the sole transmitter of monetary policy impulsesw is certainly too narrow and is also very possibly misleasding.[17]

Viewing the short rate as the sole transmitter of monetary policy is, unnecessarily restrictive both theoretically and empirically. Allan Meltzer (1999a) has recently summarised the body of theory and evidence which considers that specification to be inadequate. He argued that although so long as prices are sticky the real interest rate is affected by central bank operations, so too is the real monetary base, and changes in the latter affect aggregate demand in ways additional to the effect of

[16] We do not imply that without such demand it would lose control of short rates. The argument in Goodhart (op.cit.) that the central bank can control rates through its being able to sustain losses seems to us to be correct, despite the objections of Selgin and White (2002).

changes in the real interest rate. Meltzer (1999b) reports empirical results for the USA which support this argument, as does Nelson (2000) for the UK. (The result is not novel; earlier work (eg Mills and Wood, 1977) found a relationship between the base and the price level over long runs of data in the UK.) Nelson (op.cit.) provides a clear summary of his results as follows:

"The common feature of the regressions is that for the United States and the United Kingdom, real money growth enters output regressions sizeably, positively, and significantly. The real interest rate generally enters with a negative sign, though both the sign and the significance of the real interest rate term appear to be less consistent across sub-samples than those of the money growth terms. (p13, emphasis added.)

These empirical results are consistent with two quite distinct bodies of analysis. One is an approach which assumes utility is non-separable in consumption and real money holdings. This justifies a real money balance term in the IS function as a result of optimising behaviour. Koenig (1990) reports results which support this; but others (eg McCallum, 1999) suggest that the coefficient on real balances is likely to be small.

A direct role for base money is perhaps better defended and explained by an approach with much earlier origins. David Hume (1752) thought that money affected the economy through a wide variety of channels, and expressed this thought in a metaphor – water flowing from one place to another - that frequently recurs in the discussions of the money transmission process.[18]

"Money always finds its way back again by a hundred canals, of which we have not notion or suspicion….For above a thousand years, the money of Europe has been flowing to Rome, by one

[17] A compelling case for its being misleading is set out in King (2002).
[18] See Wood (1995) for a discussion of the development of the quantity theory and the history of the "water" metaphor.

open and sensible current; but it has been emptied by many secret and insensible canals." (p48, 1955 reprint).

The many channels view is also articulated by Friedman and Schwartz (1982, p486-487).
"…the attempt to correct portfolio imbalances (resulting from an increase in the money stock) raises the prices of the sources of service flows relative to the flows themselves which leads to an increase in spending both on the service flows and then produce a new source of service flows….Sooner or later the acceleration in nominal income will have to take the form of rising prices, since the initial position was assumed to be one of equilibrium and we have introduced nothing to change the long-run trend of nominal income."

This argument is also expressed in Brunner and Meltzer (1993) and was stated very succinctly in Meltzer (1999b), as follows:

"Monetary policy works by changing relative prices. There are many, many, such prices. Some economists erroneously believe….monetary policy works only by changing a single short-term interest rate."

He also argues (1999a) that money balances are crucial in this interpretation of the transmission mechanism. He sees "…the gap between desired and actual real balances as a measure of the relative price adjustment required to restore full equilibrium,". An implication of this is that money demand is a function of many interest rates, and that <u>many</u> interest rates therefore affect aggregate demand. (See also Friedman, 1956.) A model which captured all these effects would be very complex. It would incorporate several – possibly many – interest rates, and therefore many assets with imperfect substitutability between them. Nelson (op.cit.) sets out a basic version of such a

model, arguing that a long rate, not just a short rate, should appear in an optimising IS specification; the argument is based on the expectations theory of the term structure of interest rates.[19]

Our formal model (section III) which compared fiat money with electronic barter also yields the result that control of the issue of fiat money controls the price level without any intermediation through an interest rate channel. Our model manifests real as well as nominal determinacy. This is unlike the classical competitive model which possesses a 'finite' number of equilibria with respect to real allocations; only relative prices can be determined. Our model resolves nominal indeterminacy through the presence of *private liquid wealth*. By liquid wealth we mean a commodity or a monetary instrument which can be used interchangeably with money in real, financial, or bank transactions, and its conversion rate is institutionally predetermined. The essence of the determinacy argument and consequently of the non-neutrality result is that monetary policy affects nominal variables, yet if private liquid wealth is non-zero then monetary changes affect directly the endowments of agents resulting in different optimisation choices and consequently different real consumption. The issues of determinary and money non-neutrality are intimately connected and are analytically equivalent.

Finally, if a model does not possess equilibria that are nominally determinate then any discussion of exchange with a particular means of payment (either fiat or e-money) is not legitimate. If multiple price levels support the same equilibrium real allocations then it is impossible to compare the relative virtues of exchange with different means of payment.

[19] Mills and Wood (1982) provide some evidence on the role of a long-term rate in money demand functions.

The Domain of a Currency

Before concluding, it is worth touching very briefly on why the arguments we have advanced for the informational superiority of central bank money over e-money have not led to the worldwide adoption of a single money. The answer again lies (aside from purely political or nationalistic reasons) in transaction costs. If prices are perfectly flexible in either direction against the unit of account, then countries could readily have fixed exchange rates, and might as well have a common money, even in the presence of random asymmetric shocks. But because there are costs of acquiring information, all prices cannot be perfectly flexible. They are changed only after transactors have sorted out permanent from temporary and real from nominal shocks, and done such things as compare the costs of price change against those of inventory adjustment. (For an elaboration of this argument, see Clower, (1969). Thus, the very presence of information costs on which money can economise serves to constrain the optimal domain of any individual money.

VI Conclusion

In this paper we first set out the argument (a very traditional one) that money evolved to reduce transaction costs by economising on information.

A formal model in which money existed by virtue of that property was then developed, and the costs of operating a fiat money system were compared with the costs of operating a system of electronic barter. The key cost parameters were identified, and it was shown that within this framework fiat money dominates – is cheaper than – electronic barter unless inflation drives up the nominal interest rate, that increases in the number of commodities increase the costs of electronic barter faster than they do the costs of using fiat money, and that the lower bound to the cost of using fiat money is always below that of electronic barter. Thus fiat money is a superior transaction technology to electronic barter; transaction chains which use it have intrinsically lower information requirements.

The resulting demand for fiat money by the non-bank public will in turn give rise to demand by the banking sector. Their joint demands will ensure both that central banks survive, and that they will retain control of a price level measured in the money they issue.

REFERENCES

Brunner, Karl and Meltzer, M (1971) "The Uses of Money: Money in the Theory of an Exchange Economy". *American Economic Review*, 1971, 61 (December) pp 784-805

Brunner K and Meltzer A (1993) Money and the Economy: Issues in Monetary Analysis Cambridge University Press,Cambridge.

Capie, F.H (1986) "Conditions in which very Rapid Inflation Appears" Carnegie- Rochester conferences on Public Policy, spring Vol 24 pp115-165

Capie,F.H and Gomez, Y (2002) "Electronic Money: A survey of "Potential Users", Economic Trends: Finland

Clower, R W (1969) "Introduction" in Readings in Monetary Theory ed R W Clower. Penguin, London

Dubey, P and Granakoplos, J (1992) 'The value of money in a finite-horizon economy: a role for banks', in Dasgupta, P and Gale, D et al. (eds), Economic analysis of markets and games, Cambridge: MIT Press.

Dubey, P and M. Shubik (1978). "The Non-cooperative Equilibria of a Closed Trading Economy with Market Supply and Bidding Strategies," *Journal of Economic Theory, 17:1-20.*

Friedman M and Schwartz A J (1962) A Monetary History of the United States Princeton UP, Princeton.

Friedman M and Schwartz A J (1982) Monetary Trends in the United States and the United Kingdom. *University of Chicago Press*, Chicago

Fuhrer J C and Moore G R (1995) "Monetary Policy Trade-offs and the correlation between nominal interest rates and output". *American Economic Review*, Vol 85 (1) pp 219-239

Glasser, D (1989) Free Banking and Monetary Reform. CUP Cambridge and London

Goodhart, CAE (2000) "Can Central Banking Survive the IT Revolution?" International Finance, Vol 3, July, pp189-202

Gomez Y (2001) Electronic Money and the Monetary System Unpublished PhD Thesis, City University, London

Hayek, F.A (1976) "The Denationalisation of Money". Institute of Economic Affairs, London.

Hume D (1752) "Of Money" reprinted in eg Writings on Economics ed E Rotwein, Nelson, London 1955

Keynes J M (1935) A Treatise on Money Vol 1. Macmillan, London

King Mervyn (1999) "Challenges for Monetary Policy: New and Old" in New Challenges for Monetary Policy Federal Reserve Bank of Kansas City.

King, Mervyn (2002) "No money, no inflation – the role of money in the economy" Bank of England Quarterly Bulletin, Summer 2002, pp 162-174

Koenig E F (1990) "Real Money Balances and the timing of consumption: an empirical investigation" *Quarterly Journal of Economics*, Vol 105(2) pp 399-425

Latzer, Michael and Schmitz, Stefan W (2002). Carl Menger and the Evolution of Payment Systems, Cheltenham, Edward Elgar

McCallum B (1989) Monetary Economics: Theory and Policy Macmillan, New York.

McCallum B (1999) "Theoretical Analysis regarding a zero nominal bound for Interest Rates". *Journal of Monetary Economics*, Vol 32, pp 163-172

McCallum B and Nelson E (1999a) "An Optimising IS-LM specification for monetary policy and business cycle analysis". *Journal of Money, Credit, and Banking* Vol 31 (3) pp 296-316

Meltzer, A H (1998) "What is Money?" in Money, Prices and the Real Economy ed G E Wood, Edward Elgar, Cheltenham.

Meltzer A H (1999a) "The Transmission Process". Working Paper, Carnegie-Mellon University

Meltzer A (1999b) "A Liquidity Trap". Working Paper, Carnegie-Mellon University

Menger C (1892) "On the Origin of Money". *Economic Journal* 2 (June) pp239-255

Mills, T C and Wood G E (1977) "Money Substitutes and Monetary Policy in the UK", 1922-1971. *European Economic Review*, Vol 10 pp 19-36

Mills T C and Wood G E (1982) "Econometric Evaluation of Alternative UK Money Stock Series, 1870-1913". *Journal of Money, Credit and Banking*, May pp

Monnet, Cyril (2002) "Optimal Public Money". (Typescript)

Nelson E (2000) "Direct Effects of Base money on aggregate demand: theory and evidence": Bank of England Working Paper Series No122.

Radford R.A. "The Economic Organisation of POW Camp", Economica 145 Vol 12, No 1945, pp 189-201

Selgin, George and Lawrence H White (2002) "Mengerian perspectives on the future of money" in Latzer and Schmitz (op. cit.)

Shubik M and Tsomocos D P (2002) "A Strategic Market Game wit Seigniorage Costs of Fiat Money". *Economic Theory*, V.19, Nr1.

Shubik M (1999). The Theory of Money and Financial Institutions. Cambridge: MIT Press

Stigler, G J (1972) "The Law and Economics of Public Policy: A Plea to Scholars" *Journal of Legal Studies.*

Tsomocos D P (1996). Essays on Money, Banking and General Economic Equilibrium. *Unpublished PhD Thesis*, Yale University.

Tsomocos, D.P (2002) "Equilibrium Analysis, Banking, Contagion, and Financial Fragility". B of E Working Paper, forthcoming.

Yeager L B (1968) "Essential Properties of the Medium of Exchange". Kyklos, 21, pp 45-69