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New models of old(?) payment questions

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New models of old(?) payment questions*

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Abstract

Is private money feasible and desirable? In its absence, is there a central bank policy that partially or fully substitutes for private money? In this paper, some recent modeling ideas about how to address these questioned are reviewed and applied. The main ideas are that people cannot commit to future actions and that their histories are to some extent unknown—are not common knowledge. Under the additional assumption that the private monies issued by different people are distinct, a strong recognizability assumption, it is shown that there is a role for private money.

JEL classification number: E40

Key words: inside money, discount-window policy, mechanism design

1 Introduction

In both the U.S. and the U.K., a monopoly on "currency" issue grew out of a system in which there were many issuers of banknotes. In the U.K., that monopoly was created in 1844, and was accompanied by a 100% specie marginal reserve requirement against banknote issue. The 1844 law, Peel's

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Act, was a victory for the *currency school*, whose members advocated some version of *hard* money, or what much later came to be called *monetarism*. The 1844 law was opposed by members of the *banking school*—those who advocated some version of laissez-faire in intermediation. Among the questions alluded to in the debates were: Was the private note-issuing system accomplishing anything? If it was, then would it be desirable to have the Bank of England manage its monopoly so as to emulate what the private note system was accomplishing? In this paper, we revisit those questions and do so for at least three reasons. First, one test of progress in monetary theory is its ability to provide new insights about old questions that have never been satisfactorily resolved. Second, those old questions have modern analogues: Should central banks operate lending facilities and, if so, how? Should stored value and other modern analogues of private note-issue be regulated and, if so, how? Third, the modeling ideas that throw light on those questions have implications for seemingly unrelated questions—for example, how best to model cashless economies.

Why do we assert that the 19th century debates were never satisfactorily resolved? At the beginning of the 20th century, the dominant monetary theory consisted of the classical dichotomy. While that theory could accommodate private credit instruments that to some extent substitute for outside or base money, either by treating such substitutes as part of the stock of a broader concept of money or by treating them as increasing the velocity of outside or base money, neither treatment could say anything about the welfare consequences of different monetary systems—or, for that matter, the welfare consequences of money. At the beginning of the 21st century, the dominant monetary theory consists of descendents of the classical dichotomy: models with real balances in utility or production functions or models with cash-in-advance constraints. These descendents were designed to overcome the blatant inconsistencies of the classical dichotomy—the kind of inconsistency that Patinkin [13] pointed out. They were not designed to and cannot address the questions raised in the 19th century debates any better than could the classical dichotomy.

In this paper, we set out some ideas about how such questions might be approached. Our goal is to convince readers that the ideas are fruitful—both for the 19th century questions about good monetary systems and for other questions concerning monetary systems. However, one warning is in order; we have essentially no results about the implications of the modeling ideas we set out.

2 Some general ideas

One challenge to any model of money is: Why is trade being modeled using *money* when trade could conceivably be accomplished with some version of borrowing and lending between people? There is, by now, a well-known answer. Individuals cannot commit to future actions *and* to some extent their histories are not known. This answer goes back at least to a 1973 paper by Ostroy [12] (see also Townsend [17] and Kocherlakota [8].) Neither part is controversial. The inability to commit, although inconsistent with the Arrow-Debreu model, is a standard and plausible assumption of game theory. The partially unknown histories is in modern game theory labeled imperfect monitoring. It means that previous actions of some people are not common knowledge. It is *the* assumption in moral-hazard models and is implicit in the idea that money is used in trade among strangers and the related idea that money is evidence of past actions that are otherwise imperfectly known. We like the answer, and, therefore, build a model that rests on it. Throughout we maintain the assumption that people cannot commit to future actions. As regards monitoring, we assume that some people are not monitored at all and others are perfectly monitored. The nonmonitored people are the demanders of tangible media of exchange; the monitored people are the potential issuers of private money and, in most respects, are the focus of our discussion.

The kind of private money we analyze is best thought of as payable-to-the-bearer bills of exchange that have only the issuer's name on them. The private money has this form, a form which bypasses banks as we ordinarily describe them, because this form more easily gets us to a model in which the welfare consequences of different systems can be analyzed. (Something like this is done in the Diamond-Dybvig model of banking in which what is described as a banking system is best thought of as a *mechanism* in a model consisting only of consumers—who are necessarily the owners of a consolidated banking-business sector [see [4]]).

Throughout, we work against the background of a model in which each person, including any issuer of private money, is individually a small part of the total economy and in which for purposes of production and consumption people meet in pairs. In our model, people do not choose to meet in pairs and a pair need not be viewed as a natural production unit, as it is in models of marriage and seems to be in many search models of labor. (In our setting, larger production-consumption meetings, if they could occur, would enhance welfare.) In our model, one pairwise meeting per date for the purpose of

production and consumption is free and any other kind of meeting for that purpose is infinitely costly. The pairwise meeting structure helps us in several respects; it is consistent with absence-of-double-coincidence difficulties, with imperfect monitoring (each person may know only what the person has seen in the meetings in which the person has been a participant), and with non-trivial float (although float will not play a significant role here).

As in any model of private money, potential over-issue has to be prevented. In our model, it is prevented by threatened punishment. The punishment we use here, although rather mild, always includes the loss of the ability to issue valuable money. To make that feasible, we assume throughout that the private money issued by one person is potentially distinguishable from that issued by anyone else. This is a strong recognizability assumption. We suspect that weakening it, by permitting some sort of counterfeiting, would matter a lot.

3 The model

The model is almost identical to that in Wallace [19], which, in turn, builds closely on our previous work (see [2] and [3]). In particular, the sense in which there is imperfect monitoring is carried over from the specification in our earlier papers.

3.1 A background specialization environment

We use the familiar specialization setting of Shi [14] and Trejos and Wright [16]. Time is discrete. There is a unit measure of each of $K \geq 3$ specialization types of infinitely lived people and there are K distinct, produced, and perishable goods at each date. A specialization-type k person, $k \in \{1, 2, ..., K\}$, produces only good k and consumes only good $k+1$ (modulo K). Each person maximizes expected discounted utility with discount factor $\beta \in (0, 1)$. For a specialization-type k person, utility in a period is $u(q_{k+1}) - q_k$, where $q_{k+1} \in \mathbb{R}_+$ is consumption of good $k+1$ and $q_k \in \mathbb{R}_+$ is production of good k. The function $u : \mathbb{R}_+ \to \mathbb{R}$ is strictly concave, strictly increasing, differentiable, and satisfies $u(0) = 0$ and $u'(\infty) = 0$. In addition, $u'(0)$ is sufficiently large.

A word is in order about the assumption that the number of people is uncountable. So far as we can see, this assumption plays only one role. It

implies that a person's action in a two-person meeting does not influence his or her future trading opportunities except by way of what happens to the person—not by way of what happens to the person's trading partner. That should hold approximately for a sufficiently large finite number of people. In other words, we suspect that the outcomes we describe resemble those of the comparable model with a sufficiently large finite number of people—provided there is discounting that is held fixed as the number of people is allowed to get large.

3.2 Imperfect monitoring and the sequence of actions

We make one other distinction among people. We assume that the set of each specialization type is partitioned in an exogenous way into two parts. Throughout, the fraction α_n, are *not* monitored at all. The history of each such person, except as may be revealed by the person's money holdings, is private to the person. The rest, the fraction $\alpha_m = 1 - \alpha_n$, (m for monitored) are perfectly monitored. That is, the history of each monitored person is common knowledge. It is as if each monitored person wears a computer chip that transmits actions of the person to everyone else. In this model, α_m represents the economy's monitoring capacity. As part of not being monitored, each nonmonitored person can hide money.

We use the following sequence of actions in discrete time. At the start of a date, each person has a state consisting of the person's type, history, and money holding. A person's type, specialization type and whether monitored or not, is assumed to be common knowledge and is permanent. Money holding, a scalar, is defined to be the sum of outside money plus private money acquired from others. As this suggests, we only consider allocations in which all *valuable* monies, all private monies and outside money, are perfect substitutes. (Richer allocations that distinguish among valuable monies, both subsets of private money issuers and between private money and outside money, could be considered.[1]) Then, there are pairwise meetings at random during which there is production and consumption which gives payoffs according to the preferences and technologies described above. After those meetings conclude, monitored people simultaneously meet the planner and, to be consistent, are all together. However, by assumption, there is no pro-

[1]Distinctions among the money issued by subsets of monitored people are discussed in Wallace [18].

duction or consumption that goes on after the pairwise meetings. At best, there are transfers of money. (The planner can be thought of as a benevolent central bank running a discount window and having unlimited access to outside money, while trades among the monitored people after the pairwise meetings can be thought of as being something like a federal funds market.[2])

3.3 Weakly implementable allocations and welfare

We will be doing a limited kind of mechanism design analysis. We start by defining a set of allocations. Then, we describe a simple coordination game in which people choose individually either to *cooperate* or *defect*. If everyone *cooperates* and nonmonitored people, who can hide money, choose to truthfully self-select, then the allocation is weakly implementable; otherwise not. A goal is to describe the *best* weakly implementable allocation, where best is defined below.

An allocation describes what happens in pairwise meetings and what happens when monitored people meet the planner, all conditioned on the date and on the states of the people in the pairwise meeting and the state of each monitored person when meeting the planner. Then, given an initial condition in the form of a distribution over money holdings and histories, such a description of what happens in meetings at each date is sufficient to describe the evolution of the economy.

Given a suggested allocation, the following game is played. Consider a pairwise meeting. The allocation includes a suggested trade in the meeting. Both parties simultaneously choose between *cooperate* and *defect*. If both *cooperate*, then the suggested trade is carried out. If either says *defect*, then they leave the meeting without trading. If a nonmonitored person defects, then there are no further consequences. The person goes on to the next date with what the person has. If a monitored person defects, then there are further consequences to be described momentarily. In the meeting with the planner, each monitored person again chooses between *cooperate* and *defect*.

As regards the consequences of defection for a monitored person, we as-

[2]In a sense, excluding the nonmonitored people from meeting the planner and others after pairwise meetings is without loss of generality. Because nonmonitored people can hide money, the planner can at best give nonnegative transfers to them that are weakly increasing in their money holdings. And even that can be regarded as problematic. How does the planner prevent the same nonmonitored person from showing up many times at a date for a transfer?

sume that the person can at any time join the ranks of the nonmonitored people and suffer no additional punishment except that the person's private money is no longer accepted. In describing the consequences of defections, we are explicitly ruling out punishment of a large segment of the economy in response to individual defections. For example, we are ruling out permanent autarky for the entire economy as a response to an individual defection. Notice that our defection scheme permits free exit from the set of monitored people. However, we do not permit free entry into that set.

Definition 1 *An allocation is weakly implementable if there is a sub-game perfect Nash equilibrium in which each person cooperates and each nonmonitored person also self-selects the trade intended for people with the person's actual holding.*

Two comments are in order about this definition. First, it only requires that there be some equilibrium that implements the allocation. Second, it permits only individual defections, not group defections. In particular, it does not permit cooperative defection by the pair in a meeting.

There are several obvious consequences of the definition. It is weakly implementable to have any recognizable money be worthless and for the usual reason: if a person thinks that others will not accept an intrinsically useless object in the future, then the person will not accept it now. Thus, it is weakly implementable to have all private monies be worthless, to have outside money be worthless (it is important that we are assuming that outside money is uniform), and to have all money be worthless. In particular, allocations in which there is no valuable private money are special cases of more general allocations that include valuable private money. (According to our model, the Peel's Act monetary system could arise without a law.) Therefore, in order not to dwell on the completely obvious, our focus will be on describing as carefully as we can what is sacrificed by *not* having valuable private money.

The simplest welfare criterion for the model is an ex-ante representative-agent criterion—one that treats people as identical before the assignment of types and states. In particular, according to this criterion, the probability of being in the monitored set is α_m and the probability of being in the nonmonitored set is α_n. Finally, because there is no capital in this model, the initial condition, the distribution of money holdings and histories, can be treated as something that the planner chooses along with the allocation.

The ex-ante welfare criterion can be expressed as the expected discounted value of the gains from trade over all single-coincidence pairwise meetings—gains from trade in the sense of the magnitude of $g(q) \equiv u(q) - q$. Obviously, maximum ex ante welfare is achieved by production and consumption equal to $q^* = argmax_q[u(q) - q]$ in every single-coincidence meeting. As we will see, the constraints on monitoring and punishments rule out that allocation. However, the maximum nicely summarizes the economic problem represented by the model; good arrangements will tend to weaken the tie between what happens in single-coincidence meetings and the individual histories of the participants in the meeting.

4 The role of inside (private) money: An example with $\{0, 1\}$ money holdings

We present a simple example that shows that private money can actually play a role. Although we do this in the context of individual money holdings in the set $\{0, 1\}$, the forces at work are general. We describe stationary and symmetric allocations that are weakly implementable with valuable private money, but that are not in its absence.

Consider an allocation in which the same output level, some $y \in (0, q^*]$, is produced in all single-coincidence meetings except in two circumstances: when a nonmonitored producer has money or when a nonmonitored consumer does not have money. Suppose that nothing is produced in those single-coincidence meetings. (The exception for nonmonitored producers is implied by the bound on money holdings and their participation constraint; that on nonmonitored consumers is an arbitrary part of the allocation and will be discussed below.) Moreover, suppose that nonmonitored consumers surrender money when they consume y and that nonmonitored producers receive money when they produce y. In single-coincidence meetings between monitored and nonmonitored people, the monitored consumer provides (newly issued private) money to the nonmonitored producer and the monitored producer collects (outstanding private) money from the nonmonitored consumer, which is then turned over to the planner. In meetings between monitored people, no money changes hands. Suppose further that half the nonmonitored people start without money and half with money and that all monitored people start without money. The above trades imply that that distribution

persists (is a steady state).

In order to express the participation constraints, it is a helpful short-hand to compute the discounted values implied by this allocation. Let $v^n(z)$ be the discounted value for a nonmonitored person at the beginning of a date with money holdings $z \in \{0, 1\}$. These values satisfy

$$K(1-\beta)v^n(0) = \alpha(-y + \beta\Delta) \tag{1}$$

and

$$K(1-\beta)v^n(1) = \alpha(u(y) - \beta\Delta) \tag{2}$$

where $\Delta = v^n(1) - v^n(0)$ and $\alpha = \alpha_m + \alpha_n/2$. (These linear equations have a unique solution that implies $\gamma\Delta = u(y) + y$, where $\gamma = 2\beta + K(1-\beta)/\alpha$.) And let v^m be the discounted value for a monitored person at the beginning of a date without money. It satisfies

$$K(1-\beta)v^m = \alpha(u(y) - y). \tag{3}$$

We do not need to express the discounted value for a monitored person of starting a period with money, money issued by another monitored person, because (i) there are no such people in equilibrium, and (ii) a defection does not give rise to such a person.

For incentive feasibility, there are three relevant constraints. One is the participation constraint for a nonmonitored producer:

$$\beta v^n(1) - y \geq \beta v^n(0). \tag{4}$$

The others are two constraints for monitored people:

$$\beta v^m - y \geq \beta v^n(0) \text{ and } v^m \geq v^n(1). \tag{5}$$

The first is the participation constraint for a monitored producer (the payoff for a monitored producer who defects is that of a nonmonitored person without money because the defector's printing press becomes worthless); and the second says that a monitored person is willing to surrender to the planner the money received in a trade. Because $v^m = v^n(0) + v^n(1)$ (see (1)-(3)), participation constraint (4) implies participation constraints (5).

Next, we describe necessary conditions for duplicating the above consumption and production pattern without private money. In order to duplicate the pattern, each monitored person must begin a period with outside

money. Otherwise, when a monitored person is a consumer in a meeting with a nonmonitored producer without money, the producer cannot be induced to produce y.

In the simpler set-up of our earlier paper [3], there was nothing like a discount window or a federal funds market, and the stock of money was constant. Hence, it was simply impossible to have the spending described in the allocation: the monitored people who spent money in the previous period would not have money at the start of the next date. Now, that argument does not apply because the planner could give money to those monitored people who spent money and could collect money from those who have acquired money. If that is done and the trades are as described by the allocation, then v^m as given by (3) again describes the discounted value for any monitored person. In addition, the $v^n(z)$ are unaffected. However, the constraints are now different. In place of the constraints on v^m in (5), there is just one relevant constraint:

$$\beta v^m - y \geq \beta v^n(1). \tag{6}$$

The constraint says that there will be no defection when a monitored person with money is called on to produce y.

The new constraint is tighter than the two it replaces and is not implied by (4). In fact, it is easy to describe magnitudes of y and the other parameters for which (4) holds, but for which (6) does not. For example, if $y = \beta\Delta > 0$, as is implied if y is the outcome of a take-it-or-leave-it offer by a nonmonitored consumer to a nonmonitored producer, then $v^n(0) = 0$ and $v^n(0) = v^m$. Therefore, (4) holds, but (6) does not. Hence, implementabilty can fail without private money.

The greater temptation to defect when a transfer of outside money replaces private money issue does not seem to depend on the special assumption about money holdings. The result does, however, depend on two features of the model. One is the assumption that outside money is uniform. If each unit of outside money were unique, then a defection could render worthless the particular unit held in the same way as the person's printing press is rendered worthless. And it depends on the uncertainty about spending. If future spending were known when the monitored person meets the planner, then without private money the planner's transfer could be made just sufficient to support that spending.

Although the above comparison is suggestive, it is not decisive even about this simple setting with the special $\{0, 1\}$ money holdings. The example does

not establish that private money is necessary for an optimum—even among stationary allocations. Even with $y = q^*$, the allocation described above does not maximize welfare. In that allocation, a monitored producer does not produce for a nonmonitored consumer who has no money. But some production in such meetings—even if offset by lower production in other meetings in order to satisfy participation constraints—would almost certainly increase welfare because u is strictly concave.

Given $\{0, 1\}$ money holdings, an upper bound on welfare is given by $y = q^*$ in all single-coincidence meetings except those in which the nonmonitored producer has money and $y = 0$ in those meetings. However, it is immediate that any allocation with the same positive output in all meetings except those in which the nonmonitored producer has money is not implementable. Given such an allocation, in a meeting with a monitored producer, a nonmonitored consumer with money will envy the trade of a nonmonitored consumer without money unless the former is not asked to turn over money. But, if not, then money never flows from the set of nonmonitored people to the monitored, which, in turn, implies that money cannot flow the other way. But that contradicts the presumed spending of monitored consumers in meetings with nonmonitored producers. This immediately tells us that the optimum will have some binding truth-telling or participation constraints. That, in turn, makes it challenging to describe optima even in the highly special case of money holdings in the set $\{0, 1\}$.

5 The planner or a *market* as a potential substitute for private money

The above discussion points to the potential gain from private money. Suppose, however, that we are stuck with only outside money. Is there a presumption that there is a role for an active planner?

For this question, the simple case of money holdings in the set $\{0, 1\}$ is misleading. So let's think about general money holdings. It should be evident that dispersion of money holdings is not a good thing in this model. In general, if the consumer has small money holdings, then it will be impossible to get a nonmonitored producer to produce much for such a consumer. And, as we have seen in the example above, it will be difficult to get even monitored producers with large money holdings to produce much. Hence, it would seem

desirable for the planner to transfer money from those monitored people with large holdings and to transfer money to those with small holdings. Of course, those who are asked to give up money have to be willing to do so because they have the option to defect.[3]

A scheme of such transfers is an insurance arrangement. One of the things sacrificed by a monitored person who defects is the right to continue in it. Another is participation as a monitored consumer in meetings with monitored producers; in such meetings, an optimal arrangement will tend to have output be less dependent on the consumer's money holdings if the consumer is monitored than if the consumer is not monitored. It, too, is a kind of insurance.

Obviously, the binding constraints for transfer schemes arise when taking money from monitored people. One way to avoid those constraints is to inflate. An extreme is to give only nonnegative transfers to monitored people and to make them a decreasing function of the wealth of monitored people. That will shift purchasing power toward the monitored people with little money. Of course, that will also produce a falling value of money, which, itself, tends to have undesirable effects because it tightens participation constraints. It should be emphasized, by the way, as we did in our earlier papers, that inflation and deflation are not the only ways to produce non-zero returns on money in this model. Even in the simple case of $\{0, 1\}$ money holdings, there is no reason why output in meetings should not depend on the monitoring status of the participants. In particular, a positive average return on money for nonmonitored people can be achieved by having a monitored consumer get less in a meeting with a nonmonitored producer than does a nonmonitored consumer in any single-coincidence meeting.

Is a *market* among monitored people a perfect substitute for activity by a planner? This question seems particularly relevant in our model because there are no aggregate shocks in the model.

In the model, the market would be one in which people are insured against the kind of pairwise meetings they experience. Moreover, the market would have to be subject to participation constraints because individuals can defect.

[3]There is a literature on matching models that avoids heterogeneity of money holdings. One route is the so-called large family model (see Shi [15]). Another is the device introduced by Lagos and Wright [10]—quasi-linear preferences in a good that is traded in a centralized market. These models have two limitations. First, the assumptions that do away with the heterogeneity are special. Second, the possible role of policy in dealing with heterogeneity is lost.

One possible specification is a special case of the formulation in Kehoe and Levine [7], a competitive formulation in which each person faces a budget set of the usual sort and the person's own participation constraints—constraints that are common knowledge. And, obviously, the market would be subject to a feasibility constraint on total money holdings, a constraint that the planner does not have to satisfy. (By the way, the scheme of transfers of outside money described above in the case of $\{0, 1\}$ money holdings could be accomplished by a market with the following *trades*: each monitored person who ends up after pairwise trade with 2 units of money willingly surrenders 1 unit in the market (the second unit would violate the bound) and each monitored person who ends up with 0 *acquires* 1 unit.)

One way to think of a market is as a constraint on what the planner can accomplish (see Hammond [6]). This view of a market seems to be the same as imposing the stronger requirement on allocations that a *group* not want to defect to anything that is feasible for the group. A surmise is that under such a more stringent notion of implementability, the only advantage of a planner over a market is the planner's freedom to change the total amount of outside money.

6 Generalizations of the model

Given that we have done little but pose questions of the simple model that we have set out, it seems gratuitous for us to suggest generalizations of the model. However, showing that the model lends itself in a straightforward way to various generalizations is part of its attractiveness.

Imperfect monitoring is, of course, consistent with having people experience private-information shocks to preferences. One extreme version of such shocks was described in [2]. There, we assumed that people receive at each date a private-information realization that determines whether or not they can produce at that date. The presence of such a shock has essentially no consequences for how we describe the nonmonitored people because they cannot gain by misrepresenting their realization. For monitored people, in contrast, such shocks introduce into the model the kind of truth-telling constraints in Green [5]. One of the consequences is to make the planner's dealings with monitored people dependent on individual histories.

The model above has the simplest timing consistent with uncertainty about spending opportunities. Obviously, there are many alternatives that

would retain that feature. And nothing in the model is inconsistent with aggregate shocks or with something like a deterministic seasonal.

The imperfect monitoring we have assumed is very special. A troubling aspect of imperfect monitoring is that there are innumerable ways of specifying it. A lag in updating each person's history is adopted in Kocherlakota and Wallace [9]. Such a lag is applied to the monitored people of the model above in Mills [11]. And, although they do not attempt a mechanism-design analysis, implicit in Cavalcanti et. al. [1] is the assumption that the planner's only information about issuers of inside money comes from the money that shows up in a clearing house run by the planner.

In some respects, the crucial assumptions we have made are about recognizability. We have assumed that outside money is uniform , but that private monies can be distinguished according to the issuer. Missing from the model is the notion that uniformity of money is desirable.

7 Concluding remarks

This conference is about the future of payments and the challenges that that future poses for central banks. We have focused on seemingly old questions: Is private money useful? In the absence of private money, is there a role for a central bank discount window over and above what a federal funds market could accomplish? Our model hints at affirmative answers to both questions. Moreover, the model seems relevant for some new questions.

Is management of central-bank, intra-day credit a new question or is it a version of the question about a role for a discount window as we have posed it? That depends in part on whether it is sensible to think of intra-day credit as being extended to perfectly monitored agents who have a demand for it because of their dealings with strangers.

And what sort of model of a cashless economy should we focus on? Presumably, the relevant cashless economy should be a limit of a cash economy as cash becomes less important. Because we like the ideas we described at the outset that explain why cash rather than IOUs are used, we are inclined to use such a model as our model of a cash economy. But what sort of limit should we take? In such a model, we can get a cashless economy in one of two ways: we can let the ability of individuals to commit to future actions get *perfect* or we can let monitoring get *perfect*. To us, the choice is clear. We should let monitoring get perfect; after all, that is what improved infor-

mation technology makes possible. This has an immediate implication: the limiting cashless economy is *not* an Arrow-Debreu economy.

We have suggested some ideas about how to deal with a fundamental issue in monetary theory: the margin between money and credit. And we think that those ideas are fruitful both for old questions about monetary systems and for new ones related to the future of payment systems.

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