THE APPEARANCE OF CARRIERS AND THE ORIGINS OF MONEY

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Abstract

The main goal of this essay is to provide microfoundations in a spatial general equilibrium framework for the fact that individuals use money to make transactions, and hence microfoundations for the cash in advance constraint. We analyze the emergence of a monetary economy out of a redistribution barter system where goods are sent to a central market and then redistributed among individuals. We show that, as the population increases beyond a certain point, the barter exchange system becomes too expensive. To reduce the exchange system cost, and as a result of individuals' rational behavior, a new specialized merchant, the carrier, appears and causes frictions among traders leading to the appearance of money. There are, however, certain conditions for this process to succeed. These conditions concern the economic characteristics of those goods chosen to act as money, and the level of economic development.

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THE APPEARANCE OF CARRIERS AND THE ORIGINS OF MONEY

Jose Noguera S., CERGE-EI

Socrates:	A city is a response to human needs. No human being is self-sufficient and all of us have many wants… The origin of every real city is human necessity… The first and greatest necessity is food… Next a place to live; third, clothing and the like… Then we must ask how our city will provide these things. A farmer will be needed, and a builder and a weaver as well… Then how should they proceed? … Should he produce food for his own needs alone devoting only a fourth of his total effort to that kind of work? Then he could allot the other three-fourth of his time to building a house, making clothes, and cobbling shoes. Choosing the latter, he wouldn't have to bother about associating with others; he could supply his own wants and be his own man.
Adeimantus:	I don't think he should try to do everything. He should concentrate on producing food.
Socrates:	I agree that this would probably be the better way… We can conclude, then, that production in our city will be more abundant and the products more easily produced and of better quality if each does the work nature has equipped him to do, at the appropriate time, and is not required to spend time on other occupations… Then there will be a market place and money as a medium of exchange… Supposing the farmer or other craftsman brings his produce to market but does not arrive at the same time as those who would buy from him. Would he sit idly in the market place, wasting time he could otherwise devote to productive work?
Adeimantus:	Not at all. There will be men at the market who will offer their services to remedy the situation by acting as salesmen…
Socrates:	So the need for money in the exchange of goods produces the class we know as tradesmen.

Plato, The Republic, Book II (369-371)

I. INTRODUCTION

People gather to overcome difficulties. Among these difficulties are people's needs to protect themselves from their enemies or the hazards of nature. People also gather to help each other to build a better life together. One way to attain this goal is by joining efforts to obtain the goods needed to survive. These ideas were present in Socrates' mind when he said that "the origin of every real city is human necessity." This conclusion also follows from Anas' (1992) and, Berliant and Konishi (2000)'s papers on the economics of city emergence.

The next step in this argument is that, once men decided to live in cities, they realized that they could better satisfy their needs if they specialized, and the idea of the division of labor was also in Socrates and Adeimantus' dialog. It is interesting to notice that according to Socrates, as well as Plato, Aristotle, and likely many other Greek philosophers before them, specialization does not cause an increase in efficiency per se, but is a result of allowing everyone to specialize in what each finds more suitable, as emphasized in Schumpeter (1954, pg. 56). The reasoning continues by arguing that specialization brings the need of exchange, and difficulties in exchange are overcome by money.

The influence of these ideas survived in Smith (1776) in his chapters on the division of labor and the origin of money. As the Greek philosophers did more than two thousand years ago, Smith (1776) argues that difficulties in exchange came from the lack of a double coincidence of wants, and that money appeared to resolve these frictions. A century later, Jevons (1875) again strongly emphasizes this idea. Menger (1892) stresses the use of money as a medium of exchange. He also points out three other important features. The first is that people accept money as long as others do as well. The second is that the appearance of money was an evolutionary process involving a learning process through several generations, and the third one is that this evolutionary process was the result of individuals' attempts to maximize their utilities.

For many years, after this literature, no important essay on the origins of money was written based on the "absence of a double coincidence of wants" idea, until Jones (1976) developed a model based on Menger's ideas. Assuming the existence of a specialized economy, Jones' model states that each individual produces only one good and wants to consume a bundle of goods. To obtain this bundle, the individual "randomly searches" for one other individual wanting to exchange the good that he produces for the bundle that he needs. *Random matching* is the key assumption used by Jones (1976) to generate money based on the idea of the absence of a double coincidence of wants. Kiyotaki and Wright (1989) sets up a random matching model in which several objects are potential mediums of exchange, but only one of them, based on its physical properties, is ultimately chosen for that role. More recently, Wallace (1997) presented a random matching model explaining the coexistence of money with higher return assets, and the short run real effects of a change in the quantity of money.

Although this logically well-structured theory, based on the random matching assumption, is able to explain many facts about monetary economies, it misses a couple of ideas already present in Socrates and Adeimantus' dialogue. The first is the existence of a city where people gather and exchange the goods they need. The other is the presence of middlemen to resolve frictions caused by the lack of a double coincidence of wants. If each individual produces only one good, then nobody but a middleman has a bundle of goods. However, people usually know who and where the middleman is, so if someone needs to barter, he simply needs to visit the middleman. In that case, there is no random matching. Noguera (2000) sets up a spatial general equilibrium model to analyze the evolution of barter economies, and shows some circumstances under which a barter economy with a double coincidence of wants problem evolves to a more sophisticated barter system in which the appearance of central merchants overcome the frictions created by the specialization process.

Historians and anthropologists have found many elements supporting the importance of these two factors in the genesis of money. For example, Renfrew and Bahn (1996, pg. 351–353) argue that once the economy reaches a minimum level of technical progress, the division of labor and barter intensifies together in a system in which commodities travel "Down-the-

Line”. At the beginning, there is no middleman and no money and individuals meet randomly. But when individuals learn how to locate each other, a more systematic barter starts. This barter economy begins, first, as a reciprocity system in the way of exchanges of gifts among people well known to each other in well-defined contexts. Over time, a redistribution system with centralized and traveling merchants or peddlers emerges. Frequently, goods are sent to a market center and then redistributed. Individuals produce one or a few goods but consume many. In the redistribution system, exchange operates better than in an unstructured barter, overcoming the absence of the double coincidence of wants problem. In all likelihood money appears under this system. This view has been widely accepted by anthropologists after Polanyi’s (1957) “The Economy as Instituted Process” article. It is also supported by Einzig (1966)’s famous book on primitive money. In fact, as Laidler (1997, pg. 1920) asserts: “The basic insight about the role of mutually consistent beliefs in supporting monetary exchange yielded by models like that of Kiyotaki and Wright is therefore important, even though such models seem incapable of getting the grips with the historical emergence of money.”

An important point that remains to be ascertained about the genesis of money is the circumstance under which money arose out of a redistribution system. Hicks (1989) suggests that people made credit arrangements facilitated by a unit of account and that this unit of account eventually emerged as a medium of exchange. On the other hand, Clower (1995) asserts that, as an economy grew, merchants obtained benefits by becoming specialized traders, causing frictions among individuals that were resolved with the use of a medium of exchange. Nevertheless, neither author says anything about the object that became money, the circumstances that made it possible for this object to appear, or the conditions under which a monetary economy dominates a barter economy.

The main goal of this essay is to provide microfoundations for the fact that individuals use money to make transactions, and hence microfoundations for the cash in advance constraint. We use a spatial general equilibrium framework to analyze the emergence of a monetary economy out of a redistribution barter system in which goods are sent to a central market and then redistributed among individuals. We show that, as the population increases beyond to a certain point, the barter exchange system becomes too expensive. To reduce the exchange system cost, and as a result of individuals' rational behavior, a new specialized merchant, the carrier, appears and causes frictions among traders, leading to the appearance of money. There are, however, certain conditions for this process to succeed. These conditions concern the economic characteristics of those goods chosen to act as money, and the level of economic development.

We set up a spatial general equilibrium model in which goods differ in their perishability rate and transportation cost. It will be shown that, under some circumstances, goods with the lowest transportation cost arise endogenously as money. This will be a consequence of the relationship between their physical properties and individuals' optimization behavior. Jevons (1875, pg. 31) gives a long list of the properties of those objects used as money. We assume here that each good is homogeneous, cognizable and divisible. The other properties given by Jevons are described by two variables: transportation cost and perishability rate. Portability is measured by transportation costs, stability of value and indestructibility by perishability, and non-monetary utility by the importance of goods in the utility function. The only reason to assume that all goods are equally homogeneous, cognizable and divisible but may differ in their portability, stability of value, indestructibility, and utility, is that the former characteristics are concerned mainly with physical properties, and the latter ones have an economic meaning.

The environment assumed here is a city in which specialized producers trade to acquire goods for consumption. There is a production technology and exchange is costly. Individuals do not trust each other and act in their own interest to maximize their utilities. Each individual produces only one good that he wants to exchange for many others. Townsend (1989) also sets up a model with "spatially separated agents". In his models, however, there are no spatial costs like transportation or storage costs, and money is exogenously determined.

In Section II, we set up a spatial general equilibrium model to analyze barter redistribution economies and use it as a framework to analyze barter redistribution economies. In this spatial model, exchange is done through centralized merchants. Goods are sent to a central market and then redistributed among individuals wanting to consume the most goods available. As emphasized by Ostroy and Starr (1990), to trade successfully, individuals pay transaction costs, which include transportation, meeting, and search costs. Goods perish at some specific rate and trade is still made through barter.

In Section III, we determine the conditions under which an object emerges as a medium of exchange. We prove that, as the scope of the economy grows and under certain technological conditions, it is profitable for some individuals to become carriers. This new specialist and the absence of trust cause frictions among individuals that are solved by bringing money about. It also causes the economy to grow beyond the limitations of a barter economy. It is noteworthy that money appears as a consequence of individuals' optimization decisions and that individuals decide which object will be used as money.

In Section IV, we set up a monetary general equilibrium model in which carriers allow producers to save transportation cost and increase their production. In Section V, we analyze the conditions under which this monetary economy dominates over the barter economy with merchants. We prove that the emergence of money contributes to growth by lowering transaction costs and inducing the creation of new goods. Also, an economy with a more diverse set of goods creates conditions in which money becomes more desirable from a social point of view. Finally, we conclude in Section VI.

II. THE BARTER ECONOMY WITH MERCHANTS

Assumptions of the Model

Consider a "long narrow city" on an interval [-g, g], so the city size is 2g. There is a continuum of individuals of Lebesgue measure N living in that city that specialize in either production or exchange activities. Assume that every individual is endowed with one unit of time, and that there is a Central Business District (CBD) located at the center of the city, where individuals physically meet for barter purposes.

Producers specialize in producing only one good at their locations that can be totally different or simply differentiated from all others. Merchants produce nothing but devote their whole time availability to facilitating exchanges.

Assume that there are F merchants located inside the CBD. Producer i is located at a distance $|i|$ away from the CBD. He can be identified by his location in the city, and hence, by the good that they produce. Therefore, there are 2g individuals, and

$$N = 2g + F. \tag{1}$$

Merchants are *busy and centralized*. A centralized merchant means that the merchant receives the producer's production and exchanges it for all other consumption goods, that is, the merchant receives the only good that the producer offers and gives him a "basket" of the 2g goods existing in the economy.

A busy merchant means that the merchant spends his whole time with two kinds of exchange activities. The first activity is to exchange with producers. After a producer drops the goods off at a warehouse, the merchant has to do inventory, etc. Let η be this amount of time. The second kind of activity is the time that every merchant spends dealing with other merchants.

Since there are F centralized merchants that exchange all consumption goods for only one good with the producer, each merchant obtains directly from the producer, at most, $2g/F$ goods. To acquire all other goods that he needs to exchange with the producer, the merchant must deal with other merchants to purvey their storage. Assume that in doing this, he must meet every other merchant, and let φ be the average amount of time that a merchant spends looking for and meeting all other merchants. Hence, all merchants' time availability is $2g\,\eta + F\,\varphi$. On the other hand, since every merchant is endowed with one unit of time, all merchants together have F units of time available. Therefore,

$$F = 2g\,\eta + F\,\varphi. \tag{2}$$

Let $C^i(j)$ be the individual i's consumption of good j, and assume that individual i (located at i) has a preference set represented by the following utility function:

$$U^i(C^i(j)) = \int_{-g}^{g} Log\left(C^i(j)\right)dj \tag{3}$$

where $\int$ is the Lebesgue integral operator. In consequence, every individual wants to consume some of every good j, but not the entire production of j. Therefore, the coincidence of wants is *incomplete* and i must trade the rest of his production with other individuals until he acquires all the goods that he needs.

Suppose also that every good produced belongs to one of the following sets

$\Lambda = \{x \in [-g, g]$ such that it has a perishability rate δ_0 and a transportation cost $\tau\}$ or

$\Phi = \{x \in [-g, g]$ such that it has a perishability rate δ_1 and a transportation cost $\tau_1 = 0\}$.

The transportation cost τ is defined in units of time per unit of distance. Notice also that the set $\{\Lambda, \Phi\}$ is a partition of the interval $[-g, g]$. Assume also that the set Φ is of measure zero. We interpret this in the following way: goods in the set Φ constitute a group small enough so that its size is insignificant in comparison with the whole economy. The aggregate production and the quantity of goods in the set Φ, however, are not zero.

Assume that every producer has the following production function $q = AL$, where q is production, L is the amount of labor measured in units of time, and A is a constant representing the production technology. Every individual i is endowed with a fixed amount of time available for production and exchange activities which we normalize to one.

The producer located at i works L_i hours to produce q_i. At the end of the period, he transports the merchandise to the CBD. Since the distance from location i to the CBD is its absolute value, it results the following constraint:

$$L_i + \tau_i \mid i \mid = 1.$$

When the producer arrives at the CBD he finds his merchandize perished at a rate δ_i. Then, he barters the remaining merchandise with a merchant in exchange for consumption goods. Assume, for simplicity, that the time spent by the producer exchanging with the merchant is insignificant, so we set it to zero.

Producer i sells his whole production to the merchant for a price P_i, and buys the consumption goods he needs for a price ξP_i, where ξ is the merchant's markup. Hence, his problem is to maximize the utility function (3) subject to the following budget constraints:

$$(1 - \delta_i) P_i \mathrm{A_i}(1 - \tau_i \mid i \mid) = \int_{[-g,g]} \xi P_j C^i(j) dj . \tag{4}$$

On the other hand, assume that the F merchants are identical. They buy an amount $(1 - \delta_i)\, q_i$ from producer i for a price P_i, and sell it for a markup ξP_i. Assume also that every merchant sets his own markup and knows the markup set by all other merchants. Assuming a competitive equilibrium, all merchants will set the same markup, and therefore, all merchants will have the same profits, so we can obtain every individual merchant's profit by finding the average merchant profits.

Notice that, from every good j, merchants obtain a net profit equal to $(\xi - 1)(1 - \delta_j)P_j q_j$ that they spend buying their own consumption goods. Hence, merchant f 's problem is to maximize the utility function (3) subject to the budget constraint

$$\frac{(\xi - 1)}{F} \int_{[-g,g]} (1-\delta_j) P_j q_j \, dj = \int_{I_f} \xi P_j C^f(j) \, dj \,. \qquad (5)$$

Finally, assume that individuals do not incur any cost to transport himself or the consumption goods back home.

Equilibrium

Definition: Consider a long narrow city of size $2g$, with N individuals, the preference order implied by (1), a parameter set $\{\delta_0, \delta_1, \tau, \eta, \varphi, A\}$, and a production function $q_i = A_i L_i$. We define an equilibrium in this *Barter Economy with Merchants* (*BEM*) as the set $\{C^i(j), C^f(j), L_i, P_i, \xi, 2g, F\}$ for $i, j \in [-g, g], f \in [0, F]$ such that the following conditions hold:

1) Every producer maximizes (3) subject to constraints (4).
2) Every merchant maximizes (3) subject to constraint (5).
3) Good i's production offered for barter in every period t equals the aggregate consumption for this good during this period. That is,

$$\int_{-g}^{g} C^i(k)\,di + \int_{0}^{F} C^f(k)\,df = (1-\delta_0)q_k = (1-\delta_0)(1-\tau|k|)A \qquad \text{for all } k \in \Lambda$$

and

$$\int_{-g}^{g} C^i(k)\,di + \int_{0}^{F} C^f(k)\,df = (1-\delta_1)A \qquad \text{for all } k \in \Phi.$$

4) Every individual chooses the occupation that is most convenient for him, that is, individuals choose between being merchants or producers.
5) Producers and merchants are busy, that is, they spend their whole time availability producing and exchanging goods.

Equilibrium condition (3) allows us to find producers' equilibrium prices, and equilibrium condition (4) to find the equilibrium markups. Finally, the equilibrium condition (5) allow us to determine the number of merchants and producers, so these two variables become endogenous.

Theorem 1: In a BEM, the equilibrium number of producers and merchants are

$$2g = \left(\frac{1-\varphi}{1-\varphi+\eta}\right)N \qquad \text{and} \qquad F = \left(\frac{\eta}{1-\varphi+\eta}\right)N .$$

Proof: Comes directly from solving $2g$ and F in (1) and (2).

From Theorem 1 it follows that the equilibrium number of merchants decreases if merchants spend less time either bartering with producers or among them, that is, if the exchange technology employed by the merchant improves.

Theorem 2: In equilibrium, the BEM has the following equilibrium prices, markup and consumption functions:

$$P_k = 1 \qquad \text{if } k \in \Phi, \tag{6a}$$

$$P_k = \frac{1-\delta_1}{1-\delta_0}\frac{1}{1-\tau|k|} \qquad \text{if } k \in \Lambda, \tag{6b}$$

$$\frac{F}{G} = \xi - 1 \qquad \text{or} \qquad \xi = 1 + \frac{\eta}{1-\varphi}, \tag{6c}$$

$$C^i(k) = (1-\delta_0)(1-\tau|k|)\frac{A}{N} \qquad \text{for } k \in \Lambda \text{ and } i \in [0, N], \text{ and} \tag{6d}$$

$$C^i(k) = (1-\delta_1)\frac{A}{N} \qquad \text{for } k \in \Phi \text{ and } i \in [0, N]. \tag{6e}$$

Proof: From the producer and the merchant's maximization problems, we find the following demand functions for any goods $j, k \in [-g, g]$:

$$C^i(k) = \frac{(1-\delta_0)(1-\tau|i|)AP_i}{2g\xi P_k} \qquad \text{if } i \in \Lambda, \tag{7a}$$

$$C^i(k) = \frac{(1-\delta_1)AP_i}{2g\xi P_k} \qquad \text{if } i \in \Phi, \quad \text{and} \tag{7b}$$

$$C^f(k) = \frac{(\xi-1)(1-\delta_0)A}{2g\xi FP_k}\int_\Lambda (1-\tau|i|)P_i dj \qquad \text{if } f \in [0, F], \tag{7c}$$

and that

$$P_j\, C^i(j) = P_k\, C^i(k) \qquad \text{for} \qquad i, j, k \in [-g, g]. \tag{7d}$$

Let's first find the producers' equilibrium prices. Assume first that $k \in \Phi$. From equilibrium condition (3) we have that

$$\int_\Lambda \frac{(1-\delta_0)(H-\tau|j|)AP_j}{2g\xi P_k} dj + \int_{[0,F]} \left(\frac{(\xi-1)(1-\delta_0)A}{2g\xi FP_k} \int_\Lambda (H-\tau|j|)P_j dj \right) df$$

$$= (1 - \delta_1)\, AH \qquad \Rightarrow$$

$$P_k = \frac{1-\delta_0}{1-\delta_1}\frac{1}{2gH}\int_\Lambda (H-\tau|j|)P_j dj\,.$$

Since P_k does not depend on location k if $k \in \Phi$, and all are identical, we can choose goods in Φ as numeraire so that $P_k = 1$ if $k \in \Phi$ and (6a) follows. Using this and (7d), we divide (7a) by (7b), to find (6b). On the other hand, from equilibrium condition (4) producers may become merchants if merchants' utility is higher and vice-versa. Thus, in equilibrium, the utility level for all individuals must be equal. A sufficient condition for this is that $C^i(k) = C^f(k)$ for every $k \in \Lambda$. Then (6c) follows functions (7a, b, c) and Theorem 1. Finally, substituting (6a, b, c) into (7a, b, c) we obtain individual consumption functions (7d) and (7e).

Q.E.D

Equation (6c) shows that the equilibrium markup is one plus the ratio between the time spent by the merchant for meeting one producer and his total time availability to meet with producers. This ratio is the profit obtained by the merchant for facilitating the exchange of one unit of production. Notice that the equilibrium markup decreases as the merchant's technology for transactions improves, that is, as φ or η decreases.

Observe that all individuals consume the same quantity of a particular good $k \in \Lambda$ and the same quantity of all goods $k \in \Phi$. This means that the total production of every good available for consumption is distributed equally among the whole population, and does not depend on the merchant's cost.

Welfare Analysis

In equilibrium, the utility level is the same for all individuals. Hence, if we consider any welfare function in which all individuals are treated equally, and social welfare is an increasing function of any one individual's utility, then a welfare optimum is reached by maximizing the equilibrium utility level. Therefore, we define the social welfare function as:

$$W(g) = \int_{-g}^{g} \log\left(C(j)\right) dj \,. \tag{8}$$

Let's denote $\alpha = (1 - \varphi)/(1 - \varphi + \eta)$, then $2g = \alpha N$. Hence, using this and Theorem 2, we can rewrite the welfare function for the BEM as

$$W_{BEM}(n) = \frac{[2 - \tau\alpha N]\{1 - Log[\alpha a_0 (1 - \alpha\tau N/2)]\} - 2 + 2 Log \alpha a_0}{\tau} - \alpha N Log(\alpha N)\,, \tag{8'}$$

where $a_0 = (1 - \delta_0)A$ is a technological parameter. Notice that individuals' welfare increases as the exchange technology that the merchant uses improves, so φ and η decrease. It also increases as the transportation cost decreases. This means that there is a strong relationship between transaction costs and individuals' welfare.

Theorem 3: In a BEM, the population is bounded by $2/\alpha\tau$, and the scope of the economy by $2/\tau$.

Proof: From the welfare function, we can directly check that the welfare function is defined only for N less than $1/\alpha\tau$, and considering that $2g = \alpha N$, the scope of the economy is bounded by $2/\tau$.

Q.E.D.

From Theorem 3 follows that the number of goods cannot grow to more than $2/\tau$, and population to more than $2/\alpha\tau$. The reason is that, if the number of goods grows beyond that point, transportation costs would not allow enough time for the production of those goods at their distant locations.

Theorem 4: In the BEM, W_f tends to zero as N tends to zero, it tends to a positive number as N tends to $1/\tau$, and the welfare function is a concave function of N, that has a maximum at

$$0 < N^{**} = \frac{a_0}{2e + \alpha a_0} < \frac{1}{\tau}. \tag{9}$$

Proof: Taking the limits as N tends to zero, and as it tends to $1/\tau$, we can easily check that W_f tends to zero, and to $(Log(\alpha\, a_0) - 1)$, which is positive if the technology parameter a_0 is high enough. Taking the derivative of the welfare function with respect to N and rearranging terms, we obtain

$$\tau W_{BEM}'(N) = -\tau + \tau Log \frac{a_0(1 - \alpha\tau N)}{2N}.$$

N^{**} follows from solving the equation $W_{BEM}(N) = 0$. Finally, note that $N^{**} < 1 < 1/\tau$.

Q.E.D.

Using the information provided by theorems 3 and 4, the welfare function can be drawn as shown in Figure 1.

FIGURE 1 COMES HERE

It is noteworthy to make several comments about the barter economy with merchants. First, note that centralized merchants allow overcoming the absence of a double coincidence of wants problem without the need to evolve into a monetary economy.

Second, since the producer does not need to spend time looking for other producers for bartering, he devotes more time to producing. On the other hand, they must give up a share of their production to the merchant who facilitates exchange activities.

Third, both producers and merchants consume the same amount of a good. This is a consequence of the utility function, in which all consumption goods have the same weight, and the assumption that every individual chooses the most convenient occupation.

Fourth, notice that goods in Φ are chosen as numeraire since all of them have the same price. Notice also that prices in the set Λ reflect only the transportation cost (τ) and the markup (ξ) reflects the exchange cost.

Fifth, the city size cannot grow to more than $2/\tau$ goods. The limitation comes because the transportation cost to the CBD makes it impossible to produce beyond a radius of $1/\tau$.

III. CARRIERS AND THE CONDITIONS FOR THE EMERGENCE OF MONEY

Suppose that there are economies of scale in transportation that allow lowering the unit cost of transportation from the place of production to the central merchant. A carrier, for example, can visit all producers in the same trip. This is an incentive for someone to become a carrier or "peddler merchant". If the producer can lower his transportation cost, he will specialize even more and have more time and resources available for production. In this way, he can increase his consumption and utility level. On the other hand, since he obtains benefits from lowering transportation costs, he is willing to pay a carrier a fee for transporting his production to the CBD. However, as Gale (1978) emphasizes, there is one inconvenience: the producer does not trust the carrier. Now, the carrier does not own the consumption goods that the producer needs.

Hence, in order for the carrier to acquire the producer's output he must give the producer "some other good" in exchange. Wang (1998) also uses a spatial framework to show that frictions among traders bring money about as the market decentralizes.

The carrier can pay the producer by using a good in the set Λ or a good in the set Φ. Suppose first that the producer produces a good in the set Λ, then he will not be willing to spend time exchanging his production for other goods with the same characteristics since he will face the same perishability rate and transportation costs. Nevertheless, he will accept in exchange a good in the set Φ as long as the profit of accepting this good is greater than that of his original production. Let $\pi_\Lambda{}^i$ be producer i's profit if he accepts payments in terms of a good in Λ, and $\pi_\Phi{}^i$ if he accepts payments in terms of a good in Φ. Then:

$$\pi_\Lambda{}^i = (1 - \delta_0)\,(1 - \tau\,|\,i\,|\,)\,AP_i \qquad \text{and} \qquad \pi_\Phi{}^i = (1 - \delta_1)\,AP_i.$$

The first equation is the value of producer i's profit of the Λ good, were he to decide not to deal with carriers, and the second equation, were he to decide to do it, both measured in units of Φ goods. In that case i will not have to travel and can produce more by placing more time into production. Then, the producer will accept the carrier's offer if $\pi_\Phi{}^i > \pi_\Lambda{}^i$, that is:

$$(1 - \delta_1) > (1 - \delta_0)\,(1 - \tau\,|\,i\,|\,). \tag{10}$$

Note that, because of the income effect, if the inequality (10) holds, the producer's utility is also higher were the producer to accept the carrier's offer. However, the producer now assumes a perishability cost for holding Φ goods. Suppose that goods in Φ are gold and silver, so $\delta_1 = 0$. At this point the reader may think that gold and silver have some transportation costs that we do not include here, but the important point is that these costs are very low, and I ignore them in this model, assuming that they are zero. Then, inequality (10) clearly holds and the producer will accept the carrier's offer. Note that even if $\delta_1 > 0$, there is room for a Φ good to become the medium of exchange as long as condition (10) holds. In fact, we find many examples of primitive economies using goods other than metals as mediums of exchange. Examples of these are the rice standard in the Philippines, feather money in Santa Cruz, coconuts in the Nicobars, grains in India, and barley in Babylon and Assyria. Many more examples are found in Einzig (1966).

Assume now that $\delta_0 = \delta_1$, then transportation cost is the determinant variable for the appearance of goods as mediums of exchange. The only requirement is that the good used as a medium of exchange be very light. In the rest of the essay, we are going to assume that the goods chosen as money are very durable metals as gold or silver so as their perishability rate is zero, that is, $\delta_0 = 0$. Therefore, if this monetary system dominates the barter economy with merchants, it would be optimal to use a medium of exchange to acquire consumption goods. This conclusion allows us to use the cash in advance constraint (CIA): individuals use money to buy goods. This constraint is frequently criticized because money is imposed and the constraint does not specify clearly the exact role of money (see for example Walsh (1998), pg. 118). In this model, however, we will see that money emerges endogenously as a consequence of individuals' maximization behavior.

Assume now that the producer deals with the carrier. Hence, the carrier will assume the transportation cost and own the merchandise that the central merchant needs. Assume also that the carrier transports the merchandise and sells it to the merchant at the beginning of the period. Then, the merchant must assume the perishability costs.

On the other hand, what happens with those producing the Φ goods? They have no interest in exchanging with a carrier and hence, they will keep bartering with the central merchant. On the other hand, producers of Φ goods are natural candidates to become intermediaries. Davies (1995) and Ederer (1964) give examples in which goldsmiths decided to specialize in lending and became bankers during the Middle Ages.

IV. THE MONETARY ECONOMY WITH CARRIERS

Assumptions of the Model

Assume that there is a monetary economy with carriers that behave in the following way: producer i sells his production to a carrier at a price P, so producers now can spend their whole time availability on production activities because they no longer need to engage in transport. Assume that the carrier buys the producers' output early within the period and transports the merchandise in such a way that the merchant assumes the perishability cost. The carrier sells to a central merchant the goods brought from location i for a markup γ, and incurs a unit transportation cost τ. This transportation cost reflects both time and operational costs. For simplicity, I will assume that both are equal. Finally, central merchants sell consumption goods to both producers and carriers for a markup ξ. As assumed before, individuals incur no cost of transporting themselves and bringing the consumption goods back to home. Notice that goods belonging to the set Φ are used mainly as mediums of exchange, so we can refer to them as money.

FIGURE 2 COMES HERE

In this economy, all individuals demand money to facilitate transactions. The flow of goods and money is shown in Figure 2. Notice that, unlike the merchant barter economy, in this *Monetary Economy with Carriers* all producers charge the same price because all of them have the same productive structure, use carriers and hence, incur no transportation cost. Each producer now has his whole time available for production. His production is now A units of good i, that he sells to the carrier at a price P. This means that he demands AP units of goods in Φ from the carrier in exchange for his production. That is, he demands AP units of money. Since there are $2g$ producers, then aggregate producers' demand for money is $2gAP$. Let Q denote the aggregate production of goods, then $Q = 2gA$ and producers demand PQ units of money from carriers in exchange for their production, to buy merchants' consumption goods. Let M^p denote producers' aggregate demand for money, that is Φ goods, then, since there is no capital accumulation, producers maximize their utility if they use all the money to buy as much consumption goods as they can. Hence,

$$M^{p} = P\xi\gamma\int_{-g}^{g} C^{p}(k)dk = PQ \tag{11}$$

where now the subscript "*p*" represents producers. The reason for this change in notation is that *i* represents a specific location and now all producers charge the same prices, regardless of their location.

Carriers demand γPQ units of money from merchants in exchange for producers' production and charge a fee γ. For their intermediary services, carriers obtain a monetary profit of (γ - 1) per unit of good sold to merchants that they use to buy merchants' consumption goods. Let M^{τ} denote carriers' aggregate demand for money then, as in the former case, carriers will buy as many consumption goods and sell as much merchandize as they can buy, so

$$M^{\tau} = PQ + P\xi\gamma\int_{-g}^{g} C^{\tau}(k)dk = \gamma PQ\,. \tag{12}$$

To pay the carrier, the merchant sells consumption goods to individuals. Notice that carriers and producers pay an amount of γPQ units of money in exchange for consumption goods. On the other hand, merchants buy themselves the consumption goods that they need, assume the perishability cost and charge a markup ξ. Let M^f denote merchants' aggregate demand for money, and we have

$$M^{f} = \gamma PQ + P\xi\gamma\int_{-g}^{g} C^{f}(k)dk = (1-\delta_0)\xi\gamma PQ\,. \tag{13}$$

To collect the merchandize, carriers make only one trip in which they go to every location of the city. Starting at the CBD located at the center of the city, carriers go until location g visiting every other location on the way and come back to the CBD with the merchandize. After that, they go until location $-g$ and do the same. In this way they have economies of scale in transportation cost. Hence, carriers spend their time traveling a distance equivalent to the city size, $2g$, to meet $2g$ producers. They also meet F merchants to sell the merchandise, so their time constraint is:

$$T = 2g\,\tau + (F + 2g)\eta. \tag{14}$$

The reader may think that a particular carrier only needs to visit those producers that will exchange with him or her, which is a number less than $2g$. However, for mathematical simplicity, we assume that they visit every producer. This assumption will not affect any important result.

Merchants also meet producers and carriers to sell them consumption goods. They also look for and meet other merchants to supply their own storage. Hence,

$$F = \eta\,(T + 2g) + \varphi\, F. \tag{15}$$

Observe also that equations (11), (12) and (13) represent budget constraints for producers, carriers and merchants respectively. This allows us to define equilibrium.

Equilibrium

Definition: Given a long narrow city of size G with N individuals, a utility function U^i, a parameter set $\{\delta_0, \delta_1, \tau, h$ and $A_i\}$, and a production function $q_i = A_i L_i$, equilibrium allocation in the *Monetary Economy with Carriers* (MEC) is given by the set $\{C^p(j), C^\tau(j), C^f(j), L_i, P, \gamma, \xi, G, F\}$ for $i, j \in [-g, g]$ and $f \in [0, F]$ such that the following conditions hold:

1) Every producer maximizes utility function (3) subject to constraint (11).
2) Every carrier maximizes utility function (3) subject to constraint (12).
3) Every merchant maximizes utility function (3) subject to constraint (13).

4) The good k market, for every $k \in \Lambda$, must be in equilibrium at every period t, that is, good k aggregate consumption equals good k production:

$$\int_{-g}^{g} C^p(k)di + \int_0^T C^\tau(k)di + \int_0^F C^f(k)df = (1-\delta_0)\frac{q_k}{2g}. \qquad (16)$$

5) The monetary market is in equilibrium, that is $M = M^d$, where M is the total amount of money or the production of goods in the set **Φ**.

6) Every individual chooses the occupation that is most convenient for him, that is, individuals choose between being merchants, carriers or producers. This implies that $U^p = U^\tau = U^f$.

7) Producers, carriers and merchants are busy, that is, they spend their whole time availability producing, transporting and exchanging goods.

Note that, in the monetary market equilibrium condition, I do not consider individuals' demand for consumption for those goods in the set **Φ**. The reason for this is that, by definition, this is a set of measure zero, so we can ignore it in the equilibrium conditions.

On the other hand, from equilibrium condition (6), in equilibrium, all individuals reach the same utility level. Hence $C^p(j) = C^\tau(j) = C^f(j)$, and the left hand of the general equilibrium condition (16) becomes

$$2g\, C^p(j) + T\, C^\tau(j) + F\, C^f(j) = (1 - \delta_0)q_k.$$

This means that the equilibrium condition 4, equation (16), is redundant since it is a consequence of the assumption that every individual chooses the occupation most convenient for him and the utility maximizing behavior of all individuals.

<u>Theorem 5</u>: The economy's GDP (Y) is

$$Y = [\gamma + (1 - \delta_0)(\xi - 1)]\, Q \qquad (17)$$

and the following quantitative equation holds:

$$M\,v = P_f\,Y, \qquad \text{where} \quad v = \frac{\gamma + (1-\delta_0)(\xi - 1)}{1 + \gamma + (1-\delta_0)\xi\gamma}\xi\gamma\,. \tag{18}$$

Proof: From (11), (12) and (13), notice that producers contribute to the aggregate production with Q, carriers with $(\gamma - 1)Q$ and merchants with $(1 - \delta_0)(\xi - 1)Q$, respectively. Adding these three terms we obtain (17).

Observe that the term $\xi\gamma P$ represents the consumer price index. Let's denote it by P_f. Adding (11), (12) and (13) we obtain the aggregate demand for money. If we denote the aggregate supply of money by M, then $M = M^p + M^\tau + M^f$ and we obtain (18).

Q.E.D.

Equation (15) constitutes a quantitative equation of money. It can be easily checked that the velocity of money is an increasing function of both merchants and carriers' markup and the depreciation rate. The reason is that a higher markup implies a higher transaction of money, and a higher depreciation rate implies using more money in exchange for each unit of production.

Theorem 6: In an MEC, the equilibrium numbers of producers, carriers and merchants are

$$2g^* = \mu N, \qquad \text{where} \quad \mu = \frac{1 - \varphi - \eta^2}{(1 - \varphi + \eta)(1 + \tau + \eta)}, \tag{19a}$$

$$T^* = \frac{(\eta + \tau)(1 - \varphi) + \eta^2}{(1 - \varphi + \eta)(1 + \tau + \eta)} N, \qquad \text{and} \tag{19b}$$

$$F^* = \frac{\eta}{1 - \varphi + \eta} N\,. \tag{19c}$$

Proof: The proof comes directly by solving (14), (15), and the fact that $N = 2g + T + F$.

Taking derivatives in equations (19), it is easy to verify that the number of producers is a decreasing function of η, φ and τ. The number of merchants is an increasing function of the average time that a merchant spends meeting producers and carriers (η), and the average time a merchant spends looking for and meeting all other merchants (φ). However, it does not depend on the transportation cost (τ).

Taking partial derivatives in (19b) with respect to τ and φ we find out that $\partial T^*/\partial\tau > 0$ and $\partial T^*/\partial\varphi < 0$. Hence, the number of carriers is an increasing function of the transportation cost and a decreasing function of the meeting cost. Nevertheless, the effect of an increase in the average time spent in meetings on the number of carriers is not clear. However, if we neglect the terms $\eta\tau$, $\eta\varphi$, $\tau\varphi$, and the squares of η, φ and τ, which are very small terms, we obtain $\partial T^*/\partial\eta > 0$, which is clearly positive.

<u>Theorem 7</u>**:** Consider a Monetary Economy with Merchant. In equilibrium, we can set all good prices equal to one, and obtain the following equilibrium markups and consumption functions:

$$\gamma^* = 1 + \frac{T}{2g} \qquad \text{or} \qquad \gamma^* = 1 + \frac{(\tau+\eta)(1-\varphi)}{1-\varphi-\eta^2}, \tag{20a}$$

$$\xi^* = \frac{1}{1-\delta_0}\frac{N}{2g+T} \qquad \text{or} \qquad \xi^* = \frac{1}{1-\delta_0}\frac{1-\varphi+\eta}{1-\varphi}, \tag{20b}$$

$$C(k) = \frac{(1-\delta_0)A}{N} \qquad \text{or} \qquad C(k) = \frac{(1-\delta_0)\mu A}{2g}. \tag{20c}$$

<u>Proof</u>: From the producer, carrier and merchant's maximization problem, we obtain the following demand functions for any consumption good k:

$$C^p(k) = \frac{Q}{(2g)^2\xi\gamma} \qquad \text{for any producer } i, \tag{21a}$$

$$C^\tau(k) = \frac{(\gamma-1)Q}{2gT\xi\gamma} \qquad \text{for any carrier } \tau, \quad \text{and} \tag{21b}$$

$$C^f(k) = \frac{[(1-\delta_0)\xi-1]}{2gF\xi}Q \qquad \text{for any merchant } f. \tag{21c}$$

Since all individuals have the same equilibrium utility level, $U^i = U^\tau = U^f$, each of them has the same income, and $C^p(k) = C^\tau(k) = C^f(k)$. Using this system of equations and the demand functions (21) we find (20a) and (20b). Finally, plugging (20a, b) in any of the (21) functions we get (20c).

Q.E.D.

It is directly observed that the carrier's markup is an increasing function of transportation costs. Taking derivatives of (20a) with respect to τ, η and φ, we obtain that the carrier's markup (γ^*) is an increasing function with respect to any of these variables. Therefore, the carrier's markup is an increasing function of any transaction cost. This is because the role of the carrier is that of an intermediary facilitating transactions.

On the other hand, taking derivatives of (20b), we observe that the merchant markup is an increasing function of η, φ and δ_0. This means that the merchant markup is also an increasing function of all transaction costs involved in his work as intermediary, that is, φ, η and δ_0. In other words, both the time spent in meetings (η) and the searching cost (φ) cause an increase in both the carriers' and merchants' markup.

Finally, consumption is an increasing function of production technology and good k production is distributed equally among all individuals, regardless of their occupation. This allows us to drop the superscript in the consumption function.

V. THE MONETARY AND THE BARTER ECONOMIES COMPARED

As in the BEM, we use (8) as the welfare function. Then, using (20c), we can write the welfare function for the MEC as

$$W_{MEC}(N) = \mu N[Log(1-\delta_0)\, A - Log\, N] \tag{22}$$

where μ is defined in (19a). From (22) we obtain the social welfare function in terms of the production technology, the depreciation rate, transaction costs, and population.

Taking derivatives of (22) with respect to N, we find that W_{MEC} is a concave function that achieves a maximum as $N = (1 - \delta)A/e$, where e is the Neper number.

Notice that, unlike the barter economy with merchants, in this monetary economy with carriers, transaction costs do not impose any limitation to production other than the carrier's capacity to transport production to the CBD. The city population, however, cannot grow to more than $(1 - \delta)A$, so W_{MEC} looks like it is shown in Figure 3.

FIGURE 3 COMES HERE

Let's now compare the welfare function in the monetary economy with carrier and that of the barter economy with merchants. Consider the difference $\Delta W = W_{MEC} - W_{BEM}$. This difference is positive, the MEC dominates the BEM and the monetary economy. Otherwise, the BEM dominates and no money is present. From (8') and (22), this difference can be written as

$$\tau\, \Delta W(a_0, N) = \tau\alpha N + (\alpha - \mu)\, \tau N\, [Log N - Log a_0] + (2 - \tau\alpha N)\, Log(1 - \tau\alpha N/2).$$

Since τ, α, and μ are exogenously determined, the sign of ΔW depends of the population size, N, and the technological parameter, a_0. Using (7) and (19a), we can check that

$$\alpha - \mu = \frac{(1-\varphi)(\tau+\eta)+\eta^2}{(1-\varphi+\eta)(1+\tau+\eta)} > 0.$$

Solving $\Delta W \geq 0$ for $Log(a_0)$, we obtain that

$$Log\ a_0 \leq \frac{1}{(\alpha-\mu)\tau}\left(\tau\alpha + (\alpha-\mu)\tau Log N + \frac{(2-\tau\alpha N) Log(1-\alpha\tau N/2)}{N}\right) \tag{23}$$

Taking the first derivative on the equality in (23) we find

$$\frac{d(Log\ a_0)}{dN} = -\frac{\mu\tau N + 2 Log(1-\alpha\tau N/2)}{(\alpha-\mu)\tau N^2}$$

Doing some algebra it can be shown that this expression is non-negative if $1 - \alpha\tau N/2 \geq e^{-\mu\tau N/2}$. But this happens somewhere in the interval $0 < N < 2/\alpha\tau$. Then, ΔW is an concave function with respect to N.

Let's denote by K_0 the technological level at the moment when the man specializes and hence starts to exchange. Then, we can use Figure 4 to understand the transition from a BEM to an MEC. Below the horizontal line K_0, the man has not specialized yet, there is no trade and city size can increase indefinitely. The curve AB represents the locus $\Delta W = 0$. Above this curve, the BEM dominates the MEC. The BEM cannot grow beyond $N = 2/\alpha\tau$. Consequently, the BEM prevails in the upper area of the curve K_0ABC, and beyond that population size, the MEC prevails.

FIGURE 4 COMES HERE

There are several facts that are worthy to note in comparing the BEM and the MEC. In time, both technology and population increase, so once the man achieves a technological level K_0, the transition to a specialized economy follows one of the arrows, v_1, v_2, or v_3. For small economies, the arrow v_1 shows that it is optimal to evolve to a BEM. However, as the population increases, arrows v_2 and v_3 show that the MEC dominates the BEM. Notice that arrow v_2 shows that the transition path can go from a primitive communal system to an MEC and after to a BEM. In any case, arrow v_4 shows that the economy eventually evolves to an MEC, as population increases. This explains why we find some very primitive societies that evolve directly to some kind of monetary economy and some others, which were even more advanced, like ancient Egypt and the Incas in Peru, that took more time to take this step. It also explains why, during the hyperinflation episode in Germany, where millions of people and different goods interact, people did not return to a barter economy, but they used many goods sharing some physical characteristics, that is Φ goods, as mediums of exchange.

VI. CONCLUSION

The appearance of carriers is one step further in the specialization process that allows increasing advantages from trade. This process is possible because of the economies of scale in transportation cost that allows producers to increase aggregate production to be distributed among the population. Consequently, individuals obtain a higher level of consumption and welfare. Without trust, this process causes frictions among individuals that are overcome with the appearance of a medium of exchange.

Notice that although the individual who bears a particular cost (meeting, search, perishability or transportation cost) depends on the assumptions of the model, it is clear that as the economy becomes more complex, the bearing of the costs becomes more specialized. Different costs are shifted among agents as the economy evolves, allowing producers to increase their production and individuals' utility levels.

The Table below shows how this displacement takes place. In a primitive barter economy, the producer bears all costs, transaction, perishability, search and transportation cost. As the population grows, merchants appear and assume search and transaction costs. Perishability and transportation costs are still borne by producers. As the population grows even more, it is profitable for some individuals to become carriers and assume transportation costs. The perishability cost is shifted to merchants who still bear the transaction cost.

	PRIMITIVE BARTER ECONOMY	BARTER ECONOMY WITH MERCHANTS	MONETARY ECONOMY WITH CARRIERS
MEETING COST	Producers	Merchants	Merchants
PERISHABILITY COST	Producers	Producers	Merchants
TRANSPORTATION COST	Producers	Producers	Carriers
SEARCH COST	Producers	Merchants	Merchants

An important feature of this model is that, by lowering transaction costs, the emergence of money brings about the creation of new goods which allows the economy to grow beyond the limitation imposed by the barter exchange system and increases individuals' welfare. In other words, the appearance of money causes an increase in the production, the scope of the economy and individuals' welfare. Notice, however, that once the economy has become a monetary economy, an increase in the amount of money does not affect the aggregate production, the scope of the economy and individuals' welfare, i.e., it becomes neutral.

Notice also that, since $Q = 2gA$, from (17) and (19a) we obtain

$$Y = [\gamma + (1 - \delta_0)(\xi - 1)]\, \mu\, A\, N.$$

From this and (19a) we see that both GNP and the scope of the economy are determined by the population size and transaction cost parameters, which include transportation costs. Individuals' welfare is determined also by these variables and by the perishability rate of Λ goods too.

On the other hand, in the monetary economy, producers' prices are proportional to the amount of money. Notice, however, that the carrier and merchant's markup are not affected by the amount of money but by the transportation and transaction costs. Nevertheless, the perishability rate of money (the Φ good) does affect the carrier's markup, as becomes evident from (21).

It is noteworthy that the existence of several low transportation cost goods belonging to the set Φ can give rise to several mediums of exchange. This conclusion is supported by anthropological findings of primitive economies in which several goods simultaneously served as mediums of exchange. Some examples of these are the use of shells and teeth as money in the Solomon Islands, barley and silver in Babylon and Assyria, shells and silk in China, and several metals in many ancient societies. An extensive list of examples is given in Einzig (1966). Over time, as the technology improved and new goods were discovered, those goods with a lower perishability rate and transportation cost dominated other goods as mediums of exchange, as our model predicts. This was the case of gold and silver that were widely used as mediums of exchange as soon as technical progress allowed them to give utility to individuals, and some other physical properties like measurability and divisibility.

In the process of the appearance of coinage and modern money, other factors, such as the difficulty of accurately measuring the values of those goods used as money, led to the appearance of some "unified and certified money" through the seal of a reputable authority or a King. However, other forms of primitive money existed long before that.

The absence of a central authority can explain why, after the disappearance of the currency during the German hyperinflation episode, many objects with similar characteristics were used as mediums of exchange. Although none of them clearly dominated the others in this role, it is clear that the economy did not go back to a barter system but to a commodity money system where many goods where used for that purpose. Another characteristic enhancing this result is that, in modern economies, the scope of the economy is too large to allow a barter economy to work; modern economies would never go back to barter as a general system.

Note also that in the model, money appears as a way of overcoming frictions among rational individuals wanting to do business, and not as a means to solve the absence of the double coincidences of wants problem. However, it is necessary that the economy reach a certain level of production technology and population size before this evolution takes hold. Another important point in this model is that the increase in transportation technology allows the growth in both the number of goods produced and the individuals' welfare.

Observe that, unlike the merchant barter economy, in this monetary economy transportation costs are reflected in the carriers' markups and not in the producers' prices. Note that for a certain population size and technology, it is optimal that a barter economy instead of a monetary economy emerges. This may explain why some societies, such as Ancient Egypt or the Incas in Peru, did not advance to a monetary economy. Einzig (1966, pp. 194 and 338) provides a comprehensive analysis of the exchange system in these two great societies.

Finally, the model provides microfoundations to the Cash in Advance constraint, since it is optimal for individuals to adopt money as medium of exchange once the economy evolves from barter to a monetary one. However, as emphasized in Lucas (1980), the use of this restriction is supported only as long as there is a role for intermediaries in the economy.

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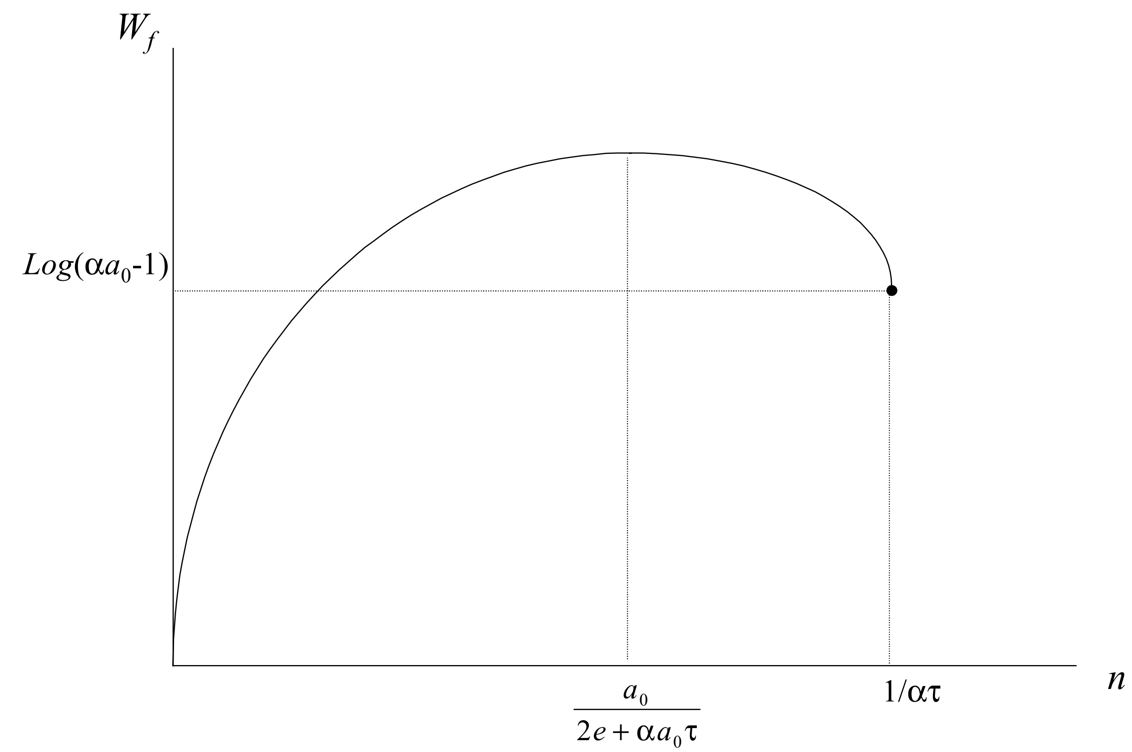

FIGURE 1. The Social Welfare Function in the Merchant Barter Economy

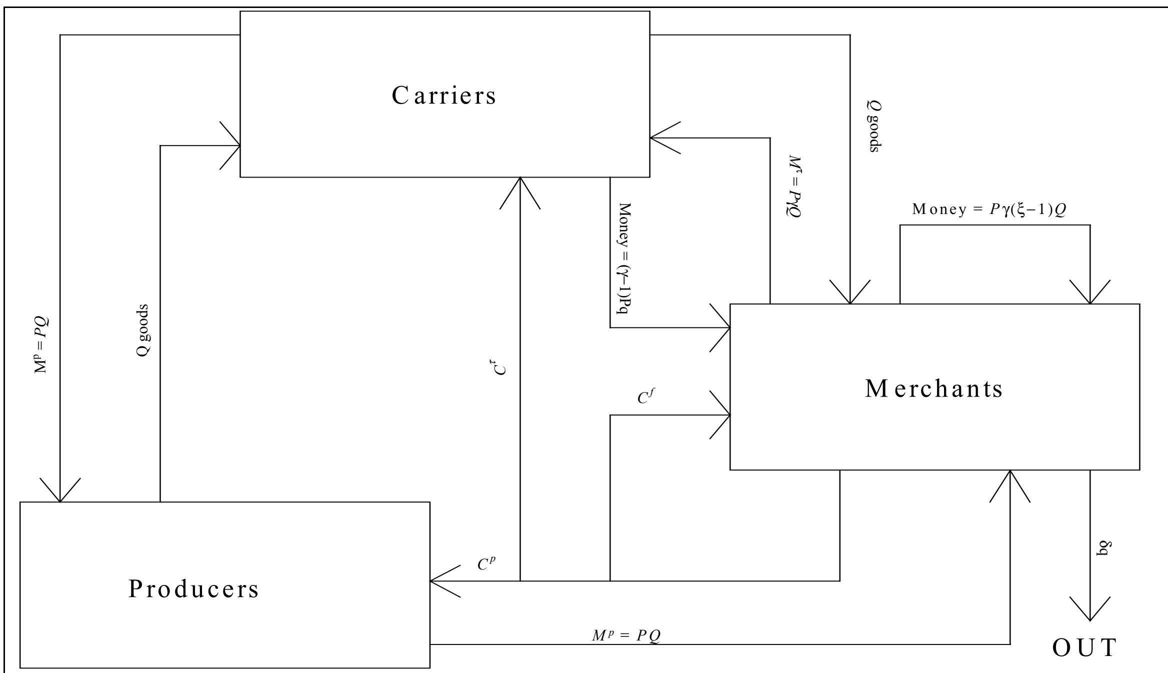

FIGURE 2. The Flow of Money in a Monetary Economy with Carriers

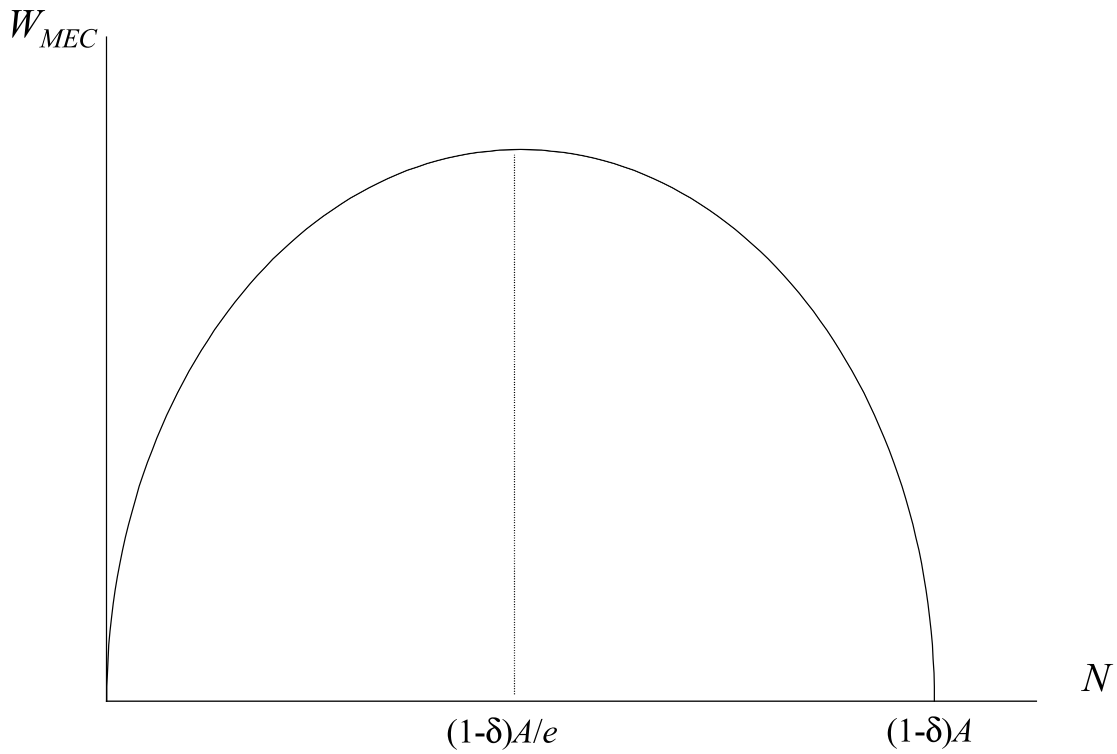

FIGURE 3. The Social Welfare Function in the Monetary Economy with Carriers.

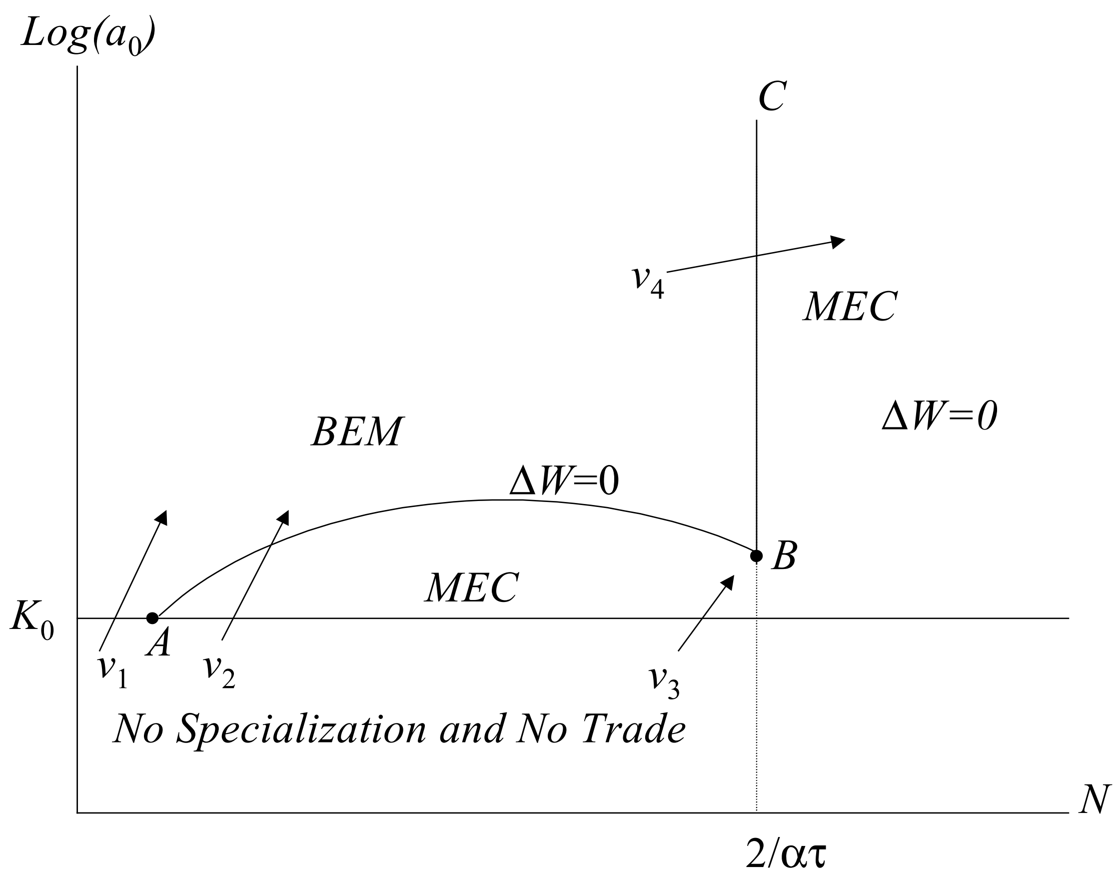

FIGURE 4. The Monetary Economy with Carriers and The Barter Economy with Merchants Compared.