INTERNATIONAL ECONOMIC REVIEW
Vol. 46, No. 2, May 2005

MONEY IS PRIVACY*

BY CHARLES M. KAHN, JAMES MCANDREWS,
AND WILLIAM ROBERDS[1]

*Department of Finance, University of Illinois; Research Department,
Federal Reserve Bank of New York; Research Department,
Federal Reserve Bank of Atlanta, U.S.A.*

An extensive literature in monetary theory has emphasized the role of money as a record-keeping device. Money assumes this role in situations where using credit would be too costly, and some might argue that this role will diminish as the cost of information and thus the cost of credit-based transactions continues to fall. In this article we investigate another use for money, the provision of privacy. That is, a money purchase does not identify the purchaser, whereas a credit purchase does. In a simple trading economy with moral hazard, we compare the efficiency of money and credit, and find that money may be useful even when information is free.

1. INTRODUCTION

In this article we investigate the role of money in providing transactions privacy. Our interest in this topic stems in part from the ongoing development of e-commerce, and in particular, consumer transactions on the Internet. From the perspective of monetary theory, Internet-based or "virtual" transactions differ fundamentally from ordinary transactions because there is currently no widely accepted form of e-cash, or "virtual money."[2] Without cash, purely anonymous transactions are not possible.

Is this lack of anonymity desirable? Some of the literature on money versus credit (e.g., Townsend, 1989; Taub, 1994; Kocherlakota, 1998; Kocherlakota and Wallace, 1998; Aiyagari and Williamson, 2000) suggest that the value of money as a transactions medium stems largely from its role as a proxy or "sufficient statistic" for more complicated, credit-based systems of individual accounts. The more costly and the more imperfect the available credit-based system, the greater the need for money. With the development of the Internet, however, the costs of maintaining

---

* Manuscript received June 2004; revised January 2005.

[1] This article was prepared for the conference "Models of Monetary Economies II," sponsored by the Federal Reserve Bank of Minneapolis and the University of Minnesota. The authors thank Akihiko Matsui, the issue editors, two anonymous referees, and conference participants for their comments, as well as participants in a seminar at the Federal Reserve Bank of Kansas City and the Clarence W. Tow conference on Money and Banking at the University of Iowa. Please address correspondence to: William Roberds, Research Department, 1000 Peachtree Street, N.E., Atlanta, GA 30309-4470. Phone: 404-498-8970. E-mail: *william.roberds@atl.frb.org*.

[2] See Kuttner and McAndrews (2001) and Schreft (2002) for surveys of the various technologies available for online payment.

and transmitting vast amounts of information are falling dramatically. Some might, therefore, argue that the low cost of Web-based information processing means that there will be no role for e-money as a medium of exchange.

Our counterargument is that in addition to its value as a possibly imperfect proxy for credit, money also derives value from its use in anonymous exchanges, facilitating certain otherwise infeasible transactions. This property of money is most often associated with various types of shady deals,[3] but we will argue that it is of potential social value in economic situations where the parties in the transaction cannot trust each other not to take subsequent opportunistic actions.[4,5]

In a simple trading economy with moral hazard, we compare the efficiency of using as a transactions technology a nonanonymous record-keeping device or anonymous money. We then consider the more realistic case of anonymous money supplemented by a voluntary record-keeping device, and in particular the effects of improvements in monitoring technologies (or equivalently, privacy protection) on the demand for money. In the latter case, we find that making money available can lead to efficiency gains. Although the joint use of money and credit is also a feature of Kocherlakota and Wallace (1998) and Aiyagari and Williamson (2000), the use of credit in those models is limited by random shocks to memory. In contrast, memory is never impaired in our model, and it is precisely the infallibility of memory that renders it exploitable by outside parties.

We also investigate an alternative arrangement that may appear on the Internet, the use of intermediaries to provide anonymity. Such an arrangement supplements nonanonymous trade, but does not always act as a perfect substitute for anonymous money. In cases where the legal structure cannot provide perfect enforcement, the use of virtual money may dominate alternative arrangements.

In the environment below we consider a particularly simple type of moral hazard, i.e., theft. Theft, as modeled below, does not coincide with the popular notion of "identity theft," but is a reasonable stand-in. What is key to our analysis is the possibility of ex post opportunistic behavior that may arise under limited enforcement, and theft fits this description admirably.

A more specialized model of identity theft would require some development of the concept of *identity*. Economists may be accustomed to thinking of agents'

---

[3] Camera (2001) explores the role of money as a facilitator of illicit activity. He et al. (2005) note that currency is more subject to theft than bank money. In the present article we ignore these disadvantages associated with the anonymity of money, in order to concentrate on its advantage in deterring theft of goods.

[4] The point is in fact of wider applicability. Monetary economies are examples of infinitely repeated games of imperfect monitoring, because individuals' monetary holdings and monetary transactions are private information. In general the imperfection of the monitoring restricts the equilibrium set of outcomes in such games (see Sekiguchi, 1997; and Matsushima, 2004, for analyses of two-player repeated games with imperfect monitoring). However, when privacy of transactions reduces opportunism, it expands the equilibrium set. We thank an anonymous referee for pointing out the connections to this literature.

[5] The increasing incidence of identity theft and related frauds suggests that this is more than a theoretical possibility. A recent survey by the Federal Trade Commision (2003) found that over 12% of Americans have been victims of identity theft within the past 5 years. See Kahn et al. (2000) for a treatment of privacy issues in a law and economics context. See also Bisin and Rampini (2004) for an examination of the policy implications of anonymity in a public finance context.

identities as their histories, but the concept of identity must clearly amount to more than this. Any credit-based system of exchange must have some way of matching up individuals to histories, even when the former do not walk around with the latter pasted on their foreheads. A systematic analysis of such matching is a tempting subject for future research.

2. THE MODEL

There are N ex ante identical, infinitely lived agents, where N is large.[6] Time is discrete. All agents are risk neutral, and have a common discount factor δ. It will be convenient to think of each agent as identified with a distinct "location," where the list of agents' locations is public information. A unique, indivisible, nonstorable consumption good can be produced at each location. In every period, one agent randomly wakes up "hungry" for the consumption good of another agent, also randomly selected. Hungry agents then journey to the location of their preferred supplier. The identity of the hungry agent may or may not be revealed at this point, according to the information structure of the economy and the transactions technology available.[7]

When hungry, an agent desires exactly one unit of the particular supplier's good, which provides a utility of u. If not hungry, or if faced with a different supplier's good, the agent receives no utility. It costs the supplier s utils to make a unit of the good, where $0 < s < u$.

After receiving the preferred supplier's good, the hungry agent takes it back to his location in order to consume it. On his return, the hungry agent may be "robbed" by another agent. For simplicity in calculations, only one agent per period will be able to attempt a theft, where the would-be robber is randomly chosen from all agents other than the consumer. A theft attempt costs the robber c utils. If the victim actually possesses the good, a theft attempt will be successful a fraction α of the time. If successful, the theft carries a cost to the victim of f utils, so that the net utility to the consumer after a theft is $u - f$, which may be positive or negative. Successful theft imparts a benefit to the robber of εf utils, where $0 < \varepsilon < 1$. The timing of events within a period is displayed in Table 1.

In this environment, information on transactions carries both costs and benefits. No one automatically knows who is hungry on a particular day, so if a would-be robber waits around another agent's location, there will be only an $\alpha/(N - 1)$ chance of committing a successful theft. In what follows, we assume that

$$\frac{\alpha\varepsilon f}{N-1} < c \tag{1}$$

---

[6] For purposes of computing equilibria, it is convenient to have N finite. Later on, we will let N approach infinity in order to facilitate welfare comparisons.

[7] In the terminology of money search models, "single coincidences" of wants are possible under this setup, whereas "double coincidences" are not. Also note that purely anonymous trades cannot occur since the seller's identity is revealed by his location. Although a buyer's identity may not be revealed, a willingness to trade necessarily reveals a buyer's preferences, in contrast to Taub (1994).

TABLE 1
EVENTS WITHIN A PERIOD

- a. Consumer, supplier, randomly chosen
- b. Consumer journeys to supplier's location
- c. Trade occurs
- d. Robber randomly chosen; theft may be attempted
- e. Consumer and possibly robber consume

which assures that no robber will attempt to steal from an individual at random. However, a supplier always knows that he has provided someone a good, and so if the consuming agent reveals his identity to his supplier, the consumer makes it more likely he will be a victim. On the other hand, if the consumer remains anonymous, the supplier may be unwilling to give him the good, since there may be no way to obtain reciprocity in the future.

In the absence of theft, fully efficient exchange would allow the hungry agent in every period to purchase a good from his supplier. We let V^* be the expected symmetric utility established by a fully informed social planner. Since each agent has a $1/N$ chance of consuming or supplying each period, and since theft is socially wasteful, an agent's discounted expected utility under fully efficient exchange would be

$$V^* = \frac{u - s}{\delta N} \tag{2}$$

2.1. *Information and Exchange Structures.* We will compare outcomes in this model under a variety of information structures. Initially we consider *bilaterally observable gift exchanges.* In this arrangement, both suppliers and consumers keep track of a history of exchanges with each other agent, but no one knows about trades to which he was not a party. The history available in such arrangements, although restricted, serves as both an incentive to exchange and an incentive to theft.

Next, we consider *publicly observable gift exchanges*—what Kocherlakota (1998) refers to as "memory." In this environment there is a perfect record of all trades made by all participants. In the record, in every transaction, each agent's identity is revealed to all other agents.

We then consider the effect of introducing money. Money is an imperfect record of the history of trades by an individual. But, it is a record that maintains the anonymity of consumers, and is, therefore, of value in supplementing exchange. In particular, it allows the achievement of outcomes that cannot be obtained without money.

We will also consider an environment of *semianonymous gift exchange*. In this case the identity of the consuming agent is never revealed, limiting the possibilities for both trade and theft. Nonetheless, trade can sometimes be sustained under "social norms" (Araujo, 2004).

Finally we will consider a semianonymous record-keeping technology, and examine its advantages and disadvantages compared to money.

2.2. *Bilateral Information on Goods Exchanged.* In this environment, each supplier in an exchange is informed of the identity of the recipient. Each potential supplier must decide whether the disutility of production is worth the gain of "reciprocal privileges" with a given consumer. Absent theft, the supplier's expected benefit from future (next period onward) exchange opportunities with a *given* counterparty is

$$\left[\frac{1}{\delta N(N-1)}\right](u-s) \tag{3}$$

Exchange can be sustained as long as s, the cost of supplying a good, does not exceed the quantity (3), the expected benefits from reciprocal privileges. In this case the expected discounted utility for each consumer (from trades with *all* other agents) is simply given by V^*.

For a given transaction, the only potential robber in this environment is the supplier of the good. Were the supplier to attempt to steal the good, the buyer would infer that the seller was the robber, and could punish the seller by not engaging in trade with the seller in any future meetings.[8]

It is immediate that

THEOREM 1. *Under bilateral information a pure credit equilibrium in which all agents supply without theft is sustainable if and only if*

$$\left[\frac{1}{\delta N(N-1)}\right](u-s) \geq \max\{s, \alpha\varepsilon f - c\} \tag{4}$$

In other words, the instantaneous expected benefit to the supplier from attempted theft is $\alpha\varepsilon f - c$. If $\alpha\varepsilon f < c$, then theft will not be attempted and trade will proceed as in the previous case. Even if $\alpha\varepsilon f > c$, an equilibrium without theft is sustainable as long as the future surplus from bilateral exchange exceeds both the disutility of supplying a good and the instantaneous benefit from theft.

Exchange can still occur even with theft, however, if the expected net benefit from continued future exchanges is large enough. The following theorem states necessary and sufficient conditions for consumption always to occur, despite the presence of theft.

THEOREM 2. *Under bilateral information a pure credit equilibrium with theft in which all agents supply is sustainable if and only if*

$$\alpha\varepsilon f \geq c \tag{5}$$

$$u - (N-1)^{-1}\alpha f \geq 0 \tag{6}$$

---

[8] For the calculations in this article, we will assume that the victim observes attempts at theft, whether successful or not. Alternatively we could assume that the victim observes successful thefts but does not observe failed attempts; this will change calculations slightly but have no significant effect on our results.

and

$$\frac{u-(N-1)^{-1}\alpha f}{1+\delta N(N-1)} \geq s-(N-1)^{-1}(\alpha\varepsilon f-c) \tag{7}$$

Proof. Three conditions are necessary and sufficient for an equilibrium in which consumption always occurs and theft is attempted whenever the seller is the robber. The first condition is that attempted theft carries instantaneous benefits. (This is condition (5).) The second condition is that the benefits of consumption must exceed the expected costs from being a victim of theft (otherwise, hungry agents will refuse to acquire). (This is condition (6).) The final condition is that expected net benefit from future exchanges with one individual must outweigh the immediate expected disutility from production—in other words

$$\frac{u-(N-1)^{-1}\alpha f-s+(N-1)^{-1}(\alpha\varepsilon f-c)}{\delta N(N-1)} \geq s-(N-1)^{-1}(\alpha\varepsilon f-c) \tag{8}$$

Here the cost of production is reduced by the expected net benefit of being the robber. (Simplifying, this condition becomes (7).) This condition is also sufficient to guarantee that the expected net benefit of future exchanges is positive. ■

In this equilibrium the expected discounted utility for each consumer simplifies to

$$\frac{u-s-(N-1)^{-1}(\alpha(1-\varepsilon)f+c)}{\delta N} \tag{9}$$

Note that (9) includes both the expected benefit of being a robber and the expected cost of being a victim of theft.

If the conditions of neither theorem hold, then there is no equilibrium in which consumers always receive the good.[9]

2.3. *Full Information on Goods Exchanged.* We next consider an environment in which there is full information about the identity of recipients of goods in any exchange that occurs.[10] A failure to supply is a publicly observable event[11]; thus we examine equilibria in which a failure to supply leads to autarky.

---

[9] Autarky is always an equilibrium. In addition, for some parameter values, there will be an equilibrium in which only suppliers who are also thieves will provide the good (and immediately attempt to steal it back). Following Sekiguchi (1997) and Matsushima (2004) there can also be more complex stochastic enforcement arrangements relying on adoption of trigger strategies after a sufficient number of periods without a trade.

[10] In this section we simply assume that a victim has no way of announcing that he has been robbed and makes no response to a theft. In a later section we consider an environment in which a victim's behavior changes as a result of the theft.

[11] This is the natural assumption given the simple structure of demand in this model: Each period some agent should receive a good and this agent is publicly observed; thus any period in which no one receives a good is a period in which trade has broken down. With more complex patterns of trade, more complex signals of breakdown of trade would be necessary.

THEOREM 3. *Under full information, a pure credit equilibrium in which all agents supply without theft is sustainable if and only if*

$$\alpha\varepsilon f - c \leq 0 \tag{10}$$

and

$$\frac{u-s}{\delta N} \geq s \tag{11}$$

To understand these conditions, consider the incentives for theft. After each exchange, the designated robber knows where his potential victim lives. The identity of a robber and the presence of stolen goods are not observable. The instantaneous expected benefit to theft is $\alpha\varepsilon f - c$, and theft will occur as long as this is nonnegative. In this case, exchange will be sustained if the cost of supplying a good does not exceed the expected future net benefit of exchange.

If on the other hand (10) is violated, autarky need not be the only result.

THEOREM 4. *Under full information, a pure credit equilibrium with theft in which all agents supply is sustainable if and only if*

$$\alpha\varepsilon f - c \geq 0 \tag{12}$$

$$u - \alpha f - s + \alpha\varepsilon f - c \geq 0 \tag{13}$$

and

$$\frac{u - \alpha f - s + \alpha\varepsilon f - c}{\delta N} \geq s - \frac{\alpha\varepsilon f - c}{N-1} \tag{14}$$

PROOF. In this equilibrium the exchange occurs subject to attempted theft after each exchange and a consequent loss of value by recipients of goods. The expected value of trade in this case is

$$\frac{u - s - \alpha(1-\varepsilon)f - c}{\delta N} \tag{15}$$

The first condition is that theft is tempting. The next requirement is that the expected value of trade is positive; this condition also implies that the consumer prefers to take each opportunity to consume.[12] The final requirement is that the

---

[12] The condition

$$u - \alpha f \geq 0$$

in other words, that the instantaneous expected benefit from consumption be positive, is sufficient, but not necessary for agents to be willing to obtain goods. Since it will be apparent if no one consumes in a period, consumption could be enforced by the threat to revert to autarky if no one volunteers to consume in a period; thus we require no condition beyond the participation constraint (13).

value of trade exceeds the cost of supply (net of expected benefits of theft); this is condition (14). ■

Comparing (14) with (7) we see that the conditions under full information on exchange differ in two important respects: On one hand, attempted theft is inevitable in the full information case, so that the expected social cost is $N - 1$ times as great; on the other hand, the enforcement is carried out by all agents, not just the counterparty, so the denominator is smaller by the same factor.

3. THE EFFECTS OF INTRODUCING MONEY

We now consider the effects of introducing fiat money into the environments described above. Here, the construct analyzed in Kiyotaki and Wright (1989) comprises a unit of money: an indivisible, inherently valueless, noncounterfeitable object, where each agent can hold a maximum of one such object. There is a fixed supply of money and not all agents possess money at any given time. Money confers anonymity: A consumer making a purchase with money does not reveal his identity to his supplier or to others. The quantity of money circulating in the economy is known to all agents, however.

3.1. *Money under Semianonymity.* Suppose that would-be consumers cannot (or prefer not to) reveal their identity to would-be suppliers. Trade in this case is "semianonymous," since the supplier's identity is always known to the consumer. Money offers opportunities for exchange in this environment. Let M be the fraction of agents in the economy with money and let $\underline{V}(n)$ be the value function of an agent with n units of money, where $n \in \{0, 1\}$. Absent theft, the flow Bellman equations for each type of agent are[13]

$$\delta \underline{V}(0) = \frac{M}{N}(-s(1+\delta) + \underline{V}(1) - \underline{V}(0)) \tag{16}$$

$$\delta \underline{V}(1) = \frac{1-M}{N}(u(1+\delta) + \underline{V}(0) - \underline{V}(1)) \tag{17}$$

Algebraic manipulation of (16) and (17) yields

$$\underline{V}(0) = \frac{M}{N}\left(\frac{1+\delta}{\delta}\right)\left[\frac{(1-M)(u-s) - \delta N s}{1+\delta N}\right] \tag{18}$$

---

[13] For computational simplicity these and other Bellman equations involving money are written as if the fraction of agents holding money does not depend on whether the agent himself holds money. This approximation is valid for large N. These calculations could also be considered in the case where there is no limit on the amount of money an individual can hold. As long as there is a finite number of units circulating in the economy the calculations become more complex but the results are similar, although it becomes possible to have multiple equilibria with different prices.

$$\underline{V}(1) = \left(\frac{1-M}{N}\right)\left(\frac{1+\delta}{\delta}\right)\left[\frac{M(u-s)+\delta N u}{1+\delta N}\right] \tag{19}$$

Monetary exchanges are assumed not to be publicly revealed; hence the instantaneous expected payoff to theft is $\alpha\varepsilon f/(N-1) - c$, which is assumed to be negative.

THEOREM 5. *A monetary equilibrium exists if and only if*

$$(1-M)u \geq s(1-M+\delta N) \tag{20}$$

The condition is equivalent to the requirement that the value of money is sufficient to induce supplying a good:

$$\underline{V}(1) - \underline{V}(0) \geq (1+\delta)s \tag{21}$$

As is common in search models of money, a monetary equilibrium obtains if agents are patient enough (for sufficiently small $\delta > 0$). In monetary equilibrium, an agent's expected utility is given by

$$\frac{M(1-M)(u-s)}{\delta N} \tag{22}$$

and the welfare-maximizing quantity of money is given by $M = 1/2$. Expected utility is less than V^* because trade can only occur if money holdings are exactly right.

3.2. *Money as an Alternative to Bilateral Information.* Now we consider allowing consuming agents to choose between transactions technologies. In this section, we allow them the following two choices: they may anonymously purchase goods with money or they may choose to reveal their identity to their suppliers (and no one else) with the intent of obtaining "credit" for future reciprocal actions. Agents purchasing on credit are expected to make repayment by supplying goods to counterparties with whom they have previously engaged in credit transactions, if they purchase on credit and not with cash. Agents failing to make these required payments lose their credit with that counterparty and subsequent transactions between the two are limited to cash. As was the case in the previous section, a credit purchase exposes the purchaser to the possibility of theft from the supplier.

Depending on the model parameters, money, credit, or both may be used in equilibrium. Credit alone will be used, for example, if there is no theft and if agents are patient enough. Money will used exclusively if the likelihood and cost of theft is high enough. We can also show that there are equilibria where both money and credit exist.

Theorem 6. *Under bilateral information, the following conditions are necessary and sufficient to sustain an equilibrium where money and credit coexist:*

$$(N-1)u \geq \alpha f \tag{23}$$

$$\alpha\varepsilon f - c \geq 0 \tag{24}$$

$$(1-M)\alpha f \geq (1-M+\delta N)(\alpha\varepsilon f - c) \tag{25}$$

$$\frac{(1-M)\alpha f + M(\alpha\varepsilon f - c)}{1+\delta N} \geq s(N-1) \tag{26}$$

and

$$\begin{aligned}\left[u - \frac{\alpha f}{N-1}\right]\left(M + \frac{(1-M)^2}{1+\delta N}\right)& \\ \geq \left[s - \frac{\alpha\varepsilon f - c}{N-1}\right]&\left(1 - \frac{M(1-M)}{1+\delta N} + \delta N(N-1)\right)\end{aligned} \tag{27}$$

Proof. For there to be an equilibrium with both money and credit, it must be the case that theft sometimes occurs in credit transactions, so that holders of money will always prefer to transact with money when they wish to consume. This will only be possible when their potential supplier does not have money; otherwise the transaction will proceed on a credit basis. Likewise, it must be the case that potential suppliers without money must prefer transacting with money, when it is available, to transacting with credit.

Taking the above considerations into account, we can write the Bellman equations for agents without and with money as

$$\begin{aligned}V(0) = {}& \frac{1}{N}\left(u - \frac{\alpha f}{N-1} + \frac{V(0)}{1+\delta}\right) + \frac{M}{N}\left(-s + \frac{V(1)}{1+\delta}\right) \\ & + \frac{1-M}{N}\left(-s + \frac{\alpha\varepsilon f - c}{N-1} + \frac{V(0)}{1+\delta}\right) + \left(1 - \frac{2}{N}\right)\frac{V(0)}{1+\delta}\end{aligned} \tag{28}$$

$$\begin{aligned}V(1) = {}& \frac{1-M}{N}\left(u + \frac{V(0)}{1+\delta}\right) + \frac{M}{N}\left(u - \frac{\alpha f}{N-1} + \frac{V(1)}{1+\delta}\right) \\ & + \frac{1}{N}\left(-s + \frac{\alpha\varepsilon f - c}{N-1} + \frac{V(1)}{1+\delta}\right) + \left(1 - \frac{2}{N}\right)\frac{V(1)}{1+\delta}\end{aligned} \tag{29}$$

where $V(n)$ is the value functions for agents with n units of money, when agents have a choice between the use of money and "bilateral credit." Equation (28) says that the value function of an agent without money equals the weighted sum of the continuation values of being a consumer in a credit transaction, a supplier in a cash transaction, a supplier in a credit transaction, and not transacting at all. Equation (29) says that the value function of an agent with money equals the weighted sum of the continuation value of being a consumer in a cash transaction, a consumer in a credit transaction, a supplier in a credit transaction, and not transacting.

Solving for $V(0)$ and $V(1)$ we obtain

$$\text{(30)} \qquad \begin{aligned} \frac{\delta N}{1+\delta} V(0) = u - s &- \left(\frac{\alpha f}{N-1}\right)\left(1 - \frac{M(1-M)}{N\delta + 1}\right) \\ &+ \left(\frac{\alpha \varepsilon f - c}{N-1}\right)\left(1 - M + \frac{M^2}{N\delta + 1}\right) \end{aligned}$$

$$\text{(31)} \qquad \begin{aligned} \frac{\delta N}{1+\delta} V(1) = u - s &- \left(\frac{\alpha f}{N-1}\right)\left(M + \frac{(1-M)^2}{N\delta + 1}\right) \\ &+ \left(\frac{\alpha \varepsilon f - c}{N-1}\right)\left(1 - \frac{M(1-M)}{N\delta + 1}\right) \end{aligned}$$

To sustain this behavior as an equilibrium, the following conditions are necessary and sufficient: (a) agents prefer to consume rather than forgo consumption, (b) agents prefer to steal if given the opportunity via credit transactions, (c) agents prefer to supply goods in credit transactions rather than lose the benefit of future credit transactions, (d) agents find it worthwhile to supply for money, and (e) both buyers and sellers prefer money transactions to credit transactions.

Conditions (a) and (b) are specified by (23) and (24); they are identical to the corresponding conditions in the pure credit case. As for condition (c) if an agent does not supply in a credit transaction, he must carry out future credit transactions with that counterparty solely in cash. Hence this equilibrium requires

$$\text{(32)} \qquad -s + \frac{\alpha \varepsilon f - c}{N-1} + \frac{V(n)}{1+\delta} \geq \left(\frac{N-2}{N-1}\right)\frac{V(n)}{1+\delta} + \left(\frac{1}{N-1}\right)\frac{\underline{V}(n)}{1+\delta}$$

for $n = 0, 1$. Recall that $\underline{V}(n)$ is the value of holding n units of money in a pure monetary equilibrium. For $n = 1$ this condition reduces to (27); for $n = 0$ this condition reduces to

$$\text{(33)} \qquad \begin{aligned} &\left(u - \frac{\alpha f}{N-1}\right)\left[1 - \frac{M(1-M)}{1+\delta N}\right] \\ &\quad \geq \left(s - \frac{\alpha \varepsilon f - c}{N-1}\right)\left[1 - M + \frac{M^2}{1+\delta N} + (N-1)\delta N\right] \end{aligned}$$

which is implied by (27) for M in $[0, 1]$.

Condition (e) for buyers (i.e., agents with money prefer to buy with money) is

$$u + \frac{V(0)}{1+\delta} \geq u - \frac{\alpha f}{N-1} + \frac{V(1)}{1+\delta} \tag{34}$$

and condition (e) for sellers (sellers without money prefer cash to credit) is

$$-s + \frac{V(1)}{1+\delta} \geq -s + \frac{(\alpha\varepsilon f - c)}{N-1} + \frac{V(0)}{1+\delta} \tag{35}$$

Since

$$\frac{V(1) - V(0)}{1+\delta} = \frac{(1-M)\alpha f + M(\alpha\varepsilon f - c)}{(N-1)(1+\delta N)} \tag{36}$$

these last two conditions reduce to

$$\alpha f \geq \frac{(1-M)\alpha f + M(\alpha\varepsilon f - c)}{1+\delta N} \geq \alpha\varepsilon f - c \tag{37}$$

The left inequality holds automatically; the right simplifies to (25).

Condition (d) is

$$\frac{V(1) - V(0)}{1+\delta} \geq s$$

which simplifies to (26).We also need that the corresponding condition holds when an individual is relegated to monetary trade; this is the necessary and sufficient condition for a pure monetary equilibrium (20). However, this condition follows from the first four conditions of the theorem. ■

In this equilibrium, money is the preferred means of trade, since it avoids the costs of theft. However, if the agents interested in trading do not have the right distribution of money holdings, they prefer to engage in credit trades rather than not trade at all. It is not difficult to verify that parameter combinations exist for which the conditions of this theorem are satisfied. For instance, given fixed values of N, $M, \delta, \varepsilon, \alpha$, f and given $u > \alpha f/(N-1)$ the conditions are satisfied by all c less than, but sufficiently close to $\alpha\varepsilon f$ and all s sufficiently small. Or if we let δ approach 0, the requirements reduce to (23) (consumption is worth the risk of being a victim of theft), (24) (theft is tempting) plus two additional natural conditions as follows:

$$\left[u - \left(\frac{\alpha f}{N-1}\right)\right] \geq \left[s - \left(\frac{\alpha\varepsilon f - c}{N-1}\right)\right] \tag{38}$$

(production, even with the expected social cost of theft, is socially desirable), and

$$(1 - M)\alpha f \geq s - M(\alpha\varepsilon f - c) \tag{39}$$

(the benefit of acquiring a unit of money—in terms of reduced expectation of being a victim of theft—exceeds the cost of acquisition, including reduced expectation of being able to rob someone).

Two points should be noted. First, given that the threat for failure to repay debts is reversion to monetary equilibrium, not to autarky, the requirements for maintaining willingness to repay debts are stricter than they otherwise would be. Thus, the existence of money to a certain extent drives out debt.[14] Second, it is the nonobservability of an individual's money holdings that necessitates imposing two of the constraints in the money–credit equilibrium (conditions (34) and (35)). Note in particular if sellers could not hide their money holdings then (35) could be relaxed.

The above results also hinge on the restriction of money holdings to no more than one unit. A buyer's money holdings are exhausted after a single purchase, increasing agents' incentives to engage in credit transactions. If agents could hold additional units of money, these incentives would be diminished, but would persist for a finite bound on money holdings. An examination of the case of unbounded money holdings, along the lines of Taub (1994), would be an interesting, but also challenging, extension.

3.3. *Money as an Alternative to Full Information.* As in the previous section, consumers have a choice between using money or revealing their identity in credit transactions. In the latter case their identity is revealed not only to their counterparty, but also to all other agents in the economy. We assume if a supplier refuses to supply in a credit transaction, his identity is revealed, and the supplier is reduced to monetary transactions only. In monetary transactions, identities are not revealed.[15] As under bilateral information, equilibria exist with only money or only credit transactions. Sufficiently patient agents will prefer to transact with credit as long as there is no theft. If theft is sufficiently likely and costly, agents will only want to use money. There are also equilibria where both money and credit are used.

As in the previous section, in such an equilibrium holders of money always transact in money if this is possible. In the money–credit equilibrium, the flow Bellman equations can be written as

---

[14] For other examples of interactions between different forms of payments media see He et al. (2005).

[15] Numerous alternate assumptions are posssible: We could suppose that identities are revealed if the supplier refuses to supply in a monetary transaction as well, or that the identity is revealed only if the demander enters the transaction without money (so that he knows from the start that the transaction will be a credit transaction). Also the penalty for not supplying in a credit transaction could be that *all* players revert to autarky, with monetary transactions ceasing as well. We have chosen the assumptions in the text primarily because they keep the analysis parallel to that for the previous sections.

$$\begin{aligned}\bar{V}(0) = {} & \frac{1}{N}\left(u - \alpha f + \frac{\bar{V}(0)}{1+\delta}\right) + \frac{M}{N}\left(-s + \frac{\bar{V}(1)}{1+\delta}\right) \\ & + \frac{1-M}{N}\left(-s + \frac{\alpha\varepsilon f - c}{N-1} + \frac{\bar{V}(0)}{1+\delta}\right) \\ & + \left(1 - \frac{2}{N}\right)\left(\frac{\bar{V}(0)}{1+\delta} + (1 - M(1-M))\frac{\alpha\varepsilon f - c}{N-1}\right)\end{aligned} \tag{40}$$

$$\begin{aligned}\bar{V}(1) = {} & \frac{1-M}{N}\left(u + \frac{\bar{V}(0)}{1+\delta}\right) + \frac{M}{N}\left(u - \alpha f + \frac{\bar{V}(1)}{1+\delta}\right) \\ & + \frac{1}{N}\left(-s + \frac{\alpha\varepsilon f - c}{N-1} + \frac{\bar{V}(1)}{1+\delta}\right) \\ & + \left(1 - \frac{2}{N}\right)\left(\frac{\bar{V}(1)}{1+\delta} + (1 - M(1-M))\frac{\alpha\varepsilon f - c}{N-1}\right)\end{aligned} \tag{41}$$

where $\bar{V}$ denotes the value function of agents who have a choice between money and multilateral credit.

The interpretation of Equation (40) is as follows. An individual has a probability $1/N$ of being hungry in a period, in which case the first term on the right side is the expected payoff. He has a probability M/N of being the supplier to somebody with money, in which case the second term is the expected payoff. He has the probability $(1 - M)/N$ of being the supplier to somebody without money, in which case the third term is the expected payoff (the middle expression within the parentheses representing the expected payoff from being a robber in this particular case). The last term is the expected payoff from being neither supplier nor consumer; this payoff also includes a component representing the expected payoff from theft in this case; theft can only occur if a credit transaction is carried out, the probability of which is $1 - M(1 - M)$. The interpretation of Equation (41) is similar.

THEOREM 7. *Under full information, the following conditions are necessary and sufficient to sustain an equilibrium where money and credit coexist:*

$$u \geq \alpha f \tag{42}$$

$$\alpha\varepsilon f - c \geq 0 \tag{43}$$

$$(1 - M)\alpha f \geq \left(1 + \delta N - \frac{M}{N-1}\right)(\alpha\varepsilon f - c) \tag{44}$$

$$(1 - M)\alpha f + \frac{M}{N-1}(\alpha\varepsilon f - c) \geq (1 + \delta N)s \tag{45}$$

and

$$\left[M + \frac{(1-M)^2}{1+\delta N}\right](u - \alpha f) \geq -[1 - M(1-M)]\frac{N-2}{N-1}(\alpha\varepsilon f - c) + \left[1 + \delta N - \frac{M(1-M)}{1+\delta N}\right]\left(s - \frac{\alpha\varepsilon f - c}{N-1}\right) \tag{46}$$

PROOF. Solving for $\bar{V}(0)$ and $\bar{V}(1)$ we obtain

$$\frac{\delta N}{1+\delta}\bar{V}(0) = (u - s) - \left[1 - \frac{M(1-M)}{\delta N + 1}\right]\alpha f + \left[(N-2)(1 - M(1-M)) + 1 - M + \frac{M^2}{\delta N + 1}\right]\left(\frac{\alpha\varepsilon f - c}{N-1}\right) \tag{47}$$

$$\frac{\delta N}{1+\delta}\bar{V}(1) = (u - s) - \left[M + \frac{(1-M)^2}{\delta N + 1}\right]\alpha f + \left[(N-2)(1 - M(1-M)) + 1 - \frac{M(1-M)}{\delta N + 1}\right]\left(\frac{\alpha\varepsilon f - c}{N-1}\right) \tag{48}$$

To sustain this behavior as an equilibrium, necessary and sufficient conditions are parallel to conditions (a)–(e) of the previous theorem. Conditions (a) and (b) become (42)–(43).[16] Condition (c) (agents are willing to supply consumption goods in credit transactions) becomes

$$-s + \frac{\alpha\varepsilon f - c}{N-1} + \frac{\bar{V}(n)}{1+\delta} \geq \frac{\underline{V}(n)}{1+\delta}, \quad \text{for } n = 0, 1 \tag{49}$$

The condition for $n = 1$ reduces to (46); the condition for $n = 0$ is implied by (46).

The conditions (d) and (e) correspond to those in the bilateral case, with $V(n)$ replaced by $\underline{V}(n)$. They reduce to

$$\alpha f \geq \frac{1}{\delta N + 1}\left[(1-M)\alpha f + M\left(\frac{\alpha\varepsilon f - c}{N-1}\right)\right] \geq \max\{\alpha\varepsilon f - c, s\} \tag{50}$$

where the middle expression equals $(1+\delta)^{-1}(\bar{V}(1) - \bar{V}(0))$. Again, the left inequality holds automatically; the right simplifies to (44) and (45). As before, the first four conditions imply the condition that individuals restricted to using money still find money valuable. ■

Circumstances under which parameters satisfy the requirements of this theorem are similar to those discussed in the preceding section.

---

[16] Note that condition (42) is stricter than the corresponding condition under full information with pure credit. Since money transactions cannot be observed, the fact that a consumer has not purchased is no longer public information. Compare the footnote in the proof to Theorem 4.

TABLE 2
MONEY VERSUS CREDIT WITHOUT THEFT

	Money	Credit	
		Bilateral	Multilateral
$\sum U$	$M(1-M)(u-s)$	$u-s$	$u-s$
Feasibility	$(u-s)(1-M) \geq s\delta N$	$u-s \geq s\delta N(N-1)$	$u-s \geq s\delta N$

TABLE 3
MONEY VERSUS CREDIT WITHOUT THEFT AS $N \to \infty$

	Money	Multilateral Credit
Steady-state $\sum U$	$M(1-M)(u-s)$	$u-s$
Feasibility	$(u-s)(1-M) \geq sr$	$u-s \geq sr$

4. SOME WELFARE COMPARISONS

We can use the above analysis to make welfare comparisons among different economies, using expected aggregate instantaneous steady-state utility as a criterion, where the expectation is taken over the success or failure of theft. We begin by comparing an economy where semianonymous transactions take place only with money (the economy of Section 3.1) to an economy where bilateral information is available on all transactions (Section 2.2) and one where full information is available on all transactions and "multilateral credit" arises (Section 2.3). In the absence of theft (when $\alpha\varepsilon f < c$), such a comparison is quite simple and is displayed in Table 2.

From Table 2 it is clear that credit dominates money where both are feasible. Bilateral credit is the most delicate arrangement and depends on a relatively small number of agents in the economy. As we drive N to infinity while allowing the interval between time periods and δ to shrink as $1/N$, we obtain the limiting results (where $r > 0$ is the limit of δN) displayed in Table 3.[17]

Bilateral credit becomes infeasible in this case as the chance of a repeated match goes to zero. Multilateral credit remains feasible, however, and absent theft we have the standard results of the money literature that credit is feasible whenever money is, and delivers higher welfare.

When theft can occur, these comparisons are less straightforward. Table 4 offers steady-state comparisons of economies under the threat of theft (for which $\alpha\varepsilon f \geq c$) with only money (Section 3.1), bilateral credit (Section 2.2), or multilateral credit (Section 2.3).

Feasibility for monetary equilibrium is the same as before, i.e., condition (20); feasibility for bilateral credit is given by (6) and (7), and feasibility for multilateral

---

[17] Technically this last step is necessary to make the environment of Section 2.4 compatible with Kocherlakota's (1998) concept of "memory." Essentially this requires that all matches be between agents without any previous contact.

TABLE 4

$E(\sum U)$ WITH THEFT FOR VARIOUS ENVIRONMENTS

Money Only	Bilateral Credit	Multilateral Credit
$M(1-M)(u-s)$	$u-s-N^{-1}(\alpha(1-\varepsilon)f+c)$	$u-s-\alpha(1-\varepsilon)f-c$

TABLE 5

$E(\sum U)$ WITH THEFT FOR VARIOUS ENVIRONMENTS

Money Only	Multilateral Credit Only	Money and Credit
$M(1-M)(u-s)$	$u-s-\alpha(1-\varepsilon)f-c$	$u-s-(1-M(1-M))$ $\times(\alpha(1-\varepsilon)f+c)$

credit is given by (13) and (14). From the table it is clear that under the threat of theft, money can dominate credit. Bilateral credit, where feasible, dominates multilateral credit, as it affords fewer opportunities for socially costly theft. Bilateral credit may dominate money if problems with theft are not too severe.

Finally, Table 5 offers a welfare comparison of the economies with money only, multilateral credit only, and a combination of multilateral credit and money (Section 3.3).

For the equilibrium with both money and credit, feasibility conditions are given by Theorem 7. A combination of both money and credit necessarily dominates credit by itself, and will dominate money as long as the surplus created in trade exceeds the social cost of theft, i.e., as long as $u-s>\alpha(1-\varepsilon)f+c$. If the cost and likelihood of theft are too high, then only exchange with money is possible.

In short, in an economy without theft and with a frictionless system of credit, money would be superfluous. When theft is present, it would be welfare improving to introduce money into a world with frictionless credit, as money introduces the possibility of anonymous, theft-free transactions. Not all potential consumers will have access to money, however, meaning that money does not completely supplant credit.

5. ROBUSTNESS

Money is not the only mechanism for sustaining exchange without theft. In this section, we consider two other possible“social norms”: gift giving and retaliation by the victims of theft.

5.1. *Gift Giving.* To analyze gift giving, consider a version of this environment under semianonymity. Each potential supplier's identity is known to the consuming agent, but the identity of the potential consumer is unknown to the supplier. Then, following Araujo (2004), we can show that exchange can sometimes be sustained under a "social norm," whereby each potential supplier agrees to supply a good to an unknown consumer, in anticipation of reciprocity when the supplier wishes to consume.

For gift giving to be a Nash equilibrium, it must be the case that the anticipated net future benefit of adhering to the social norm of gift giving exceeds the anticipated future benefits of defecting from the social norm. Defection is contagious in the sense that as a defector refuses to supply his goods, this results in additional defections. To rule out defections it must be true that

$$-s + V^{*} \geq V_d \tag{51}$$

where V_d is the expected value of defecting, which may be written as

$$V_d = u \sum_{t=1}^{\infty} \left(\frac{1}{1+\delta} \right)^{t} \frac{N - E(D_t)}{N(N-1)} \tag{52}$$

where D_t is the number of defectors as of time t and E denotes expectation as of period 0. Given that there are i defectors at time t, then

$$\Pr\{D_{t+1} = j \mid D_t = i\} = \begin{cases} \left(\frac{i}{N}\right)\left(\frac{N-i}{N-1}\right) & \text{if } j = i+1 \\ 1 - \left(\frac{i}{N}\right)\left(\frac{N-i}{N-1}\right) & \text{if } j = i \\ 0 & \text{if } j \neq i, i+1 \end{cases}$$

Let the N-dimensional vector $\boldsymbol{\pi}_t$ represent the probability distribution of D_t. It follows that $\boldsymbol{\pi}_t = A^{t-1}\boldsymbol{\pi}_1$, where $\mathbf{A}$ is the $N \times N$ transition matrix

$$\mathbf{A} = \begin{bmatrix} 1 - \frac{N-1}{N(N-1)} & 0 & & \cdots & 0 \\ \frac{N-1}{N(N-1)} & 1 - \frac{2(N-2)}{N(N-1)} & 0 & & \vdots \\ 0 & \frac{2(N-2)}{N(N-1)} & \ddots & \ddots & \\ \vdots & \ddots & \ddots & 1 - \frac{N-1}{N(N-1)} & 0 \\ 0 & \cdots & 0 & \frac{N-1}{N(N-1)} & 1 \end{bmatrix} \tag{53}$$

Furthermore,

$$\boldsymbol{\pi}_1' = (0, 1, 0, \ldots, 0) \tag{54}$$

since there are two defectors in period 1—the initial defector and his victim at time 0. Define $\boldsymbol{\Delta}$ as the N-dimensional row vector whose ith element is $(N - i)/(N - 1)$. We can then rewrite V_d as

$$V_d = u\sum_{t=1}^{\infty}\sum_{i=1}^{N}\left(\frac{1}{1+\delta}\right)^t \boldsymbol{\pi}_t(i)\left(\frac{N-i}{N(N-1)}\right) \tag{55}$$

$$= \frac{u}{(1+\delta)N}\boldsymbol{\Delta}\sum_{t=1}^{\infty}\left(\frac{A}{1+\delta}\right)^t \boldsymbol{\pi}_1$$

$$= \frac{u}{N}\Delta((1+\delta)I - A)^{-1}\boldsymbol{\pi}_1$$

where **I** is the N-dimensional identity matrix.[18]

Then, as agents become more patient and δ goes to zero, it is evident from (55) that the value of defecting tends to a finite limit, whereas the value of adhering to the gift giving norm (the LHS of (51)) grows without bound. Hence, exchange can be sustained under gift giving for sufficiently patient agents.

Gift giving becomes increasingly fragile, however, as the number of agents grows. We can bound the value of defecting by

$$V_d \geq u\left[\frac{1}{\delta N} - \frac{(1+\delta)}{N(N-1)\delta^2} + \frac{(1+\delta)^{-N+2}}{N(N-1)\delta^2}\right] \tag{56}$$

This inequality can be understood as follows: Since there is one meeting per period, the number of defections can increase at most by one per period. The worst case scenario is

$$D_t = \min\{t+1, N\} \tag{57}$$

Actual contagion must proceed more slowly than this worst-case scenario. Let

$$\underline{V}_d = u\sum_{t=1}^{N-1}\left(\frac{1}{1+\delta}\right)^t\left[\frac{N-t-1}{N(N-1)}\right] \tag{58}$$

$\underline{V}_d$ gives the value of defecting if a further defection would occur every period following the initial defection, until the entire population were exhausted; simplifying (58) we obtain the RHS of (56). Driving N to infinity and taking limits as in the previous section, we obtain a limiting lower bound for V_d

$$\underline{V}_d^{\infty} = \frac{u}{r^2}(r - 1 + e^{-r}) \tag{59}$$

---

[18] These calculations closely follow those of Araujo (2004, p. 246). Following Ellison (1994) and Kandori (1992), Araujo also examines social norms sustained by sequential equilibria. In this article we confine our attention to Nash equilibrium; extensions to sequential equilibrium in the context of money and theft would be interesting, but would require involved calculations.

where r is the limit of δN. Comparing $\underline{V}_d^\infty$ to the analogous limiting expression for V^*, we obtain a sufficient condition for gift giving to be infeasible

$$\underline{V}_d^\infty > -s + V^{*\infty} \tag{60}$$

or equivalently,

$$\frac{r(1+r)}{1-e^{-r}} > \frac{u}{s} \tag{61}$$

From (61) it is clear that for large N, gift giving is not feasible for r sufficiently large. Comparing (20) and (61) it is also clear that for large N, there will be a range of values of r for which monetary exchange is feasible, whereas gift giving is not.[19]

5.2. *Retaliation by Victims.* In describing the public information regime of Section 2.3, we assumed that victims of theft had no way to retaliate. In fact, retaliation could take many forms. In the opposite extreme, suppose that a victim of theft could make a public announcement that a theft had occurred. In an equilibrium with trade and without theft, such an announcement would signal a "defection" from the social norm of no theft, leading all agents to revert to autarky in subsequent periods. An equilibrium without theft is sustainable as long as the expected net benefits to future exchange exceed both the disutility of supplying and the private return to theft:

$$\frac{u-s}{\delta N} \geq \max\{s, \alpha\varepsilon f - c\} \tag{62}$$

The ability to make such announcements is welfare improving in that it reduces opportunities for theft. Condition (62) is also less stringent that condition (4), meaning that if such announcements are possible, theft-free trade is easier to achieve in an environment of full information than under bilateral information. If condition (62) is violated, however, trade with money may still dominate trade with credit. Note also that public announcements are the most forceful form of retaliation, and other forms of retaliation would be expected to have more limited effects. In addition, (61) may hold and (62) may fail simultaneously, whereas money is still feasible. In other words, there are parameter values where money succeeds, whereas both memory and gift giving fail.

6. INTERMEDIATION

Intermediaries can also be in the business of providing privacy. One possibility is "inside money"—a reputable agent issues a limited number of noncounterfeitable notes which circulate.[20] However, there are also ways an intermediary can provide

---

[19] More precisely, for every M^* in the open interval (0, 1) there exists a critical value $U^* > 1$ such that for all $0 < M < M^*$ and for all $u/s > U^*$, there is an open interval of values of r such that monetary exchange is feasible, but gift giving is not.

[20] For example, Cavalcanti and Wallace (1999) or Kiyotaki and Moore (2000) present models of inside money based on this idea.

privacy with a setup that does not resemble money. On the Internet, for example, there are sites which serve as “anonymizers.” These serve as gateways to other sites, scrambling the Web surfer’s information so his identity cannot be traced.

In this section we consider both an anonymizing institution that takes the form of intermediated credit and an institution providing inside money.

6.1. *Intermediated Credit.* We start with the economy of Section 2.3 in which transactions are public information. In addition, we assume that $\alpha\varepsilon f > c$ so that theft will occur (in the absence of retaliation by victims).

Let us now suppose that a bank charter is given to one agent. All other agents have the option of opening an “account” with the banker. When agents with a bank account wish to consume, they go to the banker and give him the location of their desired supplier. If the supplier has a bank account, the banker goes to the supplier, purchases the good with bank credit, and immediately and privately passes on the good to the consuming agent. Would-be thieves (other than the banker) are stymied because they do not know the location of the agent with the good. The banker is, in effect, “anonymizing” agents’ transactions.

This arrangement is sustainable as an equilibrium as long as (a) all agents have a bank account; (b) all agents believe that if they “defect” from this arrangement, all other agents will likewise defect, and the economy will return to autarky; and (c) there can be public announcements of defections by the counterparty of the defector.

Note that there are two opportunities for defection, the first being that a potential supplier can refuse to provide a good to the banker, and the second being that the banker, who knows the identities of consuming agents, can rob them after delivering their consumption good. The supplier will supply his good to the banker as long as the expected net benefit of (theft-free) future transactions exceeds the disutility of supplying the good, i.e., as long as (11) holds. The banker will refrain from robbing his “depositors” only if the expected net benefit of being theft free in future transactions exceeds the short-term gain from theft, i.e., if

$$\frac{u-s}{\delta N} \geq \alpha\varepsilon f - c \tag{63}$$

which is satisfied for $\delta N > 0$ sufficiently small. Thus, this arrangement is sustainable if the banker is patient enough. Note also that the combination of the two conditions (11) and (63) is simply the condition (62). In other words, the intermediated credit arrangement succeeds precisely in cases where public announcements of theft are effective.

Thus, a “banking” type of arrangement can in some cases deliver a first-best outcome (credit transactions without theft).[21] Intermediation is superior to both

---

[21] Given the level of abstraction of our model, we can regard this arrangement as an idealization of a money order or of a cashier’s check—in each case the transaction can be kept anonymous from the seller but not from the bank. Although it may seem farfetched for the purchaser to worry about needing privacy to protect him from his own banker, exactly the analogous problem arises on the Internet, as purchasers worry about the security of databases that underlie their online payments arrangements.

unintermediated trade under full information (without retaliation) because it reduces the scope for theft, and to trade under bilateral information because it does not require such a high degree of patience on the part of suppliers. On the other hand, if agents are too impatient, or if the temptation to steal is too great, money or a combination of money and unintermediated credit will be feasible, whereas intermediated credit will not.

6.2. *Private Banknotes.* Suppose that the information structure only allows for semianonymous gift exchange. One agent is allowed to issue private bearer notes. Technologically, the notes are the same as fiat money described above: noncounterfeitable, discrete, and subject to the restriction that each individual may hold at most one note. In addition, there is no requirement that notes be redeemed. Thus, notes circulate indefinitely and their use in a purchase preserves the anonymity of the purchaser. The quantity of notes outstanding is known by all agents.

In the long run, the same set of monetary equilibria would obtain under private money as under fiat money. Although private money would offer an improvement over autarky, a private issuer would have an incentive to issue as many notes as possible, i.e., until the incentive constraint (20) binds. If (20) binds for a per capita money stock $M > 1/2$, then the use of private money would result in an oversupply of notes.

Likewise, we could introduce private money into an economy in which all transactions are public information. Then the private money issuer would issue notes until either (20), (44), or (45) were binding. From the discussion above, this would necessarily lead to an improvement over either autarky or credit-only transactions. If the money issuer chooses a per capita money stock $M > 1/2$, it would again lead to an oversupply of banknotes.[22]

In terms of privacy, the important distinction between circulating media and accounts is that as the money passes from hand to hand, even the initial issuer no longer knows who currently holds it.

7. CONCLUSION

Somewhat paradoxically, recent advances in monetary theory have generated doubt about the value of money in technologically sophisticated economies. Money has been portrayed as, at best, an imperfect proxy for memory (Kocherlakota, 1998, and related articles) or at, worst, an enabler of illicit, welfare-reducing activities (Camera, 2001). In this article, we have argued that the "demotion" of money to a poor cousin of credit-based arrangements may have been premature.

---

[22] We have glossed over the technically interesting but (for our purposes) inessential issue of how such an equilibrium starts up. The banker enjoys seignorage in initial periods by issuing money for purchases. In those initial periods, the banker also bears an additional cost as being the most likely victim: Potential thieves in period 1 will regard the banker's location as being the one most likely to contain goods. Given the long-run benefits it may still be worthwhile for the banker to issue notes; if not he may choose a randomizing strategy in which he sometimes gives out money in early periods without obtaining goods.

In an economy with less-than-perfect enforcement, we have shown that the value of money may derive from its supposed imperfection, from the anonymity that it confers.

This is not to argue that arrangements other than money cannot also provide purchasers with anonymity. Above we have considered several such arrangements, including private intermediation and reciprocal gift giving. Yet, we have also shown that there are some circumstances where trade with money is feasible, whereas trade under these alternative arrangements is not. This suggests to us that the classic solution to the problem of transactions privacy—money—will persist well into the foreseeable future.

REFERENCES

Aiyagari, S. R., and S. D. Williamson, "Money and Dynamic Credit Arrangements with Private Information," *Journal of Economic Theory* 91 (April 2000), 248–79.

Araujo, L., "Social Norms and Money," *Journal of Monetary Economics* 51 (2004), 241–56.

Bisin, A., and A. Rampini, "Anonymous Markets and Optimal Policy," Unpublished manuscript, Northwestern University Finance Department, 2004.

Camera, G., "Dirty Money," *Journal of Monetary Economics* 47 (2001), 377–415.

Cavalcanti, R., and N. Wallace, "A Model of Private Banknote Issue," *Review of Economic Dynamics* 2 (1999), 104–36.

Ellison, G., "Cooperation in the Prisoner's Dilemma with Anonymous Random Matching," *Review of Economic Studies* 61 (1994), 567–88.

Federal Trade Commission, *Identity Theft Survey Report*, 2003.

He, P., L. Huang, and R. Wright, "Money and Banking in Search Equilibrium," *International Economic Review* 46 (2005), 637–70.

Kahn, C. M., J. McAndrews, and W. Roberds, "A Theory of Transactions Privacy," Federal Reserve Bank of Atlanta Working Paper 2000-22, November 2000.

Kandori, M., "Social Norms and Community Enforcement," *Review of Economic Studies* 59 (1992), 63–80.

Kiyotaki, N., and J. Moore, "Inside Money and Liquidity," Mimeo, 2000.

——, and R. Wright, "On Money as a Medium of Exchange," *Journal of Political Economy* 97 (August 1989), 927–54.

Kocherlakota, N. R., "Money Is Memory," *Journal of Economic Theory* 81 (August 1998), 232–51.

——, and N. Wallace, "Incomplete Record-Keeping and Optimal Payment Arrangements," *Journal of Economic Theory* 81 (August 1998), 272–89.

Kuttner, K. N., and J. J. McAndrews, "Personal On-line Payments," *Federal Reserve Bank of New York Economic Policy Review* 7 (December 2001), 35–50.

Matsushima, H., "Repeated Games with Private Monitoring: Two Players," *Econometrica* 70 (2004), 823–52.

Schreft, S., "Clicking with Dollars: How Consumers Can Pay for Purchases from E-tailers," *Federal Reserve Bank of Kansas City Economic Review* (First Quarter 2002), 37–64.

Sekiguchi, T., "Efficiency in Repeated Prisoner's Dilemma with Private Monitoring," *Journal of Economic Theory* 76 (1997), 345–61.

Taub, B., "Currency and Credit Are Equivalent Mechanisms," *International Economic Review* 35 (November 1994), 921–56.

Townsend, R. M., "Currency and Credit in a Private Information Economy," *Journal of Political Economy* 97 (December 1989), 1323–44.