ON THE LOCAL INTERACTION OF MONEY AND CREDIT[1]

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Abstract

We study the emergence and coexistence of monetary and credit transactions in a model where exchange is decentralized. Agents belong to different villages which are informationally separated. The frequency of meetings between any two different villages decreases as their respective geographic distance from one another increases. The equilibrium mix of monetary and credit transactions is characterized as a function of the frequency of meetings among agents from different villages. Our economy may be interpreted as a medieval economy. Trade takes place only among a small set of nearby villages via the use of credit. Monetary trades emerge only after interactions with faraway villages become sufficiently frequent. Even in that case, trades among nearby villages remain non-monetized.

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1 Introduction

Transactions between people that meet often might involve neither a double coincidence of wants nor the use of money. For example, one person borrows some sugar from his next-door neighbor and, instead of offering money, she implicitly agrees to help out a neighbor on a similar occasion in the future. On the other hand, this behavior might not be extended to people that we meet only once. In this case, some form of payment, say money, is offered on the spot in exchange for the good or service provided. Credit transactions among non-strangers have been prevalent throughout history. Of course, people that we meet often do not have to be located literally close to us. For example, economists might meet more often with other economists, say in conferences, regardless of their own geographic location.

In this paper, we try to capture the emergence and coexistence of monetary and credit transactions in a model where trade is decentralized. Our analysis is motivated by observations from transactions in medieval village economies. In some cases these villages were largely closed, non-market economies.[2][3] In his study of markets in England and Wales between the years 1200-1500, David L. Farmer refers to "... a network of lending and borrowing among acquaintances, mainly for small amounts, [which] could well strengthen the social fabric of a village with a fairly static population. It could not serve in the same way an international fair, a port, or even a major market town, where litigants could not wait for the next regular borough court to press their pleas.[4]" However, as mobility increased, so did the frequency of interactions with outsiders, and monetary transactions became commonplace. Still, villages kept their integrity and, at least in some cases, trades among people from the same or neighboring villages remained largely non-monetized for a long time.[5]

The setup we use is based on the work of Kiyotaki and Wright (K-W 1989). We think that the decentralized way in which goods and information are exchanged in this model makes it especially appropriate for the study of issues con-

[2] See, for example, Townsend (1993) for a detailed analysis of the medieval village economy.

[3] For example, there seems to have been little commercial exchange and no markets in Wales before 1066. See Thirsk (1991), page 332.

[4] See Thirsk (1991), page 423.

[5] Non-monetized transactions include gifts from the lord to tenants and credit transactions between the manor and villagers. There is also evidence that other trades, for example in wool, were mainly among members of the village and family groups. Virtually all trade was reported to be local, mostly within the radius of six or seven miles, or about two hours walking distance.

cerning early economies in which centralized markets were scarce or non-existent. In order to study the emergence and coexistence issues, we add two features to the standard setup. First, random matching is not uniform but local. That is, people from the same (or neighboring) villages are more likely to meet and trade with each other than with people from faraway places. Second, public record-keeping of agents' trading histories is available only within their village. As we shall see, these frictions are necessary and sufficient for the coexistence of monetary and credit transactions in our setup.

First, we study conditions that guarantee that trade take place only among nearby villages and only via the use of credit. In this case, money has no possible welfare-improving role. Monetary trades will emerge only when, perhaps as a result of improvements in transportation, interactions with faraway villages become sufficiently frequent. In that case, both means of payment coexist. Credit is used in trades across neighbors, whereas money is used in trades among "strangers."[6] Finally, we discuss the implications of improvements in record-keeping technology that lead to information on past credit histories being shared across locations on the equilibrium mix of monetary and credit transactions.

The idea that credit-like instruments are used in trades among agents with known histories while currency is used in trades among relative strangers is not new. Townsend (1989), for example, studies a model in which both types of transactions coexist and are essential to support efficient outcomes. In his model, as in ours, money and credit differ in their communication and record keeping aspects. In earlier work Lucas (1980) suggested that a friction involved in establishing one's creditworthiness might lead to the coexistence of money and credit transactions since, in that case, money will economize on record-keeping costs. This distinction is also present in Prescott (1985), who studied a model with transaction costs in which a form of bank drafts is used for large transactions while currency is used for small ones. In his model, the use of monetary transactions can be thought of as economizing on very costly information collection on agents' trading histories. In our model, money is shown to be essential for facilitating trade among agents that meet infrequently and do not have access to information about each other's trading histories. Thus, one contribution of our paper is to characterize conditions under which the random matching model of money is consistent with the above observations.

It is worth mentioning that while here we concentrate on the implications of a

[6]Our analysis is mainly positive in the sense that we will build a model that delivers this coexistence as an equilibrium outcome, and we shall largely abstract from normative issues.

local matching rule and of a locally available record keeping technology for monetary theory, our setup might be useful in the study of other issues that involve local interactions. For example, search in labor markets often has a local feature, and reputation of certain goods and services is in many cases available only locally. Similarly, separate information networks to which different groups of agents belong constitute an example of an incomplete record-keeping technology.

1.1 An Informal Description of the Model

In the standard random matching model, credit cannot exist since with probability 1, there are no two agents that meet repeatedly, and there is no public record-keeping technology. We amend the uniform random matching technology by assuming that agents meet different sets of other agents with different probabilities and by introducing record-keeping of past actions at the local level. Although other interpretations are possible, as mentioned above, for reasons of concreteness we will interpret these different meeting probabilities as being the result of the agents' respective physical distance from one another. The unit circle is assumed to be divided into a large number of arcs of equal length. Each arc is interpreted as a location or village. Villages are symmetric, each populated by a continuum of agents. Agents are specialized in production and consumption of goods. For simplicity, we assume that each agent likes only one type of good and can produce, by suffering some disutility, at most one unit of an indivisible good that gives him no utility. Agents are assumed to be randomly matched in pairs in each period. Trade is thus possible in the case where a potential producer meets with an agent that likes his production good (hence called a single-coincidence meeting). The distribution of all agents' characteristics is the same across villages. We assume that, with high probability, each agent meets with someone from his own village, and that the probability of meeting another agent decreases as the distance from the village that the agent belongs to increases. In addition, information about agents' trading histories is assumed to be publicly available only locally. More precisely, we will assume that each individual agent's trading history is public only within the village where they belong, and only in regard to their meetings with agents from that village.

What are the likely methods of payment if trade occurs in this environment? One possibility corresponds to a regime under which producers offer to produce without payment in all single-coincidence meetings regardless of the location of the consumer. In the context of our model, we will identify such a non-monetized type of exchange with a credit transaction. Suppose that if one agent deviates from this implicit agreement, say by not producing for free in a single-coincidence meeting as a producer with someone from village j, then this deviation triggers a collective punishment to permanent no-trade between the two villages by all agents in the village of the agent that was deviated on.[7] Since the credit regime implies a higher frequency of consumption for the representative agent, one may think that the above threat might induce a credit equilibrium in all meetings in the economy. However, suppose that an agent has a single-coincidence meeting as a producer with someone from a very "faraway" village. In this case, the potential producer has a very high incentive to deviate from producing. The disutility of producing is suffered now, while the punishment from not producing will be borne sometime in the distant future.[8] For sufficiently low discount factors, it will be best for the producer to deviate and refuse to produce in such a meeting. Our main result establishes conditions for the existence of a critical distance (frequency of meetings) such that in a stationary equilibrium only credit transactions will take place among close neighbors (people whose frequency of meetings is higher than a critical value) while only monetary transactions will take place in meetings between people from faraway places (people whose frequency of meetings is lower than a critical value). In addition, monetary transactions emerge as mobility improves while credit transactions become more prevalent as the record-keeping technology improves.

Our work is related to a number of papers that study credit arrangements in a search-based setup. Diamond (1990) introduced credit in a non-monetary search economy. Shi (1996) and Corbae and Ritter (1997) also study money and credit in a search setup. Unlike them, we do not allow pairs of agents to form ongoing relationships by staying together for more than one period. Kocherlakota and Wallace (1998) build on Kocherlakota (1998) and study the coexistence of money and credit in an environment where public record-keeping is incomplete because it is updated with a lag. Public record-keeping is also incomplete in our model, but in the sense that it is available only locally. This, together with the local matching rule, generates an endogenous lag that allows us to differentiate between "frequent" transactions that use a form of credit, and "rare" transactions that use money. Finally, Shi (1997) uses a search model in which each household consists of a continuum of agents in order to eliminate uncertainty at the house-

[7] In the next sections we will discuss the sensitivity of our results to the exogenous specification of the punishment.

[8] This requires that the close neighbors of the deviating producer remain unaware of his deviation and, thus, are not punishing him. The next section deals with assumptions that guarantee that this will be true in our setup.

hold level. The modelling of local interactions via a random matching technology has been applied in evolutionary game theory in order to study the emergence of conventions (see Ellison 1993), but there it is almost always assumed that agents are boundedly rational (see also Wright 1995). In contrast, in our model agents are assumed to be fully rational.

The paper proceeds as follows. Section 2 describes the environment. In Section 3, we present a benchmark case of the model under a uniform matching rule. In Section 4 we discuss the main results. Section 5 offers some preliminary conclusions. The Appendix gives the value functions.

2 The Environment

Time is discrete and the horizon is infinite. There is a large number, formally a continuum, of agents in the economy. Agents are matched bilaterally in every period. There is a very large but finite number of villages denoted by $j = 1, 2, ..., J$, forming a partition of the unit circle. There is a continuum of agents in each village. We normalize the population size of the entire economy to be of measure one. There is a finite number, $k \geq 3$, of types of consumption goods. All consumption goods are perishable and indivisible. Agents specialize in consumption and production of goods in a symmetric fashion. At the beginning of each period, there is a $[0, \frac{1}{k}]$ continuum of each type. Individuals of type i can only consume good i and produce good $i+1$ (modulo k). The instantaneous utility derived from consumption is $u > 0$. We normalize the instantaneous utility of not consuming to be 0. Production requires an effort that gives disutility $e > 0$, where $u > e$. Agents maximize expected discounted utility, and the time discount factor is $\beta \in (0, 1)$. The solution concept we employ is stationary perfect equilibrium. Because $k \geq 3$, there is no double coincidence of wants. We assume that a fraction M of agents each starts with one unit of indivisible, storable, and intrinsically useless fiat money. Current period money holdings are observable within a match. We impose an upper bound on individual holdings, i.e., individuals can hold at most one unit of currency or one unit of a good. This implies that in meetings where there is monetary trade, one unit of money is exchanged for one unit of good. Agents are assumed to be assigned to villages at the beginning of time. We assume that the initial distribution of all agents' characteristics, including money holdings, is symmetric across all consumption types and villages. We will concentrate on equilibrium outcomes that respect this symmetry.

One difference between the environment of our model and the standard setup in existing search models is in the matching technology. Matching here is not uniform but local. Each agent in any given village is matched with an agent from the same village with probability p_0; he is matched with an agent from either of the two immediately neighboring villages with probability p_1 where $p_0 > p_1 > p_2 > \ldots$ etc. This assumption captures the feature that people in the economy meet more frequently with some people and less frequently with others. By symmetry, there is no loss of generality in concentrating on a generic village, say j. We will denote by i the distance between our generic village and any other village, j', i.e., $i = |j - j'|$. Hence, p_i stands for the probability that an agent from a given village is matched with an agent from an $i-th$ order neighboring village, where $\sum_i p_i = 1$. In order for an actual match to take place between any two villages, it will have to be the case that the random matching technology assigns both villages to each other.[9] Thus, the matching probabilities are described by a step function. Agents return to their village at the end of each period. We will find it convenient to assume that the realizations of the matching probabilities are *perfectly correlated* across agents that live in the same village. In other words, if the random matching technology assigns one agent from village j to some agent from village $j^{'}$ in a given period, then each agent from village j is assigned to an agent from village $j^{'}$ in that period.[10]

When two agents have a single-coincidence meeting, after they observe each other's type and village of origin, they simultaneously make a trading proposal. The consumer can announce the request of a unit of a good offering nothing in exchange, or the offer of one unit of money in exchange for a unit of his consumption good, or propose no trade. The producer can announce the offer of a unit of the good in exchange for nothing (i.e., extend credit), or the request of one unit of money in exchange for producing (i.e., offer credit), or propose no trade. If the two proposals match in the obvious way, the proposals are realized. If they are different, then a punishment is triggered.

[9]Consider, for example, the case of four villages, A,B,C, and D, located in that order around the circle. Let $\widetilde{p}_0$ be the probability that, for example, A is assigned to itself, $\widetilde{p}_1$ the probability that A is assigned to B or D and $\widetilde{p}_2$ be the probability that A is assigned to C. These probabilities are symmetric across villages. Then $p_2 = \widetilde{p}_2^2$, $p_1 = 2\frac{\widetilde{p}_1}{2}\frac{\widetilde{p}_1}{2} = \frac{\widetilde{p}_1^2}{2}$, and $p_0 = 1 - p_1 - p_2$. In the remaining of the paper, we deal with the $p_i's$ directly and will require that $p_0 > p_1 > p_2$.

[10]If the matching probabilities were *iid* across agents in the same village, and since there is a continuum of agents in each village and a positive probability of visiting any other, the logic of the law of large numbers implies that a positive measure of agents from any village visit any other village in every period. In this case, if one village collectively triggers the punishment strategy in a given period, then this may trigger the punishment strategy for the entire economy in the next period.

An essential assumption for what follows is that information about agents' histories of actions does not travel across villages. This captures the feature that, especially in early village economies, it was costly to have access to credit histories, and these costs increase as a function of distance.[11] Thus, we do not allow agents from different villages to exchange messages regarding histories. If an agent from village j refuses to produce in exchange for nothing during a single-coincidence meeting with an agent from village $j^{'}$, then this deviation is communicated to all agents in village $j^{'}$ by the agent that experienced the deviation and triggers a punishment to permanent autarky by all agents in village $j^{'}$ in all future meetings between agents from these two villages. Of course, the deviator has no incentive to reveal to agents in his village that he deviated. We will assume that in the future, when other agents from village j experience the punishment by agents in village $j^{'}$, being unaware of what triggered this behavior, they will treat it as a new deviation, leading to a collective punishment of village $j^{'}$ by agents in village j.[12] In addition, we assume that individual actions during meetings with agents from other villages are not publicly observable in the village that an agent belongs to. This assumption implies that agents within, say, village j do not know whether an agent from their own village have deviated in a past meeting with village $j^{'}$; they will only observe that agents from village $j^{'}$ deviate from the credit regime in the future.[13]

Fix a single-coincidence meeting between an agent from a given village, j, and an agent from a village that is i steps away. Let D_j denote the subset of villages that, as a result of past deviations, have switched to permanent no trade in meetings with village j. We denote by α^{iD_j} the probability with which an agent accepts money in exchange for producing, and by m^{iD_j} the probability that an agent offers money in order to consume. In addition, we denote by $g^{iD_j}_{M_p,M_c}$ and by $h^{iD_j}_{M_p,M_c}$ the respective probabilities that a producer extends credit and that a consumer requests credit, when the producer's and the consumer's money holdings are given by M_p and M_c, respectively. The remaining probability is assigned to

[11]One could argue that these costs are relevant even with today's technology. For example, it is easier for a bank to have access to the credit history of someone who lives in the same country than of someone that lives overseas.

[12]In this discussion, j and $j^{'}$ could be the same location.

[13]Following common practice, we assume that any deviation triggers a punishment to the worst "reasonable" equilibrium. The results would still hold if we had assumed that only the deviator is punished. One issue is whether this punishment is renegotiation-proof. We believe that, while this will not be the case in general, this punishment is renegotiation-proof for some parametrizations. Nevertheless, we will concentrate on unilateral deviations henceforth.

the event that no trade proposal is made.

The punishment to permanent no-trade with the village of the deviator by the village that experienced the deviation is arbitrary, and one could think of several alternatives. The harshest possible punishment that a deviated-upon village could adopt is to revert to permanent autarky during all future meetings with all villages.[14] Even if this punishment is adopted, the long lag before it will reach the village of the deviator, provided that this village is sufficiently far away in terms of the frequency of meetings, will guarantee that the qualitative properties of our result still hold. Of course, more credit can be supported in this case.

3 A Benchmark Model - Uniform Matching

Our main focus is the study of a model where both record-keeping and matching are local. In order to separate the effects of these two assumptions, in this section we consider a benchmark case where matching is uniform, while information about histories is available only at the local level. Suppose there are n villages. Since the probabilities of meeting with an agent from any given village are assumed to be perfectly correlated, we can think of the random matching technology as operating in two steps. First, a village is matched to any other, including itself, with probability $p = \frac{1}{n}$. The second step of the random matching technology determines the individual agent matches. The following proposition asserts that in this environment, money and credit payments cannot coexist in a non-trivial way. More precisely, regardless of which villages are involved, credit exchange across all meetings can be supported as an equilibrium outcome for low values of n and credit exchange cannot be supported as part of an equilibrium outcome for high values of n.

Proposition 1 *Fix β such that $0 \ll \beta \ll 1$. There exists a unique n^* such that if $p \in (\frac{1}{n^*}, 1)$, there exists a steady state equilibrium in which all transactions involve credit. If $p \in (0, \frac{1}{n^*})$, there exists no equilibrium in which at least some transactions involve credit.*

[14]This punishment defines one end of the spectrum, but it is unattractive. For example, agents in the deviated-upon village, j, know the location of the deviator. It does not seem reasonable to punish themselves by adopting autarky in meetings within the village, or in meetings between village j and its close neighbors, especially if the deviating village is "very far away."

The above Proposition follows as a Corollary of the main Proposition in the next section, and we will omit the proof. The intuition behind it is the following. By our assumption on the exogenous punishment, once an agent deviates from offering credit, this triggers permanent no-trade between his village and the village of the deviated-upon agent. Since everything is symmetric, each agent's decision whether to offer credit or not is independent of his village and of that of his partner. Producing implies a certain amount of disutility that the producer suffers today. On the other hand, the potential cost from the autarky punishment depends on the frequency with which the no trade penalty is experienced by the deviator in the future. Thus, if the probability of meeting the same village in the future is high enough (n is small), offering credit will be the best response, while if the probability of meeting the same village in the future is low enough (n is large), deviating will be the best response. Next, we consider the case where matching is not uniform but local.

4 Local Matching and the Main Result

In this section we state our main proposition establishing conditions that guarantee the coexistence of monetary and credit transactions in a symmetric stationary equilibrium for our environment. We first prove some preliminary results. The first Lemma asserts that the search economy in Kocherlakota (1998) follows as a special case of our setup if we shut down all meetings across different villages $(p_0 = 1)$. In that case, each village is an isolated economy in which uniform matching prevails. A high enough discount factor guarantees the existence of a credit equilibrium in that case. In addition, there is no way for a monetary arrangement to provide a higher frequency of consumption for the representative agent than the credit equilibrium. This is because in a credit equilibrium trade takes place in each single-coincidence meeting while, in an equilibrium where money is essential, it is also needed that in at least some single-coincidence meetings the consumer has one unit of money holdings while the producer has none. While we will concentrate on the Pareto superior credit regime whenever such a regime exists between two locations, it is worth stating that, given our trading mechanism, for high enough discount factors both a pure credit and a pure monetary regime might exist.

Lemma 2 *Set $p_0 = 1$. Then: (a) there exists unique β^C and β^M with $0 < \beta^C < \beta^M < 1$ such that for all $\beta \in (\beta^C, 1)$, a pure credit equilibrium exists, and for all $\beta \in$*

$(\beta^M, 1)$, *a monetary equilibrium exists, and (b) welfare in the credit equilibrium is strictly higher than in any alternative arrangement where money is essential in facilitating exchange.*

Proof: *(a)* In a credit equilibrium where money is not used, the value function of a representative agent is given by

$$V^C = \frac{u-e}{k(1-\beta)} > 0.$$

In order for $g^{iD_j} = 1$ to be the best response for a producer in a single coincidence meeting where $h^{iD_{j'}} = 1$, we need that $-e+\beta V^C \geq 0$, which implies that

$$\beta \geq \frac{ek}{ek+u-e} \equiv \beta^C.$$

On the other hand, since $u+\beta V^C > 0$, $h^{iD_j} = 1$ is the best response given $g^{iD_{j'}} = 1$. That is, the credit equilibrium exists provided that $\beta \in \left(\beta^C, 1\right)$. In a monetary equilibrium we have

$$\begin{aligned} V_1^M &= \frac{1}{k}(1-M)\left(u+\beta V_0^M\right) + \left[1-\frac{1}{k}(1-M)\right]\beta V_1^M \\ V_0^M &= \frac{1}{k}M\left(-e+\beta V_1^M\right) + \left(1-\frac{1}{k}M\right)\beta V_0^M. \end{aligned}$$

Solving for V_0^M and V_1^M, we get

$$\begin{aligned} V_0^M &= \frac{M\left[\beta(1-M)(u-e)-ke(1-\beta)\right]}{(1-\beta)\left[k(1-\beta)+\beta\right]} \\ V_1^M &= \frac{(1-M)\left[ku(1-\beta)+\beta M(u-e)\right]}{(1-\beta)\left[k(1-\beta)+\beta\right]}. \end{aligned}$$

For a monetary equilibrium to exist, we need that $-e+\beta V_1^M \geq \beta V_0^M$, which is satisfied if

$$\beta \geq \frac{ek}{ek+(u-e)(1-M)} \equiv \beta^M.$$

(b) Frequency of consumption in the pure credit equilibrium is greater since an agent always consumes whenever he has a single-coincidence meeting as a consumer. For consumption to take place in a monetary regime, it is also required

that the consumer has one unit of money, and the producer has no money. More explicitly, welfare in the monetary equilibrium is given by

$$W^M = (1-M)\,V_0^M + MV_1^M.$$

It can be shown that W^M reaches the maximum, $\overline{W}^M$, when $M = \frac{1}{2}$. In that case,

$$\overline{W}^M = \frac{u-e}{4k\,(1-\beta)}.$$

Welfare in the credit equilibrium is given by

$$W^C = \frac{u-e}{k\,(1-\beta)},$$

which is clearly greater than the best monetary outcome. ■

The next Lemma describes a sufficient condition for the cost of breaking the credit regime between two villages to increase in the expected frequency of meetings between these two villages. Autarky implies a lower expected frequency of consumption for the representative agent than a credit regime. The more probable the meetings between villages j and $j^{'}$, the bigger the costs to reverting to no trade in future meetings between them. Since the punishment becomes more painful, it becomes easier to support the credit regime.

Lemma 3 *Fix* β *such that* $0 < \beta^C < \beta \ll 1$. *Consider a village* $j^{'}$ *that is matched to village* j *with probability* p. *Then: (a) the difference between the value functions of a representative agent under a credit regime and under autarky between villages* j *and* $j^{'}$ *increases in* p, *and (b) let* $\overline{p} = \frac{ek(1-\beta)}{\beta(u-e)}$. *If* $p \in (\overline{p}, 1)$, *all transactions between the two villages use credit. If* $p \in (0, \overline{p})$, *there is no equilibrium where credit transactions between the two villages take place.*

Proof: *(a)* Let $V_{j,j'}^C$ and $V_{j,j'}^A$ stand for the value functions under a credit regime and under an autarky regime between villages j and $j^{'}$, respectively. In order to support credit transactions between villages j and $j^{'}$, we need that $-e + \beta V_{j,j'}^C \geq \beta V_{j,j'}^A$ or $\beta\left(V_{j,j'}^C - V_{j,j'}^A\right) \geq e$. It can be shown that the difference $V_{j,j'}^C - V_{j,j'}^A$ is given by $\frac{p(u-e)}{k(1-\beta)}$, which is clearly increasing in p.

(b) The expression for $V^C_{j,j'} - V^A_{j,j'}$ is independent of how agents in village j trade in meetings with agents from villages other than j'. Using part *(a)* and substituting $\frac{p(u-e)}{k(1-\beta)}$ for the difference $V^C_{j,j'} - V^A_{j,j'}$ it can be shown that the condition that $-e + \beta V^C_{j,j'} \geq \beta V^A_{j,j'}$ is satisfied if

$$p \geq \frac{ek(1-\beta)}{\beta(u-e)} \equiv \overline{p}.$$

Notice that $\overline{p}$ is decreasing in β. If $\beta = 1$, then $\overline{p} = 0$, and if $\overline{p} = 1$, then $\beta = \beta^C$. ■

The previous Lemma does not automatically imply the existence of monetary trades. Producers in such meetings, however, will produce for money provided that it sufficiently increases their probability of consuming in the future. This requires that a meeting with an arbitrary "faraway" village is very likely in the near future although the probability of meeting any specific village from that set is arbitrarily small.

The next Lemma offers sufficient conditions for all transactions in meetings between agents from two given villages to be monetary. First, credit will not be used in meetings between agents from villages j and j' if these two villages will not be matched with each other again with high enough probability in the future. In that case, the expected large delay before the punishment from a deviation is felt makes deviating the best choice for producers. Let B be the set of villages that are each matched to village j with probability less than $\overline{p}$, so that a credit arrangement could not be implemented in meetings between village j and any of the villages in B. Let q be the probability that village j will be matched to a village in B. That is, $q = \sum_i p_i$, where $p_i < \overline{p}$.

Lemma 4 *Fix a meeting between villages j and j' such that the probability of a future meeting between these two villages is lower than $\overline{p} = \frac{ek(1-\beta)}{\beta(u-e)}$. Provided that the probability of a meeting with a village in B is greater than $\overline{q} = \frac{ek(1-\beta)}{\beta(1-M)(u-e)}$, there exists an equilibrium where all transactions in meetings between villages j and j' are monetary.*

Proof: From Lemma 3, we know that if $\beta > \beta^C$, then a credit equilibrium can be supported in meetings between village j and any village in the complement of the set B. The value functions for an agent in village j are given by

$$\begin{aligned} V_1 &= (1-q)[\beta V_1 + \frac{1}{k}(u-e)] + q\{\frac{1}{k}(1-M)(u+\beta V_0) + [1-\frac{1}{k}(1-M)]\beta V_1\} \\ V_0 &= (1-q)[\beta V_0 + \frac{1}{k}(u-e)] + q[\frac{1}{k}M(-e+\beta V_1) + (1-\frac{1}{k}M)\beta V_0]. \end{aligned}$$

Solving these two equations we get

$$\begin{aligned} V_0 &= \frac{(u-e)\left[(1-\beta)(k+q\beta-kq)+q^2\beta M(1-M)\right]-(1-\beta)kqme}{k(1-\beta)[k(1-\beta)+q\beta]}, \\ V_1 &= \frac{(u-e)\left[(1-\beta)(k+q\beta)+q^2\beta M(1-M)\right]+(1-\beta)kq(e-mu)}{k(1-\beta)[k(1-\beta)+q\beta]}. \end{aligned}$$

For a monetary equilibrium to exist in a meeting between village j and a village $j^{'} \in B$ we need that $\alpha = 1$, or $-e+\beta V_1 > 0+\beta V_0$. This requires that

$$q \geq \frac{ek(1-\beta)}{\beta(1-M)(u-e)} \equiv \overline{q}. \blacksquare$$

The above Lemmata lead to our main Proposition. If the probability of a meeting between two villages in the future is less than $\overline{p}$, the credit regime between these two villages cannot prevail. If the probability of a meeting between two villages in the future is greater than $\overline{p}$, the credit regime between the two villages can be implemented. On the other hand, in the case where credit will not prevail, monetary trades may be implemented if money sufficiently increases the probability of consuming in the future, i.e., if a meeting with some other "faraway" village in the near future is very likely. To better understand the economic principle at work, consider a community of people that trade almost exclusively with people from inside the community, offering credit whenever there is a single-coincidence meeting with a member of the community. Suppose that, in a very unlikely event, one of the people in that community meets someone from far away who likes his good. It will certainly not be optimal to offer to produce for free for the stranger, but what if the stranger offers money in exchange for production? Should the potential producer accept the money and produce? If, with very high probability, future meetings are expected to be only with members in the community, the offered money will not be used for a very long time and, therefore, will be rejected. On the other hand, if meetings with different strangers are frequent enough, with high probability the producer can use the money to finance consumption in the near future, and so he will accept it. These observations define the existence of a critical probability that separates the two types of transactions.

Proposition 5 *Fix* β *such that* $0 < \beta^C < \beta \ll 1$. *Let* $\overline{p} = \frac{ek(1-\beta)}{\beta(u-e)}$. *Transactions between village* j *and villages that are matched to* j *with probability* $p \in (\overline{p}, 1)$ *use credit and, provided that the probability of a meeting between village* j *and a village from B is greater than* $\overline{q} = \frac{ek(1-\beta)}{\beta(1-M)(u-e)}$, *transactions between village* j *and villages that are matched to* j *with probability* $p \in (0, \overline{p})$ *are monetary.*

Proof: The sufficient conditions of β to support the credit regime and monetary regime are given by Lemma 2. The existence of a credit regime when $p_i \in (\overline{p}, 1)$ and the non-existence of a credit regime when $p_i \in (0, \overline{p})$ follows from Lemma 3. The existence of a monetary regime when $p_i \in (0, \overline{p})$ and $q \in (\overline{q}, 1)$ follow from Lemma 4. ■

To demonstrate this proposition, we constructed a simple example. Let $u = 8$, $e = 2$, $k = 3$, and $M = 0.5$. Then we can solve for $\overline{p} = \frac{1-\beta}{\beta}$ and $\overline{q} = \frac{2(1-\beta)}{\beta}$. These two functions are plotted in Figure 1 in the Appendix. Figure 1 also demonstrates the region of values that p, q and β can take, and the possible equilibria that might be supported in these regions. We know that $\overline{p} = 1$ implies that $\beta = \beta^C$, and that $\overline{q} = 1$ implies that $\beta = \beta^M$. The two vertical lines divide the whole area into three regions. Consider the generic village j matched with another village j' with probability p_i. In region I, the only equilibrium is autarky since the discount factor β is too low to support either credit or monetary transactions between the two villages. In region II, if in addition p_i lies above the $\overline{p}$ line, all transactions between j and j' use credit. If p_i lies below that line, no trade will take place. Monetary transactions cannot be supported in this region since q is always less than $\overline{q}$ (β is always less than β^M). In region III, if in addition p_i lies above the $\overline{p}$ line, all transactions between j and j' use credit. If p_i lies below that line, then there are two possibilities: autarky or monetary exchange depending on how many other villages with which village j can be matched lie below the $\overline{p}$ line. If q, the sum of the probabilities that are less than $\overline{p}$, is above the $\overline{q}$ line, the transactions between village j and j' are monetary; otherwise autarky prevails.

5 Conclusions

We studied conditions for the coexistence of monetary and credit transactions by using a random matching model of money. These conditions are that agents meet each other with frequencies that are inversely related to their geographic distance, and that they populate regions that are informationally separated. In our model, the cost of setting up a local record-keeping system is assumed to be zero, while the cost of setting up a record-keeping system across villages is infinite. In a steady-state equilibrium, credit is used among agents that meet each other frequently, while money is used in transactions among those that meet only infrequently. A necessary condition for money to be accepted in trade between agents that are not likely to meet again in the near future is that a meeting with some other “faraway” village in the near future is likely.

It is hard to know the exact form of non-monetized transactions in medieval villages, but observations of contemporary village economies provide some clues. In their study of the financial structure of three villages in India, Lim and Townsend (1998) found evidence consistent with credit functioning well within villages while, at the same time, external credit markets do not function as well, perhaps due to a disadvantage in information sharing.

As shown earlier, the local matching rule is necessary for our result. If we consider our environment under uniform probabilities of matching across all villages, the only possible outcomes would involve either no trade or only credit transactions across all villages. Perhaps the most appropriate interpretation of our model is as a parable of a medieval village economy. Our main proposition makes predictions about the *emergence* of money as an equilibrium outcome when meetings between people from faraway villages become frequent enough, perhaps as a result of increased mobility.

In future work we would like to introduce multiple locally-issued fiat objects and study their circulation and redemption properties as a function of the local matching rule. It could also be interesting to study monetary injections and price dispersion in the context of a local interaction model with divisible goods. In such a model, newly injected money is likely to stay within a small set of villages in the short run. In addition, locally issued money could circulate globally but at discount that is proportional to the respective distance from the village of issuance.

6 References

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7 Appendix - Value Functions

Here we describe parts of the value functions for the agents in our model economy. We concentrate on the symmetric steady state value function of a representative agent from a generic village j. We let $V_0^{D_j}$ and $V_1^{D_j}$ denote the value function of an agent with no money holdings and with one unit of money holdings respectively. There are four possibilities regarding the money holdings of two agents that are in a single coincidence meeting. For the case of an agent with no money holdings we have:

$$V_0^{D_j} = \sum_{i \in I} p_i$$

$$\left\{ \begin{array}{c} \left(1-\frac{2}{k}\right)\beta V_0^{D_j} \\ +\frac{1}{k}\left(1-M\right) \\ \left\{ \begin{array}{c} \max_{g_{00}^{iD_j}} \left[g_{00}^{iD_j} h_{00}^{iD_{j'}} \left(-e+\beta V_0^{D_j}\right) + \left(1-g_{00}^{iD_j} h_{00}^{iD_{j'}}\right)\beta V_0^{D_j+j'} \right] \\ +\max_{h_{00}^{iD_j}} \left[g_{00}^{iD_{j'}} h_{00}^{iD_j} \left(u+\beta V_0^{D_j}\right) + \left(1-g_{00}^{iD_{j'}} h_{00}^{iD_j}\right)\beta V_0^{D_j+j'} \right] \end{array} \right\} \\ +\frac{1}{k} M \\ \left\{ \begin{array}{c} \left(1-m^{iD_{j'}}\right) \left\{ \max_{g_{01}^{iD_j}} \left[g_{01}^{iD_j} h_{01}^{iD_{j'}} \left(-e+\beta V_0^{D_j}\right) + \left(1-g_{01}^{iD_j} h_{01}^{iD_{j'}}\right)\beta V_0^{D_j+j'} \right] \right\} \\ +m^{iD_{j'}} \left\{ \max_{\alpha^{iD_j}} \left[\alpha^{iD_j} \left(-e+\beta V_1^{D_j}\right) + \left(1-\alpha^{iD_j}\right)\beta V_0^{D_j+j'} \right] \right\} \\ +\max_{h_{10}^{iD_j}} \left[g_{10}^{iD_{j'}} h_{10}^{iD_j} \left(u+\beta V_0^{D_j}\right) + \left(1-g_{10}^{iD_{j'}} h_{10}^{iD_j}\right)\beta V_0^{D_j+j'} \right] \end{array} \right\} \end{array} \right\}.$$

The first part of the value function describes the case of a meeting in which there is no coincidence of wants. The second part describes the case of a single coincidence meeting as a producer and as a consumer, respectively, with an agent that has no money holdings. In that case, our distinguished agent chooses the probability of offering a gift and the probability of receiving a gift, respectively. Finally, the third part describes the case of a single coincidence meeting as a producer and as a consumer, respectively, with an agent that has one unit of money holdings. In that case, our distinguished agent chooses the probability of offering a gift or offering to produce in exchange for his partner's money holdings, etc. Similarly, for the case of an agent with one unit of money holdings we have:

$$V_1^{D_j} = \sum_{i \in I} p_i$$

$$\left\{ \begin{array}{c} \left(1-\frac{2}{k}\right)\beta V_1^{D_j} \\ +\frac{1}{k}M \\ \left\{ \begin{array}{c} \max_{g_{11}^{iD_j}} \left[g_{11}^{iD_j} h_{11}^{iD_{j'}} \left(-e+\beta V_1^{D_j}\right) + \left(1-g_{11}^{iD_j} h_{11}^{iD_{j'}}\right)\beta V_1^{D_j+j'} \right] \\ +\max_{h_{11}^{iD_j}} \left[g_{11}^{iD_{j'}} h_{11}^{iD_j} \left(u+\beta V_1^{D_j}\right) + \left(1-g_{11}^{iD_{j'}} h_{11}^{iD_j}\right)\beta V_1^{D_j+j'} \right] \end{array} \right\} \\ +\frac{1}{k}(1-M) \\ \left\{ \begin{array}{c} \max_{g_{01}^{i}} \left[g_{01}^{iD_j} h_{01}^{iD_{j'}} \left(-e+\beta V_1^{D_j}\right) + \left(1-g_{01}^{iD_j} h_{01}^{iD_{j'}}\right)\beta V_1^{D_j} \right] \\ +\max_{m^{iD_j}} \left\{ \begin{array}{c} \left(1-m^{iD_j}\right) \left\{ \max_{h_{01}^{iD_j}} \left[\begin{array}{c} g_{01}^{iD_{j'}} h_{01}^{iD_j} \left(u+\beta V_1^{D_j}\right) \\ +\left(1-g_{01}^{iD_{j'}} h_{01}^{iD_j}\right)\beta V_1^{D_j+j'} \end{array} \right] \right\} \\ +m^{iD_j} \left[\alpha^{iD_{j'}} \left(u+\beta V_0^{D_j}\right) + \left(1-\alpha^{iD_{j'}}\right)\beta V_1^{D_j+j'} \right] \end{array} \right\} \end{array} \right\} \end{array} \right\}.$$