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Money and Time

Ayumu YASUTOMI
Nagoya University
Nagoya

Introduction

In the field of economics, entitling a paper "Money and Time" will likely lead readers to expect a discussion concerning interest. Economists of the Austrian school, founded by Karl Menger, developed an influential treatment of the relation between time and interest. They introduced the idea of money into this discussion, and as a result, it has become customary to view the three concepts together. However, while this paper carries this title, and despite the fact that we use Menger's theory as a guiding principle, we do not touch upon the phenomenon of interest. Here, we study economic activity, and in particular we investigate the implications of the fact that the act of exchange requires time. With this backdrop, we then attempt to understand money as a structure which appears under such circumstances.

Among the people who have undertaken the difficult task of attempting to understand the nature of money, in the present work, we consider the theories of two, Marx and Menger. Marx discussed the nature of money in his *Das Kapital.* He made the discovery that the essence of money lies hidden in that which takes the form of the mutual exchange of commodities. Menger describes the process in which money emerges in the context of exchange in the final chapter of the revised version of his book *Principles of Economics,* (published after his death) on the theory of money.

The purpose of this paper is to reconsider these theories, to identify the points these authors have overlooked, and to present a new view of money. In Section 1, we reinterpret the concept of 'direct exchangeability' Marx developed in his analysis of the mutual exchange of commodities as 'right of option' and replace his dialectic arguments by rational arguments. Our conclusion is that money is nothing other than a 'bundle of option.' In Section 2, we consider Menger's problem of determining how money is generated in the process of exchange. This is a problem Marx evades in his dialectic arguments, where he claims this to be a problem of how a 'universal or developed value-form' is converted into a 'general value-form.' Here, we reform Menger's theory, putting it into a more pure form. In Section 3 we outline the model used in our computer simulation based on the discussion presented in Sections 1 and 2. At this point, the concept of evolution (or learning) is introduced, and it is found that the very mathematical model we use to describe

the generation of money also describes its collapse. The implications with respect to the theory of time implied by the investigation undertaken in Sections 1–3 are treated in Section 4. At the same time, we consider the connection with language, the subject of this symposium.

1. From the Value-Form Theory of Marx

Marx wrote on a number of topics in regard to money, but in this paper we limit our attention to the first chapter, entitled "Commodities," appearing in Part 1, "Commodities and Money," of *Das Kapital, Volume One,* of which we offer a critical analysis. Of particular importance in this work is the third section, "The Form of Value or Exchange-Value," detailing the so-called theory on the form of value[2)], which begins with the elementary or accidental value-form. This is simply expressed as

$$x \text{ commodity } A = y \text{ commodity } B, \tag{2.1}$$

or

$$20 \text{ yards of linen} = 1 \text{ coat}. \tag{2.2}$$

Marx uses an equal sign here to express the idea that the values of the commodities appearing on either side are equal, but, according to Marx, the equal sign does not imply that the two commodities occupy equivalent positions. This is because we can think of the situation in which one requests to exchange the commodity on the left for that on the right. He states that the value of the commodity on the left takes a 'relative' form, while that on the right appears in 'equivalent' form. However, if the two commodities are qualitatively different, it is inappropriate to use an equal sign. Thus to make clear the concept that the two commodities occupy different positions, let us use an arrow in place of the equal sign. Rewriting Eq.(2.1), then, we have

$$x \text{ commodity } A \rightarrow y \text{ commodity } B. \tag{2.3}$$

Replacing the equal sign with an arrow makes it clear that the commodities on the left and right sides are not of an identical nature.

The above formula expresses the idea that a request is being made for the exchange of the commodity on the left side for that on the right and thus that it is possible to exchange that on the right for that on the left. However, it is not necessarily the case that the commodity on the left can be exchanged for that on the right. This relational difference constitutes the source of asymmetry between the two commodities. Marx refers to the 'equivalent value-form' as the 'form of direct exchangeability,'[3)] or the 'property of direct exchangeability.'[4)] These expressions refer to the situation depicted above. (Marx, [3], pp. 70, 72)

Let us refer to 'direct exchangeability' as the 'right of option.' Thus we

interpret the meaning of the above formula as follows: The two commodities possess equal value, but that on the right holds the right of option in regard to its exchange for that on the left.

Designating the value of a commodity by the letter V, the above expression can be more clearly expressed as

$$(V_a, 0) \rightarrow (V_b, 1). \tag{2.4}$$

The first component of such a vector denotes the value of the commodity, while the second designates whether or not the right of option is held by this commodity. We use the value 0 to represent the lack of this right and 1 to represent its presence. Marx does not use vectors or arrows in his formulas, but he explains that the equal sign implies equal value and designates the value type of the commodities situated on its two sides as those of relative form and equivalent form.

Now, what should be done to allow for the exchange of two types of commodities of such differing nature? Obviously, as long as the two vectors representing these commodities are distinct an exchange will not take place. However, if no exchange is to take place, use of this kind of formula loses its meaning. Therefore let us consider the following formalism. If

$$(V_a, 0) \rightarrow (V_b, 1) \tag{2.5}$$

and

$$(V_a, 1) \leftarrow (V_b, 0) \tag{2.6}$$

hold simultaneously, we write

$$(V_a, 1) = (V_b, 1), \tag{2.7}$$

expressing the idea that the two sides are equal and that exchange should take place. The last formula here expresses realization of the state in which the two commodities have been exchanged. Thus the left and right sides are now equal, and they can be reversed.

Ignoring the second component of the two vectors, we obtain from the above

$$V_a = V_b, \tag{2.8}$$

which is the meaning of Marx's original formula. Thus we realize that in fact, Marx's theory is constructed as a 'result theory.' That is, discussion is carried out with the presupposition that the linen and coat have *already been exchanged.* While making this presupposition, the meaning of the fact that such an exchange has been made is reformulated to mean that both sides of the expression are split into relative value form and equivalent value form. However, here Marx's discussion begins to become confused, and from this point he assumes that the left and right sides of this formula can always be interchanged. In other words, he confuses Eq.(2.1) with Eq.(2.8).

It can be thought that this confusion on Marx's part grew out of the fact that his interest was directed at value theory. He writes

> Here however, a task is set us, the performance of which has never yet even been attempted by bourgeois *economy,* the task of tracing the genesis of this money-form, of developing the expression of value implied in the value-relation of commodities, from its simplest, almost imperceptible outline, to the dazzling money-form. By doing this we shall, at the same time, solve the riddle presented by money. (Marx [3], p. 62)

The fact that in this way Marx attempts to solve the problem of the emergence of money while dealing with the theoretical development of value expressions is the cause for his focusing on the first component of our vector and ignoring the second component. As a result, rather than solving the 'riddle of money', he riddled his theory of money with fatal errors.

That which is important in solving the riddle of money is not value theory, but the concept of direct exchangeability, or in other words the concept of the right of option. As Marx states, "The simplest commodity-form is therefore the germ of the money-form." (Marx [3], p. 85) Thus the essential element of the elementary value-form is opposition between the relative value-form and the equivalent value-form. For this reason we must part with Marx and his dialectic arguments on value-form theory in which he focuses on only the first component in the two-component vector. We instead undertake a rational analysis.

As Marx proceeds, he treats the ideas of the 'universal or developed value-form' in order to impart upon the concept of value a generality which transcends the difference between types of commodities. However, for the present work, this discussion is unimportant, and we will thus skip over it and on to a treatment of the 'general value-form.' This value-form expresses the state in which there is only one commodity standing on the right-hand side of Eq.(2.4), all other commodities standing on the left-hand side of the expression. We express this state as

$$\left.\begin{array}{ll} x_1 \text{ units of commodity 1} & \rightarrow \\ x_2 \text{ units of commodity 2} & \rightarrow \\ x_3 \text{ units of commodity 3} & \rightarrow \\ x_4 \text{ units of commodity 4} & \rightarrow \\ x_5 \text{ units of commodity 5} & \rightarrow \\ x_6 \text{ units of commodity 6} & \rightarrow \\ x_7 \text{ units of commodity 7} & \rightarrow \\ \cdots\cdots\cdots & \\ x_N \text{ units of commodity } N & \rightarrow \end{array}\right\} \; y \text{ units of commodity A} \tag{2.9}$$

This is similar to the diagram used by Marx to illustrate the general value-form, but there is the essential difference in that his equal sign, allowing for the inversion of

the equation, has been replaced by the arrow, allowing for no inversion.

The manner in which the state described by the above formula comes into being will be discussed in the next section. In this section we assume that such a state, due to whatever cause, is already in existence. Then, the commodity on the right-hand side of Eq.(2.9) exclusively possesses the property of direct exchangeability. Assuming the N commodities on the left-hand side are present, that on the right-hand side possesses the exclusive right of option with regard to these N commodities. In order to express a state of this type, let us extend the vector notation introduced above. In the case of Eq.(2.4), there are just two commodities, and thus there are only two possible states corresponding to the second vector component, that in which the right of option is held, and that in which it is not held. The set $\{0,1\}$ facilitated the designation of the state in that case. However, in the present case, commodity A possesses the right of option with regard to N types of commodities, and thus we must redefine the meaning of the second component. This component will now be used to specify the possession (or lack thereof) of the right of option with respect to a number of types of commodities, and thus it will take some natural number value (or zero). With this convention, Eq.(2.9) can be expressed as

$$\left.\begin{array}{ll} (V_1, 0) & \rightarrow \\ (V_2, 0) & \rightarrow \\ (V_3, 0) & \rightarrow \\ (V_4, 0) & \rightarrow \\ (V_5, 0) & \rightarrow \\ (V_6, 0) & \rightarrow \\ (V_7, 0) & \rightarrow \\ \cdots\cdots\cdots & \\ (V_N, 0) & \rightarrow \end{array}\right\} (V_A, N), \tag{2.10}$$

where the quantity of each commodity has been adjusted so that $V_1 = V_2 = \ldots = V_N = V_A$ is satisfied. In this way we express the state in which one commodity exclusively possesses the right of option.

However, written in this way, the situation arises in which a second exchange is impossible. In contrast to the simple case in which two commodities are directly exchanged, in the present case commodity A possesses the exclusive right of option. Thus the situation represented by Eq.(2.7) in which the position occupied by the two commodities on either side of the formula can be reversed and exchange can take place according to this relationship is no longer possible. In order to establish an equality here, some kind of 'exchange value' allowing for the commensuration of both the first and second vector components must be introduced. For this purpose, let us consider the function

$$E = E(x, y), \tag{2.11}$$

which is assumed to be a monotonically increasing function of both x and y satisfying $E(0, 0) = 0$. Substituting (V_i, n_i) for (x, y) in such an equation determines the exchange value E_i. If V_A on the right-hand side is set less than V_i on the left-hand side of Eq.(2.10), exchange becomes possible. Making V_A smaller has the meaning of reducing the unit size of the quantity on the right-hand side until the equality $E_A = E_I$ is satisfied. If we represent this unit size by x_A, we have $x_A < 1$.

Let us consider the extreme case in which N is very large, and in order to satisfy the condition $E_A = E_1$, the quantity V_A characterizing the right-hand side must be almost 0. A situation of this type is represented by

$$\left.\begin{array}{ll} E(V_1, 0) & = \\ E(V_2, 0) & = \\ E(V_3, 0) & = \\ E(V_4, 0) & = \\ E(V_5, 0) & = \\ E(V_6, 0) & = \\ E(V_7, 0) & = \\ \cdots\cdots\cdots & \\ E(V_N, 0) & = \end{array}\right\} E(0, N). \tag{2.12}$$

Here, 'commodity A' has been removed from the right-hand side because it no longer exists as a physical entity and therefore cannot be thought of as a commodity. That which exists on the right-hand side is N units of the 'right of option.' This is a purely abstract quantity which is exchanged in this form for the physical commodities on the left-hand side.

Now, even if the 'money' situated on the right-hand side of Eq.(2.12) were in the form of some physical entity, for example gold, the situation described above would not change. In this case, the vector component V_A would not possess any essential meaning. That which expresses the meaning that this entity is acting as money is the second component, N. It may be said that one of money's important characteristics is that it enjoys universal acceptance (that is, the property that anyone will accept it). Here we are asserting that 'universal acceptance' is equivalent to 'N units of the right of option' and that this entity is nothing other than money itself. Here one point which should be noted is that the number of units N of the 'right of option' possessed is not infinite. That is to say that 'universal acceptance' is not infinite and thus is more precisely termed 'finite universal acceptance.' This finiteness is determined by the variety of commodities contained within the system in which money is accepted as such[5].

Let us now compare the relationship

$$(V_x, 1) = (V_y, 1) \tag{2.13}$$

between commodities with that,

$$E(V_i, 0) = E(0, N), \tag{2.14}$$

between commodities and money. The 'value' of money $E(0, N)$ possessing no physical existence can be expressed only by inverting Eq.(2.12):

$$E(0, N) = \begin{cases} = E(V_1, 0) \\ = E(V_2, 0) \\ = E(V_3, 0) \\ = E(V_4, 0) \\ = E(V_5, 0) \\ = E(V_6, 0) \\ = E(V_7, 0) \\ \cdots\cdots\cdots \\ = E(V_N, 0) \end{cases} \tag{2.15}$$

As can be seen by substituting Eq.(2.15) into the right-hand side of Eq.(2.14) the latter takes on the meaning of equating the value of some quantity of each commodity 1-N. In other words, the act of measuring a commodity's value using money is actually an act of measuring this value by determining this commodity's comparative value relationship with all other commodities in the system. In this way, such a measurement is fundamentally different from a commodity-commodity value expression such as Eq.(2.13). We can also use Eqs.(2.13) and (2.14) to compare a commodity-commodity exchange with a commodity-money exchange. The former is an exchange of two physical objects, while the latter is an exchange of a physical object and an abstract entity. In this sense it is not appropriate to refer to the two transactions with the same word. In place of 'exchange,' let us refer to the latter by the more appropriate term, 'the transfer of a commodity and corresponding settlement.'

2. From Menger's Theory on the Emergence of Money

In the last section we began from the concept of direct exchangeability and discussed how money, while having no physical form, possesses an exchange value and can mediate exchange. However, this discussion was carried out under the premise that one particular commodity stands in the privileged position of being granted the right of option by all other commodities. Such a premise represents a very big logical leap. Thus in this section, while referring to the theory of Menger, we study how the creation of money is possible.

2.1 Menger's Theory

Menger's theory is based on the proposition that with the development of the division of labor, it becomes increasingly difficult to realize the coincidental situation in which a commodity desired by one person is owned by a second person who happens to desire a commodity owned by the first person. Menger states [4][6]:

> The difficulties exist because in the barter market, even in those cases where some market participants offer commodities for sale and others desire the same commodities, pairs of trading partners who wish to participate in mutual trade are either non-existent or are very few in number; therefore, a turnover of the commodities in question, even though they are offered and demand for them exists among market participants with purchasing power, can only take place in relatively few cases, because of a lack of prerequisites for an economic exchange of these commodities. These difficulties are continually heightened by the development of the division of labor and with the increase in the variety of commodities brought to the marketplace. (Menger, [4], pp. 245–246)

We consider the situation in which each person (or 'participant') possesses only one type of commodity and in addition desires only one type of commodity. Then, we assume that there exist N commodities and that the probability that a given person desires a particular commodity is the same for all commodities. For example, suppose a given person owns commodity 1 and desires commodity 2. The probability that an arbitrary possessor of commodity 2 desires commodity 1 is $1/N$. Under the advancement of the division of labor, N becomes large, and this probability becomes small. Menger's assertion is this condition. This kind of difficulty is generally referred to as the 'double coincidence of wants.'

Menger states that the participants in a market for which N is sufficiently large will make the following observation.

> In a barter market...when commerce is in the stage of development, certainly any person would make the following obvious and, in fact, important observation. Namely, for the person who brings to the marketplace a particular type of commodity which enjoys greater demand than that of the commodities brought to the marketplace by any other individual, if it is this person's purpose to obtain some commodity through the exchange of that which he brings to the marketplace, his prospects of fulfilling this purpose are unusually high, or the difficulty and economic sacrifice he must make in the process are minor. (Menger, [4], p. 247)

Upon making this observation, Menger claims that people will come to exchange

the commodity of which they are in possession for a 'particular type of commodity' in the attempt to indirectly obtain the commodity they desire. As a result of this behavior, it will become increasingly easy to exchange this 'particular type of commodity.'

> With the growing realization of the above mentioned economic interest, especially as a result of propagating insight and the mechanized habit of economic trade, in all markets the most marketable commodities, in accordance with local and contemporary conditions, are those in which each person not only takes an economic interest to exchange for his own, less marketable commodity, but which each person actually accepts willingly and habitually; **they are the most marketable only because they have the greatest salableness in relation to all other commodities, and thus only they can become the universally employed commodities of trade.** (Menger [4], p. 250)

The bold-faced font is used here to point out the tautology in Menger's argument. The terms 'most marketable' and 'having the greatest salableness' are nearly synonymous. If we substitute 'most marketable' for 'having the greatest salableness,' the sentence appearing in bold-face becomes:

> *They are the most marketable because they are the most marketable.*

However, this tautology expresses the idea that this thing called 'marketability' has the ability to act as a catalyst in its own development. Thus we can assume that a 'particular type of commodity' accidentally comes to be recognized as having higher marketability than all other commodities. (As we will discuss later this kind of difference in marketability is inevitable.) If we assume that such a difference in marketability is recognized, and that as a result the self-catalyzing action takes effect, the marketability of this commodity will be increased in a self-promoting manner. As a result of this phenomenon, the commodity will begin to play the role of a general medium of exchange. Menger states:

> As soon as one or more commodities have become universally useable mediums of exchange in the markets of a country, a conspicuous and fundamental transformation of the market structure takes place. The circumstance that a commodity has become a universally useable medium of exchange has, above all, the effect of considerably raising the already relatively high marketability of said commodity with respect to itself and in relation to the rest of the commodities in the market. (Menger [4], p. 257)

> The circumstance that a commodity becomes a universally useable medium of exchange consequently heightens, to a large extent, the pre-existing great

> marketability of the same commodity; whereas the same circumstance—the emergence and generalization of the use of mediums of exchange—diminishes more and more the marketability of the remaining commodities (this marketability characterizing the age of natural exchange) to the point of nearly completely dissolving the possibility of their immediate exchange in the progressive development of the monetary economy. (Menger [4], p. 258)

With these arguments, Menger discovers the key to the rational solution of the problem Marx avoided in his dialectic development of the conversion from the universal or developed value-form to the general value-form.

2.2 Money and Edgeworth's Barter Process

As has become evident from the discussion given to this point, the condition in which some commodity occupies the position of money is equivalent to the condition in which that entity is willingly accepted by any person. The reason that any given person will gladly accept this commodity is simply that all other people will also gladly accept it. Stated differently, this commodity is money, and for this reason everyone will happily receive it. This is, of course, a completely circular argument. However, this circular logic reflects the essence of the money form, and as we will see below, when we undertake an analysis of money, we are inevitably confronted with this circularity.

In this subsection, we construct a mathematical model in order to more precisely treat Menger's ideas. First, let us construct a simple model which conforms to the traditions of study in the field of economics. Let us consider a closed system in which initially there exists nothing representing money. This system consists of N people and N 'possession vectors,' one corresponding to each person. The possession vector $\mathbf{x}_i$ of the i-th person at the initial time is represented by $\mathbf{x}_i^o$. Each component $\mathbf{x}_i$ corresponds to a particular commodity. Then, let us represent the set of commodities this person hopes to possess after exchange in the market by the vector $\mathbf{x}_i^*$. This vector maximizes this person's utility function $\mathbf{U}_i(\mathbf{x}_i)$ subject to the constraint

$$\mathbf{p}^*\mathbf{x}_i^* \leq \mathbf{p}^*\mathbf{x}_i^o. \tag{3.16}$$

Here, $\mathbf{p}^*$ is the value vector, which we take at this point to be given. We simplify the analysis by assuming the values have been appropriately adjusted so that each component of this vector assumes the value 1.

Expressing the i-th possession vector at time t by $\mathbf{x}_i(t)$, dealing will continue in the market until at some time T the condition

$$\mathbf{x}_i(T) = \mathbf{x}_i^* \tag{3.17}$$

for all $i = 1, 2, \ldots, N$. At this time, dealing will cease. When this condition comes to be realized, all participants in the system will be satisfied, and they will no longer attempt to carry out exchanges. We can thus refer to this as the equilibrium state. If the system is such that beginning with some arbitrary combination of possession vectors, the equilibrium state is reached immediately, then the existence of money as a medium of exchange is unnecessary. In fact it cannot exist. However, clearly to presume that the act of exchange requires no time is unrealistic. For this reason it is necessary for us to explicitly introduce the extended temporal nature inherent in the act of exchange and construct a model exhibiting non-equilibrium states.

For the sake of simplicity we will assume that each person present in the system initially possesses one unit of one type of commodity, and for $t > 0$, with this commodity in hand, this person goes in search of a trading partner. When some person 1 then encounters some other person 2, we will assume exchange to take place in the following manner. Person 1 calculates the utility of both the commodity in his possession and that possessed by person 2. If the utility he attributes to that commodity held by person 2 is sufficiently larger than that of the commodity he holds, he will propose exchange. That is, if the inequality

$$\mathbf{U}_1(\mathbf{x}_1)+s \leq \mathbf{U}_1(\mathbf{x}_2), \tag{3.18}$$

is satisfied he will offer his commodity in exchange for that of person 2. Here s can be considered as a kind of threshold value. Then, if person 2 makes the same judgment, that is, if

$$\mathbf{U}_2(\mathbf{x}_2)+s \leq \mathbf{U}_2(\mathbf{x}_1), \tag{3.19}$$

person 2 will also propose exchange with person 1. In this case, happily, exchange can be realized.

This model resembles a system known as Edgeworth's barter process, a model which was proposed for the purpose of treating the question of whether under repeated exchange, whereby each economic element (each person) works to improve her utility, the most appropriate prices and means of resource distribution will in some way be realized. This model differs from the searching process of Walras, loved by the mainstream of economics. In Edgeworth's barter process, the acts of both searching and exchange are carried out, and in this sense it allows us to deal easily with the meaning of the existence of time. The model used in the present paper ignores the process of the formation of price, taking this quantity as fixed, and thus the problem addressed here is fundamentally different from that addressed in works concerning Edgeworth's barter process[7].

Let us now return to consider the simple exchange of two commodities and think about the meaning of Eq.(2.4),

$$(V_a, 0) \rightarrow (V_b, 1). \tag{3.20}$$

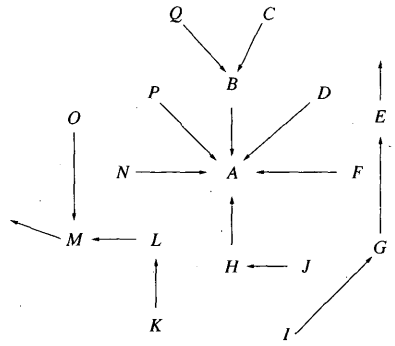


Figure 1 Commodity A becomes a 'focal commodity' by chance. (Source: Yasutomi [11], by permission from Elsevier Science.)

We claim that in the type of system described above, the symbol '$\rightarrow$' in this equation possesses a self-catalyzing effect. As we have already seen, in order for exchange to be realized, the relations $A \rightarrow B$ and $B \rightarrow A$ must simultaneously hold. However, with a situation like that we are considering in this section, such a double coincidence of wants would be quite rare. Thus, while all the participants in this system hope to realize exchange, they fall into a state in which this becomes very difficult. Here, it is easy to imagine the situation in which a number of arrows come to be directed at a single commodity, as depicted in Fig. 1 with commodity A. A state such as this in which arrows come to be pointed at a single commodity can be thought of as forming a particular structure. We refer to this type of structure as 'coupled structure,' to the arrows composing the structure as 'component arrows,' and to the commodity to which the arrows point as the 'focal commodity.'

Let us assume that a coupled structure of appreciable size is formed. Then, suppose the owner of some other commodity (J in Fig. 1) does not wish for the focal commodity, but does wish to trade for one of the commodities occupying the position from which one of the component arrows in question emanates (J). For this person, rather than proposing trade directly with the person who possesses the commodity which he desires, she could first make a trade for the focal commodity and then trade this for the commodity she desires. If she chooses this indirect method of trade, she will come to desire the focal commodity, for which she has no direct need, and she will propose a trade for this commodity. When this happens, this person, who does not desire the focal commodity for any direct purpose, and the commodity of which she is in possession will become part of the coupled structure.

Now let us consider a person who does not desire the focal commodity even indirectly. This person (K in Fig. 1) does not need any of the commodities contained within the coupled structure, and thus does not participate even indirectly in the coupled structure. For this person, there are two possible modes of action. One of these is to continue to hold his commodity and wait for a person in

possession of the commodity which he desires to grant him right of option for that commodity. The other choice is, for the time being, to trade for focal commodity, wait for the commodity he desires to enter this coupled structure, and when it does, to trade the focal commodity for that which he desires. Depending on the situation, the latter choice may be wiser, and if he in fact makes this choice, this person and his commodity too will become part of the coupled structure.

Because exchange requires a situation not easily realized in which the right of selection is granted mutually, it will usually be the case that one-sided granting of such comes to characterize the system. It is also not unusual that this will cause the creation of the coupled structure discussed above. However, for a system whose initial conditions are only slightly removed from equilibrium, this is unlikely. In the extreme case in which the initial conditions are such that equilibrium is attained immediately upon a single exchange made by neighboring people, no structure of this kind will ever appear. However, if the initial conditions place the system far from equilibrium, the situation will develop in a very different manner. In this case, the system cannot easily relax to the equilibrium state, and a prolonged non-equilibrium state will be realized. In such a system, arrows of random lengths and pointing in random directions will continually appear and disappear. It is thus possible in this situation, if the arrows come to accidentally gather to some extent, for coupled structure to be formed as described above. However, a small coupled structure will usually disappear without bringing any large change to the system.

What happens if a coupled structure appears whose size exceeds some fixed critical size? The probability for this kind of large coupled structure to appear is very small, but once such a structure does appear, even as component arrows from which it is composed disappear, new arrows contributing to its structure will appear, and the structure as a whole will continue to exist. In addition, due to the self-catalyzing effect discussed above, the fact that the focal commodity, which is granted the right of option by the commodities in the coupled structure, possesses such a wide ranging right of selection in itself will cause it to increase the number of component arrows making up its coupled structure. Thus the self-catalyzing nature of the arrows will suddenly be realized, and the state of the entire system will change from something like Fig. 1 to something like Fig. 2. At this time, this system will maintain a large 'right of option bundle' for one particular commodity acting as the focus, and in time this will develop into a 'bundle of N rights of option.' As discussed above, money is nothing but such a bundle of the right of option, and thus the development of the latter is equivalent to the appearance of money in this system.

As a result of the appearance of this money, the speed at which exchanges are realized will jump drastically. This is because after a single exchange for money it is possible to make an exchange for the commodity one desires. With this, the system quickly approaches equilibrium. However, we have set the threshold value s, appearing in Eq. (14), and thereby assumed that if the improvement in ones utility gained upon exchange does not exceed a certain level, exchange will not be

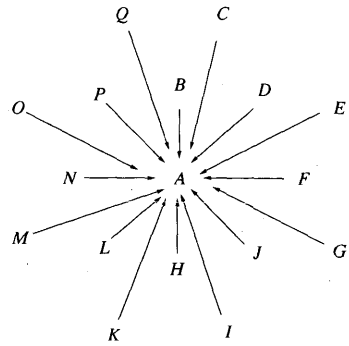


Figure 2 Due to the self-catalyzing effect, arrows converge upon A. This marks the appearance of money. (Source: Yasutomi [11], by permission from Elsevier Science.)

proposed. For this reason, the development of this system will stop just short of equilibrium. Let us call this state 'quasi-equilibrium.' In other words, a system placed initially at a position removed sufficiently far from equilibrium will not reach the equilibrium state, at best reaching only a state of quasi-equilibrium.

Let us assume that the system in question has reached such a quasi-equilibrium state. There will now be almost no exchange taking place, and in fact there will be almost no occurrence of the pointing of arrows at other commodities (i.e., almost no offers for exchange). This kind of state is fatal for coupled structure. If the appearance of new arrows ceases, coupled structure will be destroyed. In the process, money loses its existence. In other words, in a closed system, the existence of money continues only until the system realizes a quasi-equilibrium state, and if exchange proceeds at a fixed level, money will eventually disappear.

In what type of system will the existence of money persist indefinitely? Only in an open system, that is one in which consumption and production take place, can the persistence of money be realized. To this point we have considered only closed systems, those in which the only change is in the form of exchange. Thus to investigate money as a persistent phenomenon, we must introduce consumption and production and consider the resulting open system.

When, in the system studied to this point, through a number of exchanges each participant has raised his or her utility by a certain amount, exchange comes to a stop. However, if the system is opened to consumption and production, the commodity a given participant desires and comes to acquire through exchange will be taken from the system by this participant and consumed. Conversely, he will also produce some commodity that he himself does not need, a commodity which will thus be introduced into the system as his possession. In this way, he will once again seek exchange. This type of system will, of course, never reach equilibrium and will not even reach a quasi-equilibrium state. The participants in this system will repeat their production and hence undertake exchange indefinitely. As has

been made clear in the above discussion, in this paper we define quasi-equilibrium as that state in which each participant has reached a most desirable state, or a state of some fixed level of satisfaction, and in which exchange no longer takes place. But in the present situation, each participant desires to repeat exchange without end, and thus the quasi-equilibrium cannot be realized.

For the sake of clarity, let us emphasize the following point. We do not simply introduce production and consumption into the model through the use of some production and consumption functions. As we mentioned above, consumption here consists of the act of people removing commodities they have obtained from the market and represents consumption in its truest sense. For example, we are referring to the the situation in which in order to satisfy their hunger, a person acquires bread in the market and eats it. As a result of this act of consumption, the person indeed satisfies her hunger, and the system takes one step toward equilibrium. However, this state of satisfaction unfortunately will not last for many hours. Thus this person will eventually once again seek some food being sold in the market. In other words, this loss of satisfaction occurring over time tends to move the market away from equilibrium.

In a similar manner, the act of production is not put off until the state of equilibrium is realized, but rather, it is carried out recurringly in time. Again considering the person who bought the bread, if she happens to be a shoemaker, she will make shoes repeatedly and upon production surely bring them to market for the purpose of trade for a variety of things. Then, after exchanging one pair of shoes, she will immediately seek to exchange a second pair. Thus production too will always work to force the system away from equilibrium.

In the field of economics, it is customary to treat a "period" of time during which constraints concerning quantities such as utility functions and production technology do not change in time. However, here we do not consider such a "period." Rather, we treat a truly extended interval. In other words, those things which should serve as constraints in this system are thought of as being time dependent, and thus if the equilibrium state corresponding to the system (both changing from instant to instant) cannot be realized instantaneously, until the end of this model world equilibrium will never be approached. Through production and consumption, the market is endlessly pushed away from equilibrium. Thus in this continuous and extended time, which is normally not treated in the field of economics, lies the essence of the ceaseless formation of money[8].

Now, in this non-equilibrium open system, the component arrows forming the structure of money will disappear with the realization of exchange, but with production and the implicit newly arising need for exchange, they will reemerge again and again. Therefore money constitutes a normal and generic structure in non-equilibrium open systems.

Menger introduced the concept of marketability and thought of money as a spontaneously generated entity serving as a necessary intermediary in exchange. Following the arguments given in the latter half of this section, constructed with

reference to Menger's ideas, it becomes clear that money is not some fixed physical entity, but rather a structure which is continuously generated by people as a result of their interactions. Even if money were to assume a "hard" form, this money must have possessed from the beginning some value, this value itself being of some non-physical nature, namely a bundle of the right of option. Moreover, if this value-form is not continuously generated in time, this money-form cannot continue to exist. In this sense it is a 'generated structure.'

3. Money within a Computer

In this section we introduce a computer model exhibiting the formation of money (for details, see Yasutomi [11]). I created this model to reflect the discussion given above and in order to observe the spontaneous emerging aspect of money. However, this model displayed behavior exceeding my expectations. Not only did this model display the spontaneous generation of money but also its spontaneous destruction. Through computer simulation it was found that the very mechanism which insures the generation of money also brings about its destruction. As a result, we recognize the time in which the existence of money is played out as being promoted from the continuous and extended time of the non-equilibrium open system to a more high-level, historical time whose essence is more deeply rooted in the ideas of learning and evolution. In addition, as discussed in the next section, this kind of high-level time is demanded by the conflict or contradiction between individuals existing at the component level and the structure existing at the global level.

3.1 A Pure Barter Model

In this model there exist 50 identical people. Each person produces a different commodity. That is, person 1 produces commodity 1, person 2 produces commodity 2, etc. Each person can at any given time desire only one commodity. In addition, no person can ever desire the commodity which they themselves produce ('their own commodity'). Initially, they each possess one unit of their own commodity.

We now describe the manner in which the game is played. First, one person is called to the stage. Suppose this is person 1. This person then approaches that person possessing the largest quantity of the commodity she desires. Let this be person 2. These people then show each other the products they possess. If they each desire that which the other possesses, they inform the other of this. We will refer to this act of informing of ones desire as 'demand.' The difference between 'desire' and 'demand' is important. The former is something characterizing ones personal mental state and is something which others cannot see. However, when the person in question comes across the commodity she desires, with the exclamation "Give me that!" or some equivalent act, this person expresses this

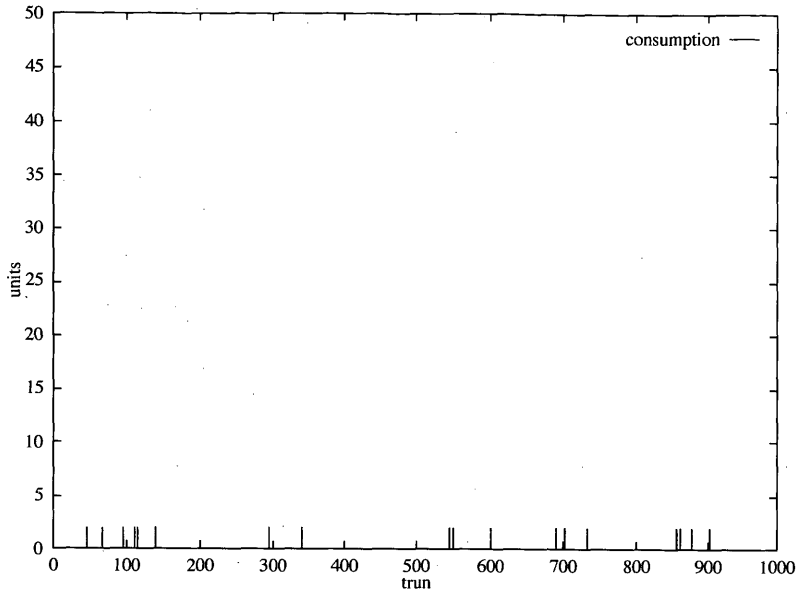


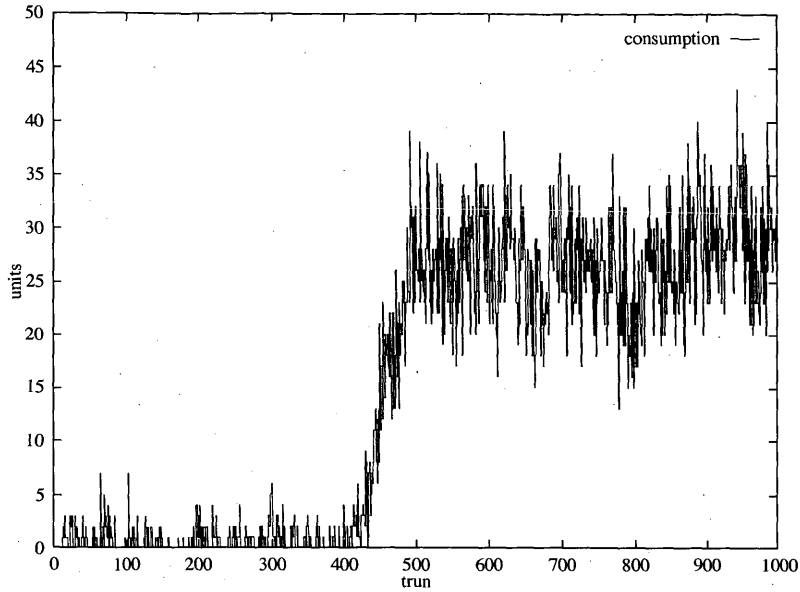
Figure 3 The change in the level of consumption in the case of a barter market. People confront the problem of the 'double coincidence of wants.' (Source: Yasutomi [11], by permission from Elsevier Science.)

desire, and this comes to be a demand which can be recognized by another person. In the present case, if both person 1 and person 2 express demand for the commodity held by the other, exchange is happily realized. In any given case, whether exchange is actually carried out or not, once the outcome is determined, the two descend from the stage and return home where they carry out the acts of consumption and production. If they succeeded in obtaining the desired commodities, they consume these, and their desires turn to some new commodities. In practice, as one desire is fulfilled, the next desired commodity is chosen randomly from the 49 possible commodities existing in the system. Also, if the stock of a person's own commodity has reached zero, he makes one new unit.

Now, with exchange conducted in this manner, what will happen? According to simulation, almost no exchange takes place. This is simply because, precisely as explained in the previous section, cases in which there is a match in the commodities desired are very rare. In this sense, this model captures the difficulty inherent in exchange (the double coincidence of wants). Fig. 3 exhibits the level of consumption taking place at each point in time for a particular simulation. As is seen, this quantity remains at zero for almost all times.

3.2 Model of the Emergence of Money

The powerful method we use to avoid the difficulty encountered in exchange is to



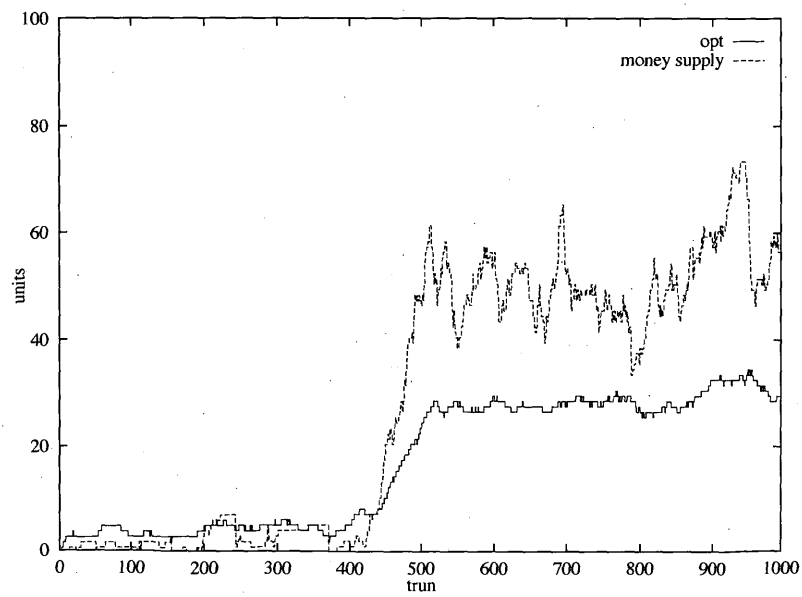


Figure 4 Change in consumption level in the case in which money appears. Somewhere around 400–500 time steps, *opt* and *money supply* can be seen to jump. At the same time, the level of consumption rises sharply. (Source: Yasutomi [11], by permission from Elsevier Science.)

obey the maxim "accept that which everyone else accepts." That is to say, we adopt the rule that if you are a participant in this game, then, on the occasion of proposed exchange, even if that commodity which the opposite person possesses is not that which you desire, if you believe this commodity happens to be that which everyone demands, then you too should demand it.

But how many people is "everyone"? If we define this to be some value X, in the case that $X \geq 13$, there is little change from the situation seen in the previous section. However, if X becomes less than 12, there is a large change. In the beginning, there is little exchange, but at some time, some commodity becomes such that it is always demanded by a large number of people. The state of being in demand enjoyed by some commodity, then, causes still more people to demand this commodity, and this state continues. At the instant that this type of commodity appears, exchange breaks out suddenly, and the level of consumption jumps sharply. Fig.4 exhibits this trend. The quantity appearing as *opt* in this figure represents the most highly demanded commodity and its value in the graph represents the level at which it is demanded. The term *money supply* here represents the number of units of that commodity which are held as a result of exchange.

The value of X is extremely important. If it becomes larger than 13, money does not appear. A point worthy of emphasis is that for $X > 20$, even if we initially prepare the system in such a way as to tell the participants "Let's use this

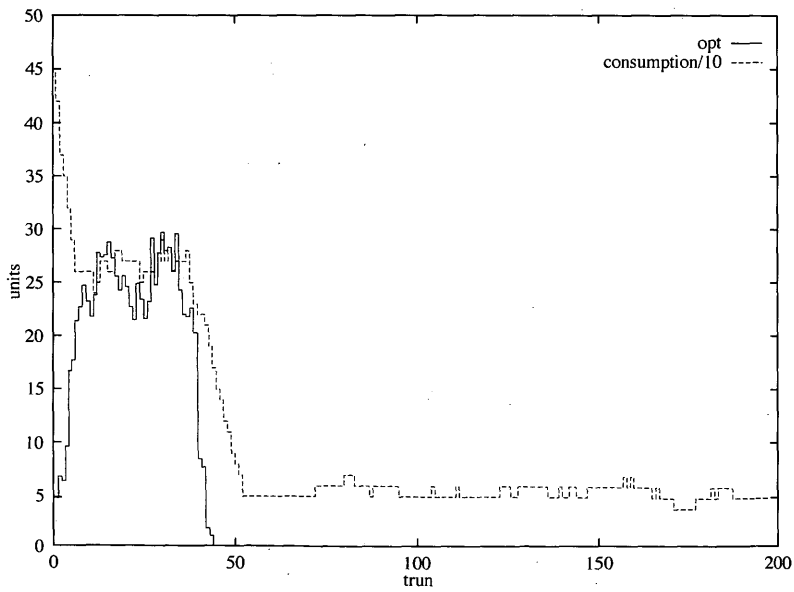


Figure 5 The case for $X=21$. Here, money is forcibly instituted initially, but after approximately 50 time steps, it has collapsed. (Source: Yasutomi [11], by permission from Elsevier Science.)

commodity as money!" this forcibly prepared money eventually collapses. Fig.5 exhibits this behavior. We fix $X = 21$ and set the system initially in such a way as to cause *opt* to attain the value 50 for a selected commodity. But after some time, the value of *opt* drops very quickly. For $13 \leq X \leq 20$, while the participants cannot themselves create money, if it is created for them, they will use and maintain it. Let us refer to this the range of values between 13 and 20 as the 'intermediate regime.' Also, we note that when X assumes the values 0 and 1 money will not appear. In this case, from the beginning, all people will gladly accept almost any commodity, and thus the difficulty in exchange itself never exists.

In this model, once the demand for some commodity exceeds some threshold, many people come to demand this commodity. This in turn supports further demand, and a cyclic relation is formed. This is nothing other than the mechanism of money bringing about its own existence.

3.3 The Spontaneous Emergence and Collapse of Money

To this point we have forced each person in the system to adopt the same value of the threshold X. Next, we do away with this restriction, allowing each person to choose their own value of X. In this way, X comes to differ from person to person. In addition, we introduce a 'carrying cost' parameter C. When a person comes to the stage carrying their possessions, for one unit of possessions they pay a cost C. At the end of one day, the number of commodities this person carried to the stage is calculated to yield the total carrying cost for this person. This is subtracted from their consumption rate, and the resulting value is considered as this person's 'score.' Then those people for whom this value is small adjust their values of X. Fig. 6 shows the result of a simulation of such a system (here $N=50$ and $C = \frac{1}{1500}$). The initial value of X for each person was set at 51. As can be seen, the average value of X (written $\langle X \rangle$) decreases rapidly. When this value drops below 10, the average score quickly rises, together with the value of *opt*. This expresses the fact that this system has the ability to produce money on its own. However, this money system is not stable. Eventually the $\langle X \rangle$ rises, and when it exceeds 10, the money which emerged now collapses, and the process begins all over again. In this way, money spontaneously emerges and collapses over and over.

Why does this kind of spontaneous collapse of money occur? Here, we should take note of the 'intermediate regime' (X from 13 to 20). As stated in the previous section, those people that adopt a value of X in this range do not have the ability to create money themselves, but they do have the ability to use money as money. In addition, people with a small value of X will at times mistake some non-money commodity for money. For middle level values of X there is no such weakness. Thus after money has appeared, the number of people adopting middle level values of X increases. However, the *opt* corresponding to money is normally quite subject to fluctuations, and there are cases in which it will become fairly small through some random cause. In this situation, if there are a large number of

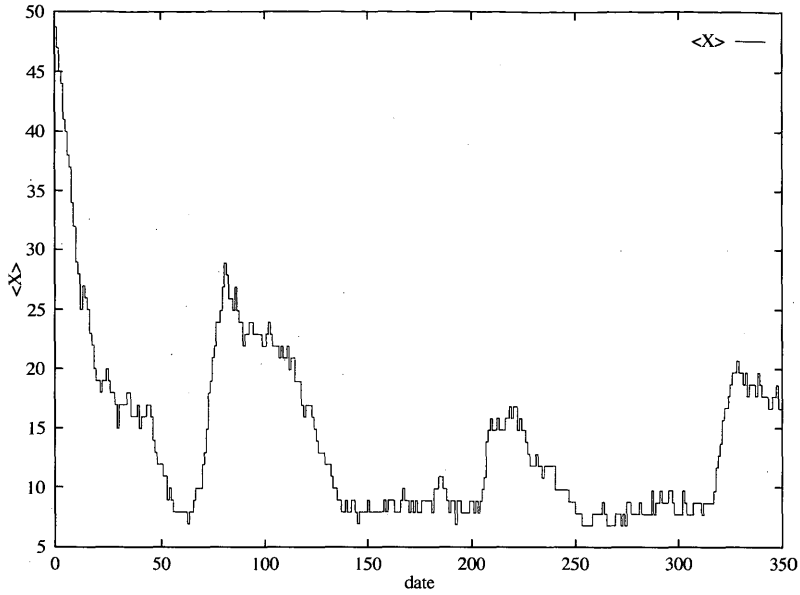


Figure 6a

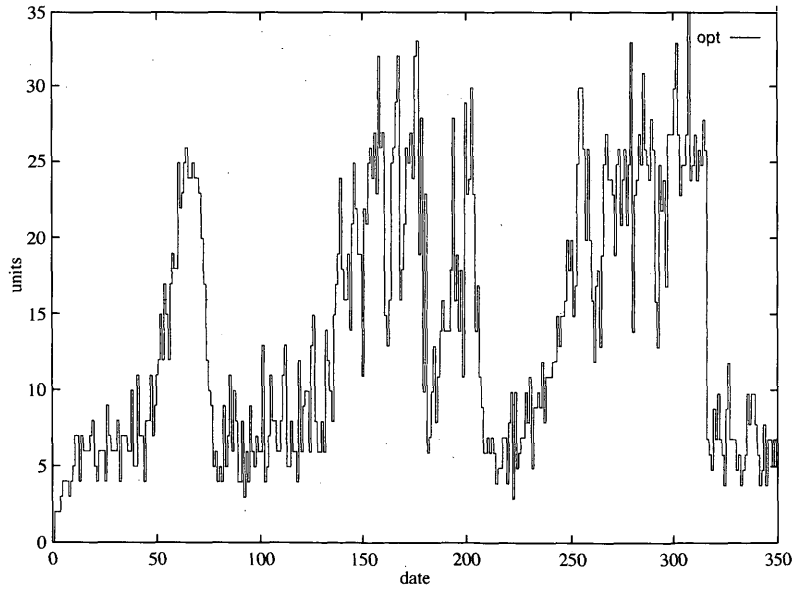


Figure 6b

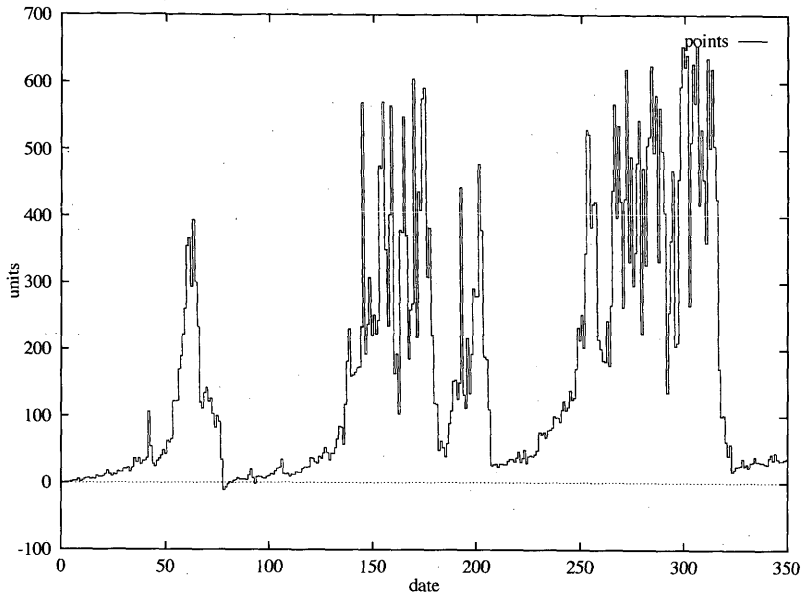


Figure 6c The case in which the value of X_i is adjusted by individuals. The spontaneous generation and destruction of money are repeated. (Source: Yasutomi [11], by permission from Elsevier Science.)

people using small values of X, there will be no problem, and *opt* will recover, but if the number of people using middle level values of X is large, there is the possibility that *opt* will become smaller than these. When this happens, the cyclic relation maintaining the form of money present is lost, and at the same time, this money spontaneously collapses. (see Figure 7)

There are several implications of this model. First, we interpret its behavior as implying that money is not a physical entity. It is a structure formed out of the relationships between people who engage in repeated interaction. That commodity which is used as money appears to possess the property that it is held by people, but in fact, that property is not one of that commodity itself but rather of the attitudes that people take toward that commodity. Furthermore, the fact that people mistake this abstract phenomenon, which is nothing more than the reflection of their own collective attitude, to be a property of this money only further strengthens this mistaken conviction. This collective attitude thus becomes strong through the positive feedback it creates.

The structure forming as a representation of the relationship between people comes to be recognized by people as taking the form of some concrete object. This structure comes to act as some objective force existing outside the people whose relations created it. This type of situation is something observed in general in the system known as 'society.' When a structure formed through the relationships of individuals becomes objectivized, the entirely different dimension of the 'whole' (in

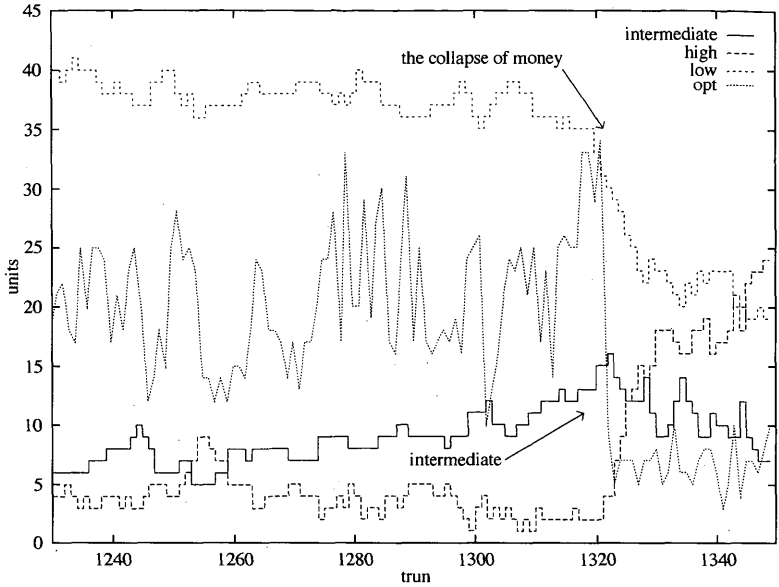


Figure 7 The form of the spontaneous destruction of money. The number of people employing middle-level values of X gradually increases, bringing on the collapse of money. (Source: Yasutomi [11], by permission from Elsevier Science.)

this case, society) appears. This type of phenomenon is not limited to social systems. The relations between single-cells and many-celled living creatures, between individual animals and groups of animals, between individual species and ecological systems, all of these situations should be subject to similar laws.

The second implication of this model is that the whole which has been formed in this way contradicts the intentions of the individual. In this model, money appears in spite of the fact that each person acts selfishly. When money does appear, exchange becomes invigorated, and each person's score (representing his or her well-being) increases sharply. This can be interpreted as one example of one of the principle traditional themes in economics, the 'invisible hand.' In this process, there does not appear to be a contradiction between the global structure of money and the adapted behavior of each individual, because this adapted behavior has produced money, and the establishment of money causes the state of each individual to become improved. However, when each individual acts according to the premise of the existence of the global structure of money, this money can also be seen to collapse. In this case, we can say that the 'invisible hand' which brought money into the system now works to destroy it. Here, the adapted behavior displayed by each individual becomes dangerous as it now acts to destabilize the global structure of money. In other words, this model suggests that when the 'whole' appears among a large group of individuals, the contradiction between the logic of the individual and the logic of the whole appears simultaneously.

4. Time, Money and Language

In this section, while organizing the points made clear in the arguments given to this point, we expand the interpretation of the discussion we have directed at the topic of money in an attempt to understand another social construct, that of language. In this process, it is important to recall the problem of time touched upon at the beginning of the previous section. In connection to this, let us sort out the various layers of time depicted in Fig. 8.

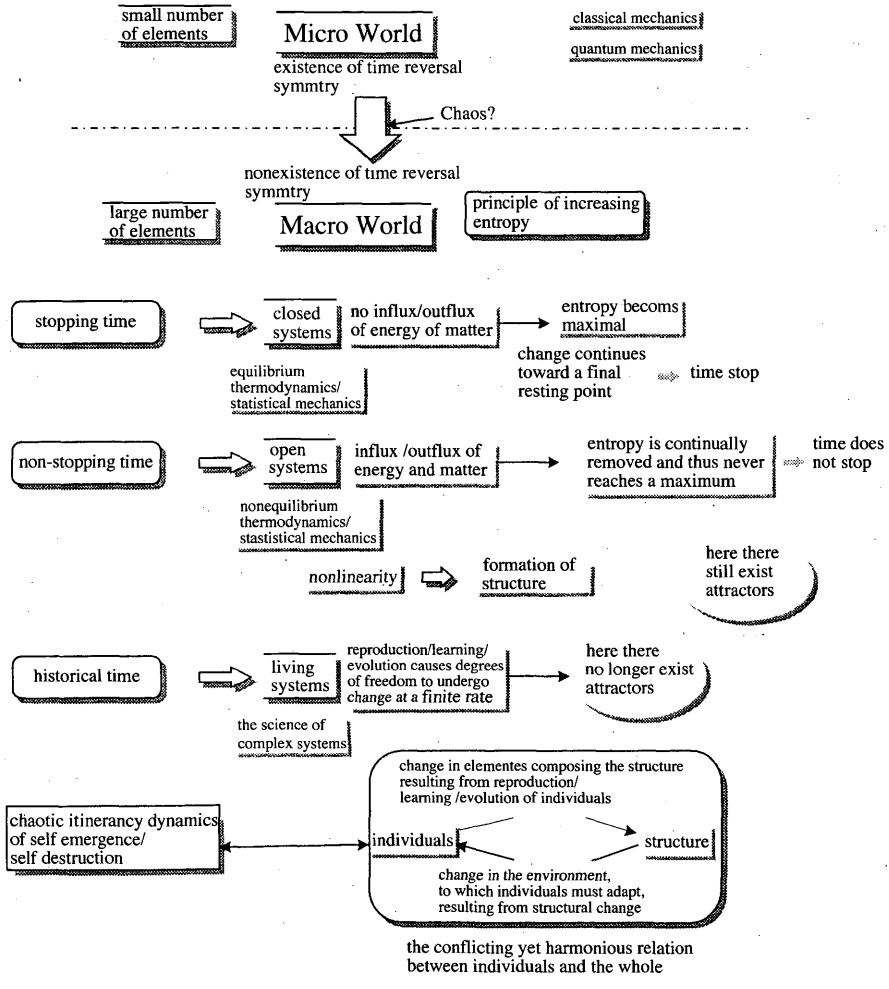


Figure 8

4.1 Stopping Time—A Closed System Which Evolves Toward Equilibrium

The most fundamental problem concerning time, or rather the theory of time, is that of how the micro-world characterized by time reversal symmetry produces a macro-world in which such symmetry is obviously lacking. In this case, the micro-world is that described by classical or quantum mechanics, and the macro-world is that described by thermodynamics and statistical mechanics. In the equations describing phenomena within the former theoretical constructs, moving forward and backward in time have the same meaning. For example, we can consider an equation of motion in a classical mechanical system. Suppose that at time 0 a force F is applied to a point particle situated at point A, and as a result, at a time T it has moved to point B. Then, if we reverse time, and at the time T apply a force $-F$ to the same particle, after a time $-T$, i.e., at the time 0, the particle will be at the point A. To actually observe such phenomenon would certainly seem not at all mysterious. The phrase "after a time $-T$" may make us feel somewhat uncomfortable, but if we simply reverse the time axis, there is no problem. In this type of world, time is on an equal footing with spatial dimensions and forces, possessing symmetry with respect to inversion.

However, phenomena such as diffusion, which belong to the realm of thermodynamics and statistical mechanics are not symmetric with respect to time reversal. To see this, let us suppose a drop of red ink is placed in a beaker of water. As time passes, this ink eventually spreads throughout the entire beaker, and the water becomes uniformly light red in color. Now, let us again reverse time and watch the system. We will then see the colorless water and the red ink gradually become separated. Such behavior, however, violates the principle of increasing entropy, and to actually observe it would contradict our experience. We cannot accept such behavior. This is to say that in the macro-world, time reversal symmetry is broken. Here, time is a privileged dimension.

The difference between classical mechanics and thermodynamics/statistical mechanics is that between treating a system with a small number of components and one with an (effectively) infinitely large number of components. Why is it the case that the time reversal symmetry which characterizes a small number of things is lost when we gather many of these things together? It is thought that deterministic chaos may provide the first step toward solving this problem. However, for our purposes it is sufficient to note that the time appearing in the world of equilibrium thermodynamics and statistical mechanics is asymmetric with respect to reversal, so let us not delve into results in the study of chaos.

The world described by thermodynamics and statistical mechanics is characterized by a time which appears in a form which is irreversible (principle of the increase of entropy). But, as long as we are interested in a closed system, this time eventually comes to a standstill. This is to say that, while until the system reaches equilibrium, time flows unmistakably in the direction of increasing entropy, once equilibrium has been reached, change stops here, and the passing of time also

becomes meaningless. In the case of the ink drop just considered, after it is placed in the water, the ink drop will display irreversible diffusive behavior. However, once it has become completely mixed, a state entirely void of change will continue forever. Then, let us think about the situation in which this beaker of water is heated for a short time from below and in which the beaker is then isolated from the outside world. Initially, the bottom of the beaker will be hot, while the surface of the water will be cold. But as time proceeds, this difference in temperature will disappear, and the temperature of the whole will become homogeneous. Then, again, from this point on there will be no further change. Equilibrium is often referred to as 'heat death.' This expression accurately describes this situation in which time has come to a halt.

The equilibrium state we defined in the model patterned after Edgeworth's barter process in Section 2 is similar to this 'heat death.' In the model, when all participants reach a state of satisfaction, the model describes a phase in which exchange no longer takes place. In this situation, there is no reason *not* to consider time as having come to a complete stop. In this model, that quantity which plays the role of entropy is the level of satisfaction experienced by the entire population. Exchange always increases a person's level of satisfaction, and the system proceeds toward a state in which everyone is fully satisfied.

4.2 Non-Stopping Time—Non-Equilibrium Open Systems

The property of moving toward and inevitable 'heat death' is characteristic of closed systems. A closed system is that which is independent of the outside world, a system which experiences neither the influx nor outflux of particles and energy. In contrast, a system which experiences some sort of interaction with the outside world is referred to as an open system. For example, we can think about the water inside the beaker discussed above as being continually heated on a gas stove. Heat is added to the water in the beaker from below, while heat rapidly escapes from the top. This system displays behavior completely different from that which is isolated from the outside world. First, let us think of the situation in which the gas flame is very weak. In the case considered above in which the beaker was isolated from the outside world after being heated for a short time, the difference in temperature between the water in the top of the beaker and that in the bottom gradually disappeared. In the present case, however, this temperature difference remains forever. This is because, while in accordance with the principle of increasing entropy, the temperature difference is always tending to decrease, heat is being continually added by the gas flame.

When the flame is weak, however, there is little difference between this open system and the system in thermal equilibrium. Therefore let us slightly increase the strength of the flame. When we do this, the water molecules, which to this time had been undergoing random Brownian motion, begin moving together in the same direction. When this occurs, one can clearly observe flow and structure in the

water. This phenomenon is referred to as 'convection.' For a flame of appropriate strength, this flow forms beautiful structure. If the flame is made even more intense, complicated structure and motion characteristic of 'turbulence' appear. That time does not come to a standstill in this state is quite clear. The flow of water is constantly changing, and the structure produced by the flow also continues to change. In other words, the time which appears to stop in closed systems clearly continues to flow in open systems.

It should be obvious that the generation of structure exhibited by this open system corresponds to the generation of money in the model discussed in this paper. In our model, the system is open with respect to production and consumption. In this system in which the desire to engage in exchange is repeatedly reignited, the structure known as money is created. Here, the money we observed assumes a very simple, very primitive form, but if the reappearance of the desire to exchange occurred at a faster rate, a more complicated, more dynamic 'money' structure corresponding to turbulence would perhaps appear. I believe that the formation of the complex and dynamic finance system accompanying the development of capitalistic society can possibly be understood in correspondence with turbulence.

The change undergone by the water-in-beaker system is not very complicated. The only variable parameter is the strength of the flame, and if we fix this, the motion and structure appearing in the system are determined. If the system at some time reaches an attractor in the phase space describing its structure and motion, it will never escape. In the situation in which a weak flame maintains a constant temperature difference, this attractor is a point, in the case of convection it is a periodic solution, and in the case of turbulence it is a chaotic attractor. If we interpret the state in which the system has entered an attractor as 'motionless,' ignoring the motion within each attractor, we can think of time as stopping in such an open system as well.

4.3 Historical Time—Living Systems

If we are interested in a higher stratum of ceaseless time, we must consider life. Life possesses two peculiar functions not found in the water and beaker system or other such simple systems. One of these functions is that of birth and death. The second characteristic function is that of evolution, learning and adaptation. This corresponds to the situation in which the water molecules in the beaker suddenly, by their own power, changed their properties. If something like this actually happened, it would not be at all surprising if the molecules suddenly changed into some unstable form and the whole system exploded. With living systems, of course this is not unusual. For example, let us think about human children. A child, which at the time he or she is born is capable of doing almost nothing, soon begins to walk and use words, and almost before anyone notices, becomes an adult, sometimes committing crimes and denouncing their parents, and sometimes going into the world and making their parents proud.

In a world occupied by living creatures possessing these kinds of faculties, an historical time is observed. Here nothing stops. Time in a myriad of forms continuously flows everywhere at every imaginable speed. This kind of time can be thought of as arising from the special type of contradiction possessed only by systems of living creatures. This contradiction appears between the level of the individual and the upper realm of the whole. For example, let us think about the relationship between a many-celled organism and the cells which make it up. The reason that many-celled organisms appeared and thrive on this Earth is because the strategy of multi-cells has many advantages over that of single-cells. However, it is not necessarily the case that the interest of an individual organism and its cells always exist in accord. An example is the phenomenon of apotosis, in which cells within an individual at the time that this individual is developing (for example a human fetus) essentially commit suicide in mass. For example, we have five nicely separated fingers on each hand. But this is a result of the fact that the cells existing between fingers committed suicide at the time they are formed. Thus the life of the individual is formed and maintained at times aided by the death of its cells. The opposite phenomenon is perhaps cancer. Suppose that radiation or some other energy form impinges upon a cell, striking a gene and knocking out one nucleic acid molecule. If the cell were left that way, it would die. For the organism, to have this one cell die quietly would be the best outcome. However, instead, the cell will sometimes grab some other nucleic acid molecule lying in the vicinity, and with this fixes the gene. With this haphazard method of repair, the cell itself can continue living, but if the gene is repaired in some strange manner, the gene will take on a fiendish nature, and the cell can become cancerous. There is similar phenomenon exhibited when a piece of the liver or some other organ is removed. For the organism, even without a piece of its liver, it can go on living, but the liver will attempt to repair this lost piece. In the process, it can happen that cancer cells are created. The relationship between the individual and the cell is always characterized by this kind of tension. (Murase [5])

The relationship between an ecosystem and its elemental species has a similar feature. The ecosystem is composed of its elemental species, and at the same time, it is their environment. Living organisms adjust to the environment composed of themselves and other living organisms through learning and evolution. Such adjustment constitutes a change in the elements composing the ecosystem and can cause a transformation of its structure. If such a transformation occurs each species is compelled to repeat its efforts to adjust to the environment, and these efforts again can cause a transformation of the ecosystem. This kind of uroboros circularity can continue forever. Here we have a non-stopping, historical time.

One of the characteristics of living organisms fundamentally responsible for this kind of uroboros circularity is that the speed with which living organisms adapt is finite. In addition, the speed with which ecological systems react upon organisms is also finite. For this reason, even in the best case that the relationship between an ecological system and the organisms inhabiting it is mutually beneficial, there is no

guarantee that this state is stable. Therefore the adaptation made by an individual can at times be detrimental to the ecological system as a whole. For example, if there appears in an ecological system a species which somehow one-sidedly exploits all the other species present, the number of individuals of this exploiting species will rapidly increase, while the number of individuals of all other species will rapidly decrease. In this way, the objects of exploitation for the exploiting species itself will be lost, and it too will become extinct. It is thought that this kind of catastrophe has repeatedly appeared on Earth, and it appears at present that we human beings are playing the role of the universal exploiter.

If we turn our attention to human society, this relationship characterized by both harmony and contradiction can be seen more clearly. We cannot exist as individuals. We are born, we grow up, and we function within society. However, it is usually the case that society and the individual are at odds. Sometimes there are individuals in the society who make great efforts to solve these problems. Usually these efforts end in failure, but occasionally a new way of living or a new method of production or a new way to form organizations is discovered, and something greatly successful is obtained. These successes in general bring with them change and progress to society, but sometimes they bring about its destruction. The time that ticks away due to these processes is the conventional historical time. The reason I refer to the time corresponding to living systems as 'historical time' is to expand the use of this term to the case of human societies.

The field in which the ceaseless flow of this historical time is studied is a new branch of mathematical science called 'complex systems.' According to the latest research in this field, there are presently two clues to the understanding of this time. One of these is the structure know as 'chaotic itinerancy.' This is observed in, for example, chaotic systems of coupled 1-dimensional maps which themselves each display chaos. In this chaotic system, each of the individual oscillators exhibits chaotic disorder, and there is the tendency for them to each behave independently. However, because they are coupled, there is also a force working to make them behave coherently. With the competition between these two tendencies, if the system converges, the motion eventually comes to settle down in an attractor. However, in certain parameter regimes, the regions in which the force attempting to cause the individual oscillators to behave incoherently is strongest and the regions in which the force attempting to cause them to behave coherently become intertwined, and as a result, the system will display behavior in which it spends a considerable length of time in the neighborhood of some 'attractor', but then eventually breaks off and after some time displays incoherent motion. Then the process is repeated as the system again approaches and remains for some time in the neighborhood of some different 'attractor' (see, for example, Kaneko and Ikegami [2]).

The second clue alluded to above is provided by the dynamics of spontaneous emergence and spontaneous collapse like those displayed by the system discussed in Section 3. Here, some commodity is chosen as money, but eventually, due to the change in behavior of the individuals in the system, this money collapses, and there

is a return to exchange and barter. Then after some time, a new form of money appears, and the process starts again. This type of behavior is brought on by the mechanism by which the existence of money leads to the favoring of a strategy which destroys it, while the non-existence of money leads to the favoring of a strategy which creates it. I believe that perhaps the behavior seen here, in which money spontaneously emerges and collapses, is generally observed when the system in question possesses a mechanism whereby at the time that the modes of behavior of the individuals become coherent, due to the discontinuous formation of some high level structure, the environment in which the individuals exist undergoes a large change.

These phenomena of chaotic itinerancy and spontaneous emergence and collapse dynamics express the idea that even when cohering structure appears between all of the individuals, the binding strength of this field is not absolute, but rather there is the possibility of tiny fissures. In certain contexts, these fissures allow for the evolution of life and the development of society, but at the same time, they allow for the destruction of life and the collapse of society. If we call the time during which a particular structure is maintained an 'era,' when a new structure appears, a new era begins, and when this structure collapses, the era ends. Due to the repetition of this phenomenon, eras pass from one to the next, and historical time ticks away.

4.4 Language and Money

I would like to bring this paper to a conclusion by considering the theme of this symposium, language. It goes without saying that I am not a linguist, and I have almost no knowledge of the expanding research in this field. The following consists of nothing more than impressions on how language may be seen in the light of the discussion given with regard to the concept of money.

I would first like to make note of two differences between language and money. One of these differences is that language is much more complex than money. In the first place, in the case of money, there is significance in its simplicity, but with language its variety is what is important.

The following Zen anecdote comes to mind as something analogous to money within language.

> At the time that the chief priest of a certain temple was troubled because he couldn't seem to reach the state of spiritual enlightenment, a traveling monk came to visit. The priest confided his worries to this monk, realizing that he was the incarnation of a great bodhisattva. Upon hearing about the priest's woes, the traveling monk slowly raised his index finger. The moment the priest saw this, he became enlightened.
>
> From that time, when studying monks would come to the priest, he would answer them by only slowly raising his index finger. One day, a

> young monk of that temple was asked by a person, "What kind of sermons does the priest give?" In response, the young monk, without a word, slowly raised his index finger, imitating the priest. Upon learning of this, the priest without warning pulled a sword and cut off this young monk's index finger. The shocked monk ran wailing into the garden. The priest then called for the monk to stop, and the monk turned back to see the priest slowly raising his index finger. At that instant, the young monk became enlightened.

Money is like the almighty index finger in this anecdote. However, this index finger is very different from conventional language. People other than Zen monks are unable to exchange information of any content with the simple raising of the index finger. It is necessary for language to describe the world through a system of many words. But among these words there are rules of grammar and usage. It is probably possible to understand these rules of grammar and usage as constituting a structure of a higher level than the words. If this is the case, then language possesses a structure like that of money on a level one rank higher[9].

The second major difference between money and language is the difficulty in separating the medium of exchange and that being exchanged in the latter case. In the case of money, that which is being exchanged is a commodity or a service, in some sense, 'packaged information.' It is thus easy to separate that being exchanged and that serving as the medium of exchange in this case. Language, however, is the framework through which human beings extract information from the world, and the question of what constitutes information and what constitutes language is quite difficult[10].

Despite these differences, language and money have several common points. First both appear as forms of structure through some self-catalyzing effect in open systems. In the case of money this self-catalyzing effect arises from the fact that if a person does not use this, they cannot engage in the exchange of commodities. In the case of language, if a person does not use that in existence, they cannot exchange ideas. Then, the components making up the structure of money are the arrows which individuals repeatedly define. Similarly, the components of the structure of language are the voices and symbols repeatedly uttered and written by individuals. The arrows constituting the components of money do not appear randomly, but rather they are organized in such a way as to point at the commodity which stands at the center of this structure. Subject to the same kind of organizing force, voices and symbols become language. Through this kind of mechanism, the repeatedly appearing and disappearing arrows form the structure of money. Then, just as the structure of money controls the generation of arrows, the continually produced words become the components forming the structure of language, and this language controls these individual words.

A further similarity between language and money is that they both have an inherent tendency toward change. The components supporting the structure of

money are not stable. They can collapse due to the adaptation in the behavior of individuals resulting from the premise of money's existence. In the same manner, through the use of new or mistaken words and usage, language is always changing, and in some cases, one language becomes two. If the fundamental cause of the change undergone by language is the desire of individuals, under the premise of the existence of language, to find new, more suitable or more convenient expressions, then this cause can be considered to be adaptive behavior. If this is the case, then money and language belong to the same category, that characterized by a structure which is formed through a self-catalyzing effect out of components taking the form of acts performed by people in their interaction with people and which evolves and collapses due to the adaptations made by people under the premise of its existence. Of course, this kind of structure is created in a never ending time, and through the collapse and subsequent rebirth of this structure, historical time ticks away.

Notes

1) Sections 1 and 2 of this paper and Section 3 are the revised and supplemented versions of Yasutomi and Katsuragi [8] and Yasutomi [9], respectively.
2) The theory due to Marx that we treat in this paper is from the fourth edition of *Das Kapital*, published in 1890.
3) die Form ihrer unmittel-baren Austauschbarkeit
4) seine Eigen-schaft unmittelbarer Austauschbarkeit
5) The finiteness inherent in the right of option is important in understanding the difference in value between the currencies of developed and developing countries (see Yasutomi [11] and [12]).
6) Menger quotes translated from German by Klaus Lindemann.
7) See, for example, Uzawa [6]
8) It is well-known that Menger used this type of non-equilibrium state as a subject of discussion, but it is a relatively unknown fact that Walras, who can be considered the originator of general equilibrium theory, touched upon the same type of world. Walras introduced the idea of a 'continuous market' and treated non-equilibrium processes as follows:

> Finally, in order to come still more closely to reality, we must drop the hypothesis of an annual market period and adopt in its place the hypothesis of a continuous market. Thus, we pass from the static to the dynamic state. For this purpose, we shall now suppose that the annual production and consumption, which we had hitherto represented as a constant magnitude for every moment of the year under consideration, change from instant to instant along with the basic data of the problem... Such is the continuous market, which is perpetually tending towards equilibrium without ever actually attaining it, because the market has no other way of approaching equilibrium except by groping, and, before the goal is reached, it has to renew its efforts and start over again, all the basic data of the problem, e.g. the initial quantities possessed, the utilities of goods and services, the technical coefficients, the excess of income over consumption, the working capital requirements, etc., having changed in the meantime. (Walras [7], p. 398)

The description given here by Walras of a continuous market is essentially the same as

that given of an open system in this paper.

9) There is a computer simulation regarding the evolution of grammar. (Hashimoto and Ikegami [1])

10) These two differences, however are not as clear as they may seem. In the model used in this paper, money takes the form of a single entity composing a simple structure, but the money seen in modern capitalistic society is diverse and complex. Moreover, different types of money themselves are now treated as commodities and have become the object of transactions. To go one step further, it can be said that money even has the ability to control our fundamental way of thinking.

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