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VEHICLE CURRENCIES AND THE STRUCTURE OF INTERNATIONAL EXCHANGE

Paul Krugman

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SUMMARY

Vehicle Currencies and the Structure of International Exchange

This paper is concerned with the reasons why some currencies, such as the pound sterling and the U.S. dollar, have come to serve as "vehicles" for exchanges of other currencies. It develops a three-country model of payments equilibrium with transaction costs, and shows how one currency can emerge as an international medium of exchange. Transaction costs are then made endogenous, and it is shown how the underlying structure of payments limits, without necessarily completely determining, the choice and role of a vehicle currency. Finally, a dynamic model is developed, and the way in which one currency can displace another as the international medium of exchange is explored.

Paul Krugman
Department of Economics
Yale University
28 Hillhouse Avenue
New Haven, CT 06520

(203) 436-3246

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Introduction

Most work in international monetary theory assumes a world in which there are only two countries and two currencies. While this is a useful simplification for many purposes, it does make it impossible to consider two interesting aspects of the international monetary system. One aspect is what we might call the structure of payments. In a world of more than two countries, each country will run balance of payments surpluses with some countries, deficits with others, even when its overall payments are in equilibrium. This multilateral structure of payments will often be of considerable economic interest. The other neglected aspect of the international system is what we might call the structure of exchange. People who want to exchange one currency for another will not necessarily make the exchange directly. They may make the exchange by way of some third currency, which becomes a "vehicle" for the transaction. Historically, certain currencies - the pound sterling before 1914, the U.S. dollar in recent years - have come to be widely used as vehicle currencies. To put it another way, these currencies have served as international media of exchange. The purpose of this paper is to examine why some currencies take on this special role.

There is an obvious parallel between the role of a vehicle currency in international exchange and the role of money in domestic exchange. In each case people choose to engage in indirect rather than direct exchange. When we ask why currencies are not exchanged directly; why one currency predominates in indirect exchange; and what determines which currency takes on that role, we are raising issues very similar to those we raise when we ask why households engage in monetary exchange instead of barter; why some one commodity tends to emerge as a medium of exchange; and why certain commodities (gold, silver, furs, cigarettes) are more suited for this role than others.

By bringing up familiar issues in a different context, the study of international exchange can cast a new light on old insights. For example, I will show that there must be indirect exchange if countries' payments are not bilaterally balanced. This, if one thinks about it, is just the counterpart in international exchange of Jevons' lack of "double coincidence of wants." Other parallels will appear in the course of the paper.[1/]

It is obvious that the international structure of exchange must depend crucially on transaction costs. Since it is notoriously difficult to integrate such costs into economic models, one might expect that any analysis of the structure of exchange will have to be extremely complex. This need not be the case, however, if one is willing to look at illuminating special cases instead of trying for a general model. In this paper I will try to set out as simple a model as possible of the structure of exchange. At each point assumptions will be chosen to make the next step in the analysis as easy as possible. This process of buying clarity at the expense of realism means that this paper must be regarded as a preliminary study. Nonetheless, the results seem intuitively plausible, and look as though they ought to generalize.

The basic model of this paper is one in which there are three countries, the minimum necessary for indirect exchange. Section I analyzes the model for the case in which there are no transaction costs. In this case the structure of payments can be determined, but the structure of exchange is indeterminate. Transaction costs are introduced in Section II, and it is shown how the structure of these costs determines the structure of exchange. Section III then allows transaction costs to depend in turn on the structure of exchange. This section shows how, under plausible assumptions about the nature of this dependence, the underlying structure of payments limits the choice of vehicle currency.

Finally, Section IV develops a dynamic model of the development of the exchange structure.

I. The Model Without Transaction Costs

Consider a world consisting of three countries: A, B, and C. Each country has its own currency, the Alpha in A, the Beta in B, and the Gamma in C. There are three exchange markets on which Alphas and Betas, Betas and Gammas, and Gammas and Alphas can be exchanged. We will call these the $\alpha\beta$, $\beta\gamma$, and $\gamma\alpha$ markets respectively. For the purposes of this section we will assume that exchanging currencies is costless.

Let us define $E_{\alpha\beta}$ as the price of Alphas in terms of Betas, $E_{\beta\gamma}$ as the price of Betas in terms of Gammas, and so on. Then because transactions are costless, arbitrage will ensure that the costs of acquiring a currency directly are the same as the costs of acquiring it indirectly, via the third currency. This condition can be written as

$$E_{\alpha\beta}E_{\beta\gamma}E_{\gamma\alpha} = 1 \tag{1}$$

These exchange rates will be determined by the supply and demand for currencies. I will assume that the relevant variables are flow demands and supplies. This goes against much recent literature on exchange rates, which views exchange rates as determined by the requirements of stock equilibrium. The only justification for the treatment here is simplicity. Asset market equilibrium in the presence of transaction costs is very difficult to model, while if we are willing to adopt a flow model the analysis is quite easy. The analysis here should therefore be regarded as preliminary, with the integration of this theory with the "asset" view of exchange rates a piece of pending business.

The demand for and supply of currencies, then, will be assumed to arise from the desire of residents of the three countries to make payments to other countries. Residents of A wanting to make payments to B, for example, will have to acquire Betas. The currency markets will clear if the demand for each currency by foreign residents equals the supply from domestic residents wanting to make payments in foreign currency. Let us define P_{AB} as the desired payment by residents of A to B, measured in Betas, similarly P_{BC} is the desired payment by residents of B to C, and so on. In each case we will assume that desired payments depend both on the exchange rates and on a vector Z of other varaibles, which will be taken as exogenous. We can write the conditions of equilibrium in the currency markets as

$$P_{BA}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) + P_{CA}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \tag{2}$$

$$= E_{\alpha\beta} \cdot P_{AB}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) + E_{\alpha\gamma} \cdot P_{AC}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \quad \text{for Alphas;}$$

$$P_{AB}(E_{\alpha\beta}, E_{\gamma\alpha}; A) + P_{CB}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \tag{3}$$

$$= E_{\beta\alpha} \cdot P_{BA}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) + E_{\beta\gamma} \cdot P_{BC}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \quad \text{for Betas; and}$$

$$P_{AC}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) + P_{BC}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \tag{4}$$

$$= E_{\gamma\alpha} \cdot P_{CA}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) + E_{\gamma\beta} \cdot P_{CB}(E_{\alpha\beta}, E_{\gamma\alpha}; Z) \quad \text{for Gammas.}$$

In each case we have written a condition of aggregate balance of payments equilibrium. Because of budget constraints, if any two countries are in balance of payments equilibrium, the third must also be in balance. Notice, however, that there is no reason why countries must be in <u>bilateral</u> balance. If, for example, $P_{AC} > E_{\gamma\alpha}P_{CA}$, i.e., C runs a balance of payment surplus with A, we can still have an equilibrium if A runs an offsetting surplus, and C an offsetting deficit, with B.

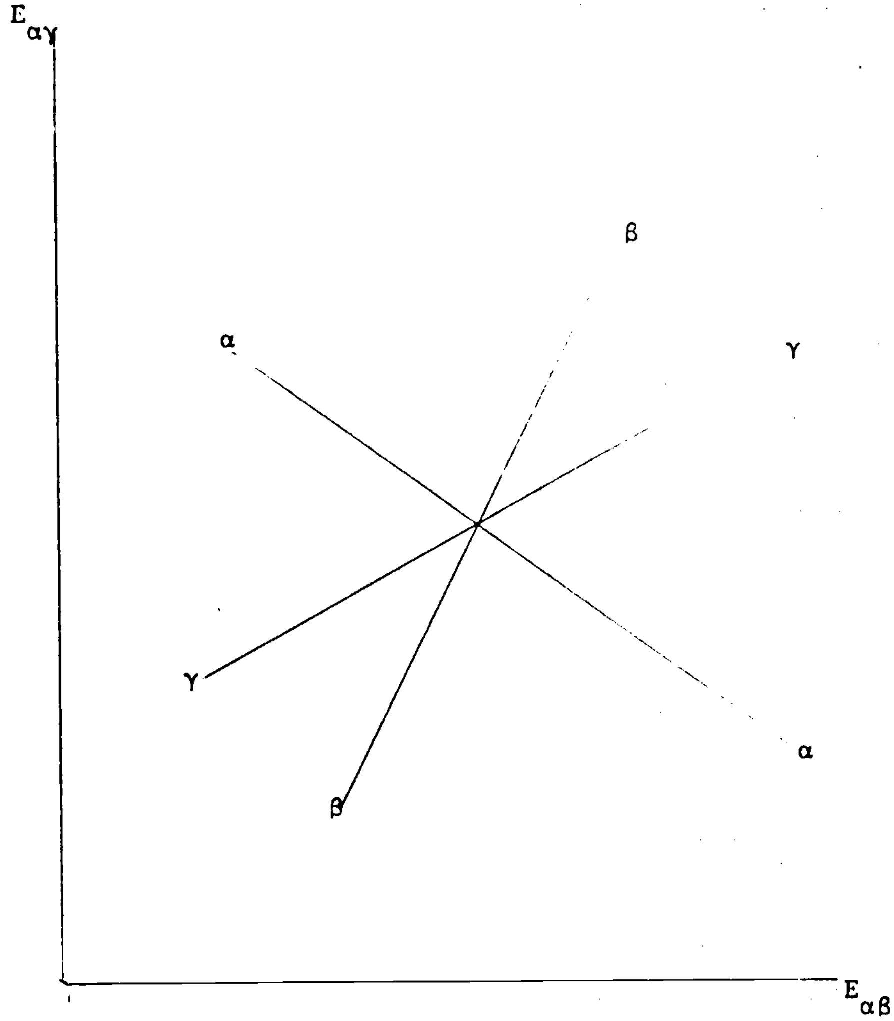


Figure 1

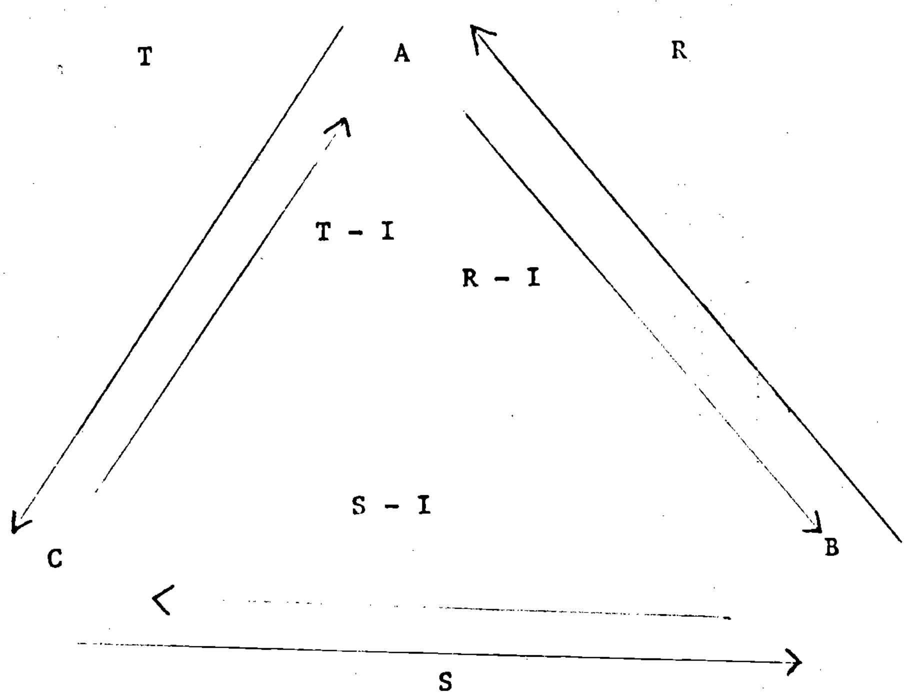


Figure 2

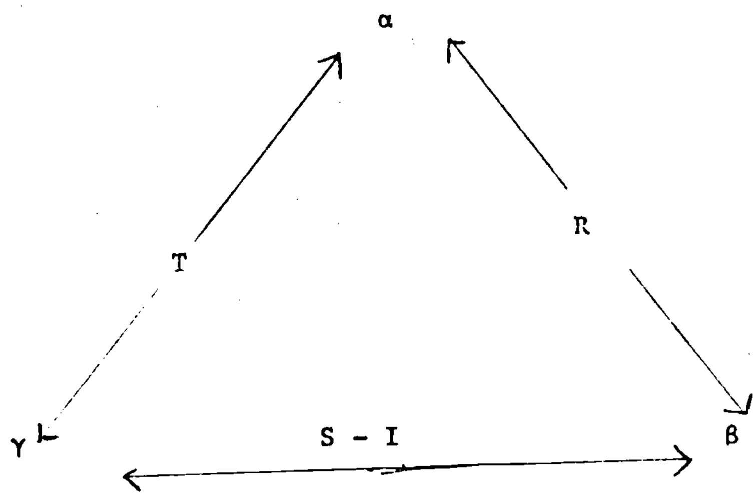


Figure 3

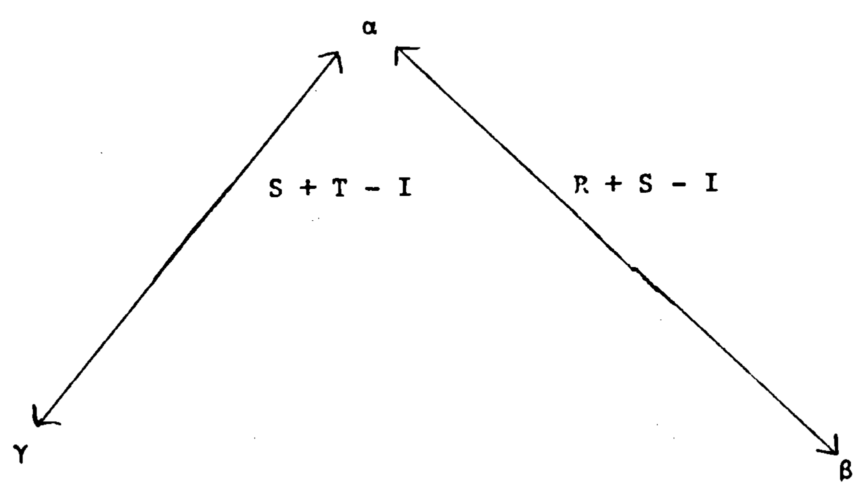


Figure 4

Figure 1 illustrates the determination of the system of exchange rates under the assumption that the currencies are gross substitutes. The horizontal axis measures the price of Alphas in terms of Betas, the vertical axis the price of Alphas in terms of Gammas. The lines $\alpha\alpha$, $\beta\beta$ and $\gamma\gamma$ lines represent positions of balance of payments equilibrium for A, B, and C respectively. Walras' Law assures that they intersect at a single point.

Now let us consider the structure of payments and the range of possible structures of exchange. It will be helpful if we choose units so that the equilibrium exchange rates are all equal to one. We can then express payments arbitrarily in any of the currencies. Given this normalization, the structure of payments will look like that illustrated in Figure 2. In the figure, payments by residents of one country to residents of another are indicated by arrows. A is shown as running a surplus of I in its exchange with B; we can relabel B and C if necessary to make this true. The figure then shows that, to maintain balance of payments equilibrium, B must run a surplus of I with C, and C a surplus of I with A. While payments need not be bilaterally balanced, then, there is a sort of conservation of imbalance. Once we specify A's surplus with B, we have also determined the imbalances between B and C and between C and A. (This is a special feature of three-country models).

Our next task is to consider what structures of exchange are possible given this structure of payments. Obviously the structure of exchange is not determinate in the absence of transaction costs. But there are limits on the range of possibilities. In particular, it will not be possible to carry out the payments in Figure 2 solely through direct exchange. If everyone tried to acquire the desired foreign currency in a single transaction, there would be an excess demand for Alphas on the $\alpha\beta$ market, an excess demand for Betas on the $\beta\gamma$ market, and an excess demand for Gammas on the $\gamma\alpha$ market. So some indirect exchange must take place because, as already pointed out, countries will not usually have a "double coincidence of wants."

What kinds of structure of exchange are possible? There are obviously infinite possibilities - for instance, one might exchange Gammas for Alphas and back again seventeen times, etc. - but once we introduce transaction costs, there will turn out to be only two types of exchange which can actually arise. An example of the first type is given in Figure 3, where the two-headed arrows represent the volume of transactions on the $\alpha\beta$, $\beta\gamma$, and $\gamma\alpha$ markets. In this example the residents of C make payments of I to B indirectly, first purchasing Alphas and then exchanging these for Betas. They continue to purchase S - I Betas directly, however. At the same time residents of B and A engage only in direct exchange. As is apparent from Figures 2 and 3, this clears all three currency markets, by increasing the supply of Gammas on the $\gamma\alpha$ market and the supply of Alphas on the $\alpha\beta$ market. Since this structure of exchange involves indirect exchange only for the imbalance in payments, let us call this a case of <u>partial indirect exchange</u> using Alphas as the vehicle currency, with the understanding that it is the payments imbalance I which is indirectly exchanged. Clearly, we can have partial indirect exchange with any one of the three currencies as vehicle.

Figure 4 gives an example of the other possible kind of exchange structure. In this case <u>all</u> payments between B and C are made indirectly, through the medium of Alphas. The $\beta\gamma$ market disappears, while the $\alpha\beta$ and $\gamma\alpha$ markets have the indicated volume. Since all three countries are in balance of payments equilibrium, it is obvious that both existing currency markets clear. Let us call this a case of total indirect exchange. with Alphas as the vehicle currency. Again, we can also have total indirect exchange with Betas or Gammas as the vehicle.

To summarize: I have defined two kinds of structure of exchange, partial indirect exchange and total indirect exchange. Each type of structure involves the use of one currency as a "vehicle" for indirect transactions. So we have to determine which currency is the vehicle and which kind of exchange structure occurs. To do this we must now introduce transaction costs.

II. Transaction Costs and Exchange

In this section I show how transaction costs can determine the structure of exchange. This analysis relies on the assumption that transaction costs are "small," so that we can use a concept of approximate equilibrium which will be defined in a moment. In essence what this concept allows us to do is determine the structure of exchange while ignoring any feedback from the structure of exchange to the structure of payments.[2/]

Let us begin by describing transaction costs. I will assume that in each of the three markets transactors must pay a brokerage fee proportional to the size of the transaction. This proportion will be $t_{\alpha\beta}$, $t_{\beta\gamma}$, and $t_{\gamma\alpha}$ in the $\alpha\beta$, $\beta\gamma$, and $\gamma\alpha$ markets respectively. It will be assumed (countries will be labelled such that) $t_{\alpha\beta}$ and $t_{\gamma\alpha}$ are both less than $t_{\beta\gamma}$. This will, as we will see, insure that the Alpha is the vehicle currency.

The way these transaction costs will work is to worsen the effective exchange rate one gets. Thus if $E_{\alpha\beta}$ is the exchange rate on the $\alpha\beta$ market, a transactor purchasing Betas will actually get only $E_{\alpha\beta}(1 - t_{\alpha\beta})$ Betas per Alpha; a transactor purchasing Alphas will get only $E_{\alpha\beta}^{-1}(1 - t_{\alpha\beta})$ Alphas per Beta.

Because of the transaction costs, the arbitrage condition (1) will no longer hold exactly. Instead there will be a deviation from triangular arbitrage,

$$D = E_{\alpha\beta}E_{\beta\gamma}E_{\gamma\alpha} \neq 1 \qquad (5)$$

I will call D, which may be either greater or less than one, the clockwisdom of exchange rates. The reason for the name is that an increase in the value of D makes indirect exchange more attractive compared with direct exchange if the indirect exchange proceeds clockwise in Figures 3 and 4, less attractive if the indirect exchange proceeds counterclockwise. Consider, for example, an exchange of Alphas for Gammas. In direct exchange, the exchange rate is

$1/E_{\gamma\alpha}$. In indirect exchange, clockwise via Betas, the rate is $E_{\alpha\beta}E_{\beta\gamma}$. There will thus be a bias in favor of indirect exchange if $E_{\alpha\beta}E_{\beta\gamma} > 1/E_{\gamma\alpha}$, that is, if $E_{\alpha\beta}E_{\beta\gamma}E_{\gamma\alpha} = D > 1$. On the other hand, an exchange of Betas for Gammas takes place at a rate $E_{\beta\gamma}$ directly, while the counterclockwise indirect exchange takes place at a rate $1/E_{\alpha\beta}E_{\gamma\alpha}$; thus there is a bias against indirect exchange if $E_{\beta\gamma} > 1/E_{\alpha\beta}E_{\gamma\alpha}$, that is, $E_{\alpha\beta}E_{\beta\gamma}E_{\gamma\alpha} = D > 1$. Clearly, individuals deciding between direct and indirect exchange will take into account both transaction costs and the clockwisdom of exchange rates.

Using the concept of clockwisdom we can now proceed to analyze equilibrium. What I will derive here is an approximate equilibrium, which will be close to the actual provided transaction costs are small. The approximateness comes from considering only the effect of transaction costs on the way payments are made, ignoring the effect of these costs on the payments themselves. Another way of saying this is to say that transaction costs are taken to affect the structure of exchange, but that the structure of payments is taken as given.

Specifically, let us define the equilibrium concept as follows. We will consider an approximate equilibrium to be (i) a set of choices of indirect vs. direct exchange which would clear the three currency markets if there were no transaction costs, together with (ii) a clockwisdom D in the exchange rates which leads people to make those choices.

Given this concept of equilibrium, we can now state the relationship between transaction costs and the structure of exchange. Recall that $t_{\alpha\beta}$ and $t_{\gamma\alpha}$ are both assumed to be less than $t_{\beta\gamma}$. Then we can state that:

(i) The Alpha will be the vehicle currency

(ii) If $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) < 1 - t_{\beta\gamma}$ - i.e., if indirect exchange is more costly than direct - the equilibrium structure will be one of partial indirect exchange, as defined in Section I.

(iii) If $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) > 1 - t_{\beta\gamma}$ - indirect exchange is <u>less</u> costly than direct - the equilibrium structure will be one of total indirct exchange.

The results (i) - (iii) make intuitive sense, since what they amount to is saying that the system acts in such a way as to minimize <u>total</u> transaction costs.

In demonstrating these results I will make use of the already-mentioned "conservation of imbalance" in a three-currency model, which insures that if exchange is balanced in one currency market it is balanced in all three markets. Thus we can focus on the $\beta\gamma$ market, and look for a value of D which would match the demand for and supply of Gammas on that market. At the same time, we can make use of a simple relationship between the structure of exchange and the excess demand for Gammas in the $\beta\gamma$ market. This is that any shift from direct to indirect exchange in a <u>clockwise</u> direction raises the excess demand for Gammas, while any shift from direct to indirect exchange in a <u>counter-clockwise</u> direction lowers it. For example, a shift from direct to indirect payments from A to C will add to the demand for Gammas on the $\beta\gamma$ market, while substituting indirect for direct payments from A to B will increase the supply of Gammas on that market.

Bearing these points in mind, it is fairly easy to see how we can find an approximate equilibrium. For each value of D, there will be a desired pattern of direct and indirect exhange, that is, a structure of exchange, with an implied excess demand $X_{\beta\gamma}$ on the $\beta\gamma$ market. As D is increased, the desired pattern will shift so as to increase that excess demand. The value of D which sets $X_{\beta\gamma} = 0$, together with the implied structure of exchange, define an approximate equilibrium.[3/] The derivation of the equilibrium D is a rather tedious matter, and carried out in the Appendix; here I sketch out the results.

Consider first the case where $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) < (1 - t_{\beta\gamma})$, that is, where indirect exchange is more costly than direct. The excess demand schedule for Gammas is illustrated in Figure 5. Flat segments of the schedule are at levels of D for which transactors between some pair of currencies are indifferent between direct and indirect exchange. As D is increased there is more clockwise and less counter-clockwise indirect exchange. As the Appendix shows, the $\beta\gamma$ market is cleared on a "flat" where transactors exchanging Gammas for Betas are indifferent between direct and indirect exchange, while all other transactors prefer direct exchange. The result, then, must be one of partial indirect exchange, as defined in Section I and illustrated in Figure 3. In equilibrium, as the figure indicates, the clockwisdom D is $(1 - t_{\beta\gamma})/(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) > 1$. We can think of this as a situation in which holders of Gammas wishing to acquire Betas are offered a slightly better exchange rate on indirect transactions, which is just enough to offset the higher transaction cost.

If $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) > (1 - t_{\beta\gamma})$, that is, indirect exchange is <u>less</u> costly than direct, the situation is somewhat different, as shown in Figure 6. Here D is indeterminate within the indicated range. The reason for the indeterminacy becomes clear when we examine the structure of exchange implied by some D in that range, say D = 1. For such a clockwisdom, transactors exchanging Betas for Gammas and Gammas for Betas will both prefer indirect exchange, while all other transactors prefer direct exchange. The implied structure must therefore be one of total indirect exchange, as illustrated in Figure 4. Since the $\beta\gamma$ market clears with a volume of zero, the exchange rate $E_{\beta\gamma}$ and hence D are of course indeterminate. The structure of exchange is, however, fully determined.

In each of these cases the Alpha plays a special role as a vehicle currency. It enters into more transactions than A's role in world payments would by itself justify. The special role of A's currency arises, of course, from the assumption that transaction costs in the exchange markets differ. We have labelled the currencies so that $t_{\alpha\beta}$ and $t_{\gamma\alpha}$ are both less than $t_{\beta\gamma}$, and this insures the Alphas will be used as a vehicle.

But why should transaction costs be different? We would like some theory to explain this; in particular, we would like to relate the structure of transaction costs to the structure of payments in some way, to make sense of the observed fact that vehicle currencies have historically been the currencies of dominant trading nations. The next section tries to sketch out such a theory.

III. Endogenous Transaction Costs

In this section I attempt to provide an explanation of why differences in transaction costs might arise. The analysis is based on a somewhat ad hoc but simple and surprisingly powerful assumption: that transaction costs as a proportion of the transaction are decreasing in the volume of transactions. This turns out to be enough to give us considerable insight both into the way the structure of payments limits the structure of exchange, and into the exchange structure's dynamics.

Since the assumption that transaction costs decrease with the size of the currency market is crucial to this section, we should consider (without, however, developing a fully-worked-out model) why this might be so. It is fairly simple to tell stories which would have this result. Suppose, for instance, that on any given day the supply and demand for a currency from transactors do not exactly match at the price set by currency traders and that the traders meet the difference from their own holdings. Then the average stocks of currency held

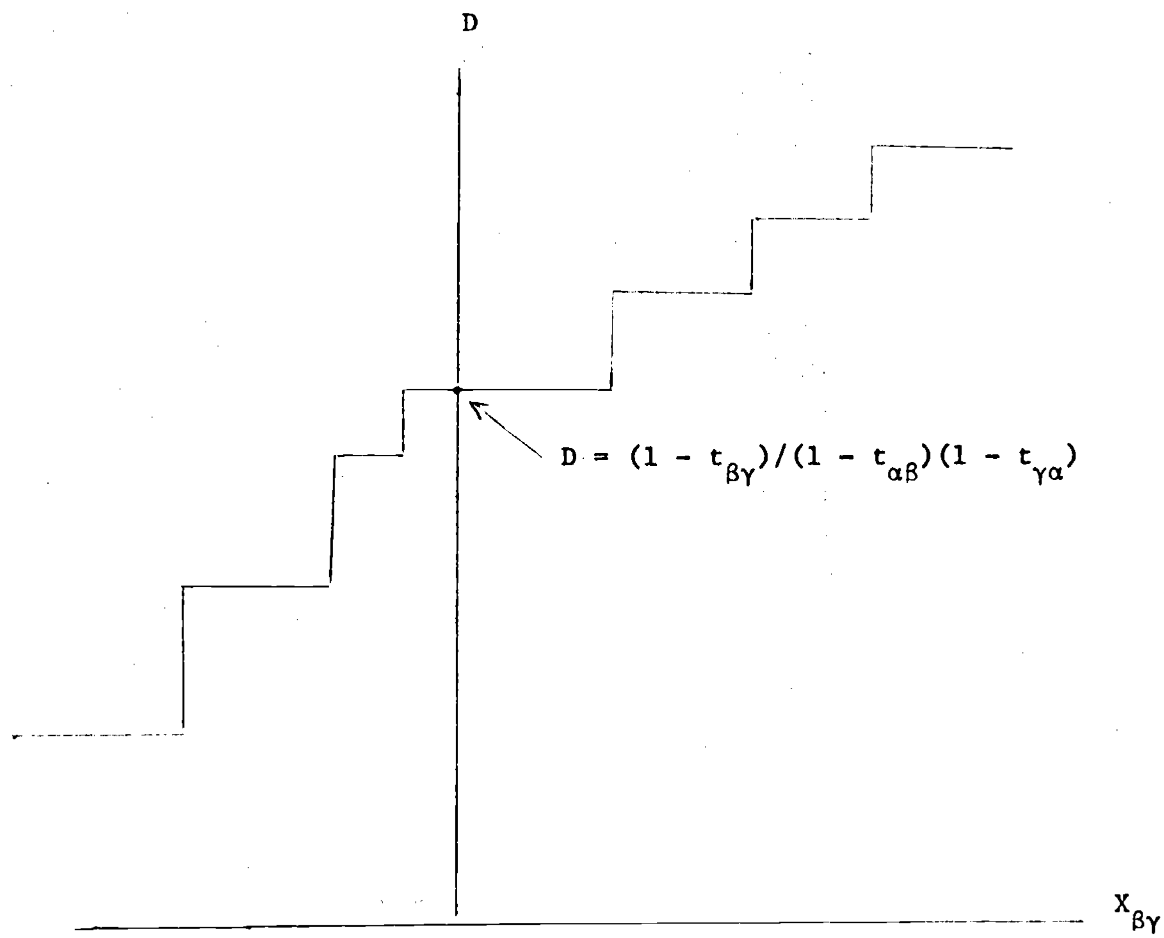


Figure 5

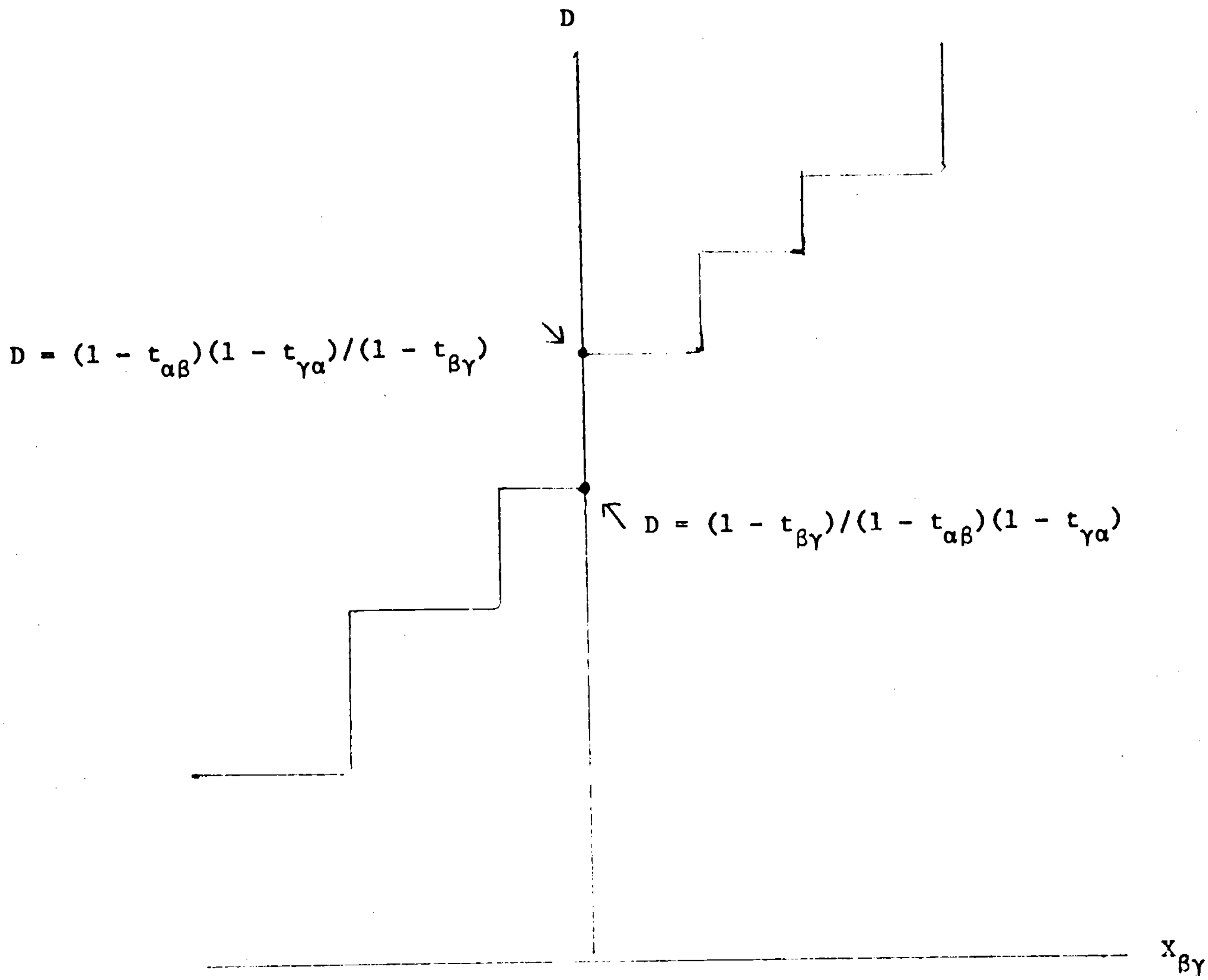

D
$D = (1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})/(1 - t_{\beta\gamma})$
$D = (1 - t_{\beta\gamma})/(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})$
$X_{\beta\gamma}$

Figure 6

by traders will reflect, not the overall volume of transactions, but the variability of excess demand. A growth in the volume of transactions would then increase traders' costs less than proportionately if, thanks to the law of large numbers, their average stocks did not have to increase in proportion. Similar but more elaborate stories could also be told. Alternatively, we might simply argue that the actual physical resources needed to run an exchange, whether it is a bourse or a computer, may be largely independent of the volume of transactions. I leave to one side the problem of modelling the industrial organization of the exchange markets in this case, except to note that it could hardly be perfectly competitive. [4/]

In any case, let us now consider the implications of letting transaction costs depend on volume. If we let $V_{\alpha\beta}$, $V_{\beta\gamma}$, $V_{\gamma\alpha}$ be the volumes of transactions on the three markets, then we have

$$t_{\alpha\beta} = F(V_{\alpha\beta}) \tag{6}$$

$$t_{\beta\gamma} = F(V_{\beta\gamma}) \tag{7}$$

$$t_{\gamma\alpha} = F(V_{\gamma\alpha}) \tag{8}$$

where the function $F(\ .\ )$ is assumed the same for all markets and we assume $F' < 0$.

If the structure of transaction costs depends in this way on the volume of transactions, then it depends on the structure of exchange. But the structure of exchange, as we saw in Section II, is determined by the structure of transaction costs. What we must look for, then, is an exchange structure which is an equilibrium in the sense that the pattern of transaction costs produced by transactors' choices of direct vs. indirect exchange sustains these choices. There is no reason why there must be only one such equilibrium; there may be as many as six. Exchange might be partially or totally indirect, and any one of the three currencies might serve as the vehicle.

The simultaneous choice of type of exchange structure and of vehicle currency makes for a very complex problem. I will simplify this problem by concentrating on two more limited choices. First, we will take the type of exchange structure as given and consider the choice of vehicle currency. Then we will take the vehicle currency as given and consider the choice of exchange structure. These limited analyses will serve to illustrate the main principles, while the general case can be analyzed only through numerical examples.

Let us begin, then, with the case in which we assume that the exchange structure is one of partial indirect exchange, and we are concerned solely with which currency is the vehicle. We start with a structure of payments like that in Figure 2. When a particular currency is chosen as vehicle, we get a structure of exchange which is an equilibrium if the implied structure of transaction costs confirms that currency's vehicle position. From (6) - (8), this means that choice of a currency as vehicle must make the volume of the two markets in which that currency participates larger than the volume of the third market.

The relationship between choice of vehicle and the volume of transactions, for the structure of payments in Figure 2, is as follows:

Vehicle Currency	$V_{\alpha\beta}$	$V_{\beta\gamma}$	$V_{\gamma\alpha}$
α	R	S - I	T
β	R	S	T - I
γ	R - I	S	T

Each currency market has a "secure" volume arising from counterclockwise payments; the volume is then increased above this level if one of the currencies traded serves as a vehicle. This suggests two things. First, because choosing a currency as vehicle swells the markets on which it is traded, we have a possibility of multiple equilibria. Second, because of the "secure" part of transaction volume, there are some limits on this; the currency of a country which plays only a minor role in world payments will not be able to overcome the advantages of other countries' "secure" volumes.

These points are illustrated by the examples in Figures 7 and 8. In Figure 7, payments are symmetrical, and any currency can serve as vehicle. If, for example, the Beta were to be the vehicle, we would have $V_{\alpha\beta} = V_{\beta\gamma} = 10$, $V_{\gamma\alpha} = 5$; this would make $t_{\alpha\beta}$ and $t_{\beta\gamma}$ less than $t_{\gamma\alpha}$ and confirm the Beta as the vehicle. On the other hand, in Figure 8, A's dominance in world payments assures that the Alpha will be the vehicle currency. If one were to try to make the Beta the vehicle, we would have $V_{\alpha\beta} = 10$, $V_{\beta\gamma} = 2$, $V_{\gamma\alpha} = 9$: the structure of transaction costs would still lead people to carry out indirect exchange through the Alpha. Similarly, using the Gamma as vehicle would produce $V_{\alpha\beta} = 9$, $V_{\beta\gamma} = 2$, $V_{\gamma\alpha} = 10$; the Alpha would still be preferred for indirect exchange. So the unique equilibrium here is a structure of exchange using the Alpha as vehicle, with $V_{\alpha\beta} = V_{\gamma\alpha} = 10$, $V_{\beta\gamma} = 1$.

In partial indirect exchange, then, only the currencies of countries important in world payments can become vehicles; but there may be more than one such currency. (Notice, by the way, that the relationship between a country's role in payments and the choice of vehicle currency is parallel to the requirement that a domestic medium of exchange be a good widely desired). This leaves open the question of which currency becomes the vehicle if more than one is capable of taking on that role. To answer this question we need the dynamic analysis of Section IV.

Before proceeding to this analysis, however, let us consider the other

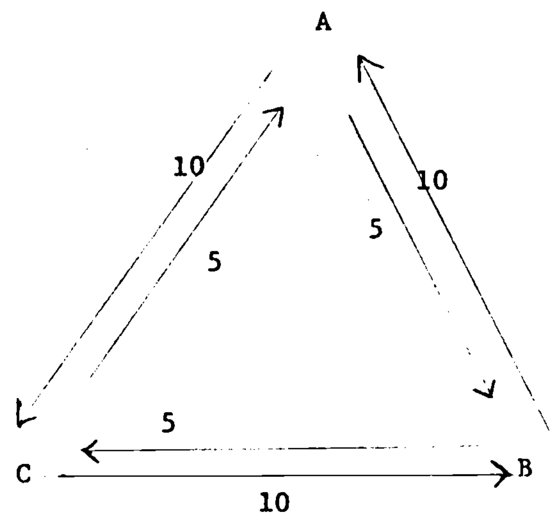


Figure 7

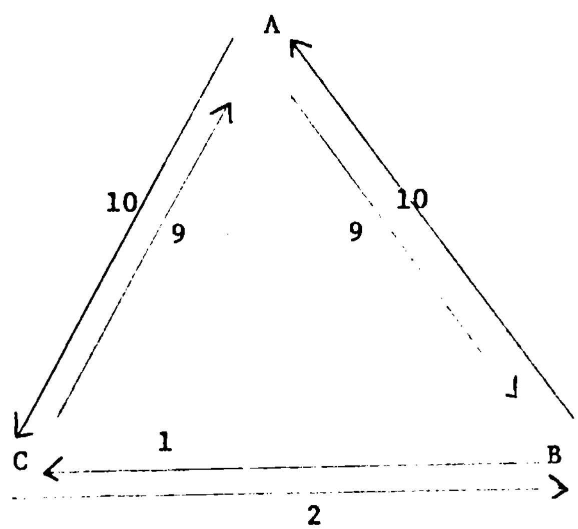


Figure 8

special case mentioned of choice of exchange structure: the choice between partial and total indirect exchange given the choice of vehicle currency. Suppose that we take it as known that the Alpha will be the vehicle currency, and the structure of payments is again that of Figure 2. Then the possible structures of exchange are (i)Partial indirect exchange: $V_{\alpha\beta} = R$, $V_{\beta\gamma} = S - I$, $V_{\gamma\alpha} = T$; (ii)Total Indirect exchange: $V_{\alpha\beta} = R + S$, $V_{\beta\gamma} = 0$, $V_{\gamma\alpha} = S + T$. We know from Section II that partial indirect exchange can be an equilibrium if $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) < (1 - t_{\beta\gamma})$, or, substituting,

$$[1 - F(R)][1 - F(T)] < [1 - F(S - I)] \qquad (9)$$

This can be the case if F does not decrease too rapidly as volume increases. On the other hand, total indirect exchange requires that $(1 - t_{\alpha\beta})(1_{\gamma\alpha} - t) >$ $(1 - t_{\beta\gamma})$, which means that we must have

$$[1 - F(R + S)][1 - F(S + T)] > [1 - F(0)] \qquad (10)$$

This is more likely to be the case if F <u>does</u> decrease rapidly with volume. However, the left-hand side of (10) is larger than that of (9), while the right-hand side is smaller; therefore (9) and (10) are not mutually exclusive.

One might expect that total indirect exchange would be more likely if some one country were very dominant in world payments. This is true in the limited sense that predominance of one country may make partial indirect exchange impossible. In (9), increasing R and T while reducing S - I may reverse the inequality. Even this is not certain, however. If

$[1 - F(\infty)]^2 < 1 - F(0)$, which is fully consistent with $F' < 0$, the exchange structure will always be only partially indirect no matter how predominant one country is.

To summarize, then, if transaction costs are a decreasing function of the volume of transactions we can relate the structure of exchange to the structure of payments in economically sensible ways. Only the currency of a country which is important in world payments can serve as an international medium of exchange; the predominance of one country makes it more likely that all transactions between the others will take place indirectly. While the structure of exchange is thus limited by the structure of payments, however, there may still be several possible exchange structures. To determine which structure emerges, we need a dynamic analysis, to which we now turn.

IV. Dynamics of the Exchange Structure

Since there may be several possible equilibrium structures of exchange, we must have some way of determining which structure actually prevails. The most plausible way of doing this is to specify a process of disequilibrium adjustment which lets us determine the eventual equilibrium given the initial conditions. This leaves open the question of where initial conditions come from; but if we can show how the structure of exchange changes over time this will usually be enough.

Let us suppose, then, a dynamic process of the following kind. Decisions on direct versus indirect exchange will be based, not on actual transaction costs, but on perceived costs $t^e_{\alpha\beta}$, $t^e_{\beta\gamma}$, $t^e_{\gamma\alpha}$. These perceived costs will be adjusted over time in response to the gap between them and the actual transaction costs:

then
$$\dot{t}^e_{\alpha\beta} = \lambda(t_{\alpha\beta} - t^e_{\alpha\beta}) \qquad (11)$$

$$\dot{t}^e_{\beta\gamma} = \lambda(t_{\beta\gamma} - t^e_{\beta\gamma}) \qquad (12)$$

$$\dot{t}_{\gamma\alpha} = \lambda(t_{\gamma\alpha} - t^e_{\gamma\alpha}) \qquad (13)$$

Since the perceived transactions costs determine the structure of exchange, and the structure of exchange in turn determines actual transaction costs, the differential equations (11) - (13) capture the complete dynamic behavior of exchange.

A general analysis of a system of three nonlinear differential equations would, of course, be very complex. We can, however, learn something by considering special cases in which the problem collapses to manageable size. What I will do in this section is consider two such cases.

Consider first a situation in which the function F and the structure of payments rule out total indirect exchange, and also rule out the Gamma as a vehicle currency. (Sufficient conditions for this are

$[1 - F(\infty)]^2 < 1 - F(0)$, and that in Figure 2 we have R - I greater than S and/or T). Then we need only be concerned with the choice between the Alpha and the Beta as a vehicle of partial indirect exchange. This choice depends on a comparison of transaction costs in the markets in which both currencies do not participate, i.e., on $t_{\beta\gamma} - t_{\gamma\alpha}$.

Figure 9 shows the dynamic system. On the vertical axis is shown the perceived difference in transaction costs, on the horizontal the actual difference. The relationship between perceived and actual costs is shown by UVWX, which can be explained as follows. If transaction costs are perceived to be lower in the $\beta\gamma$ market than in the $\gamma\alpha$ market, the Beta will be chosen as the vehicle currency and the actual difference in costs will be -OV. If, on the other hand, transactions are believed to be cheaper in the $\gamma\alpha$ market, the Alpha will be chosen as a vehicle and the actual difference in transaction costs will be OW.

The dynamics of the system are obvious, and are indicated by arrowheads. If the perceived difference in transaction costs is less than the actual (below the 45° line), $t_{\beta\gamma} - t_{\gamma\alpha}$ will rise; if more, $t_{\beta\gamma} - t_{\gamma\alpha}$ will fall. There are, as drawn, two stable equilibria, one at a,corresponding to the use of the Alpha as vehicle currency, the other at b, corresponding to the use of the

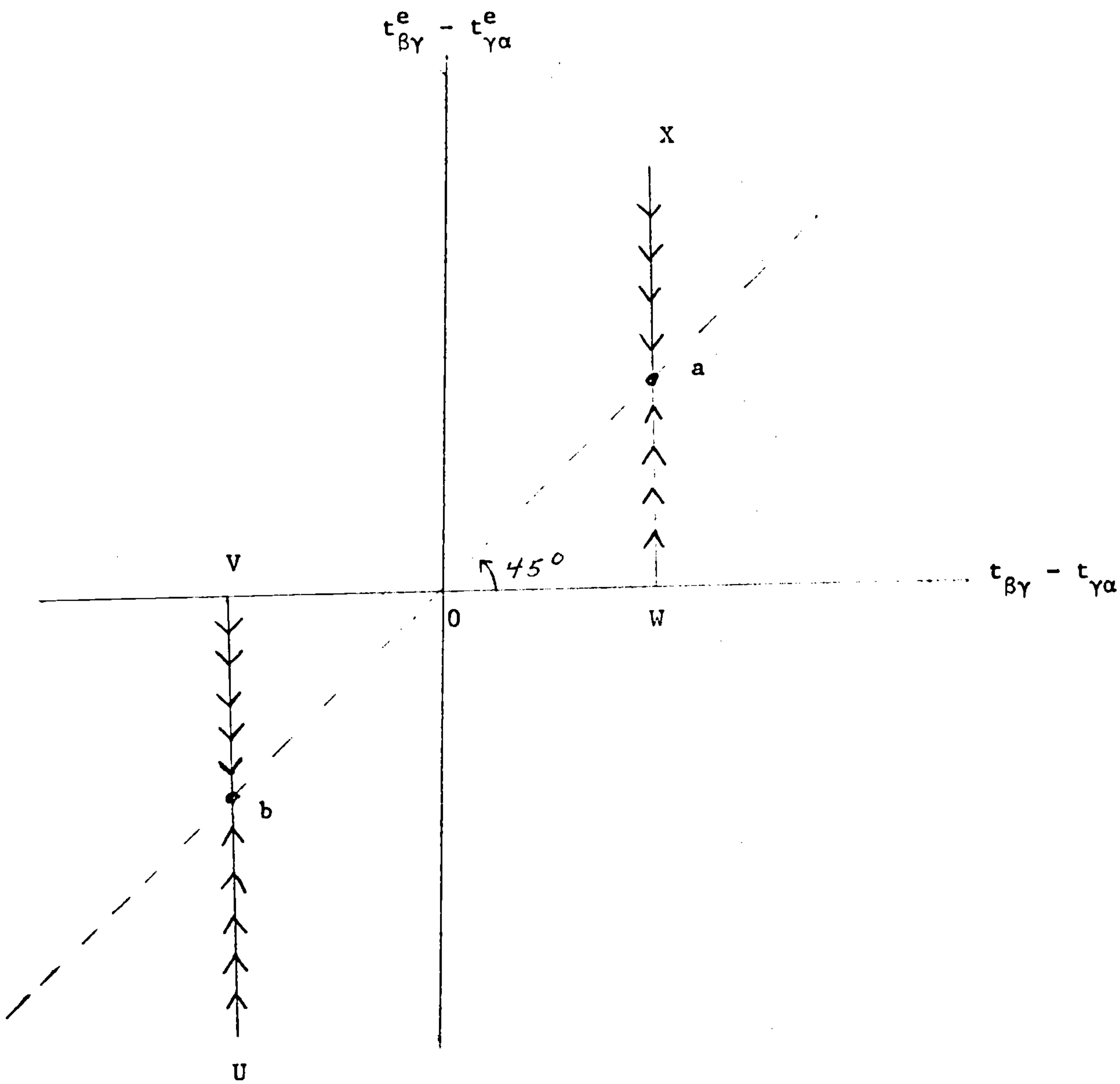
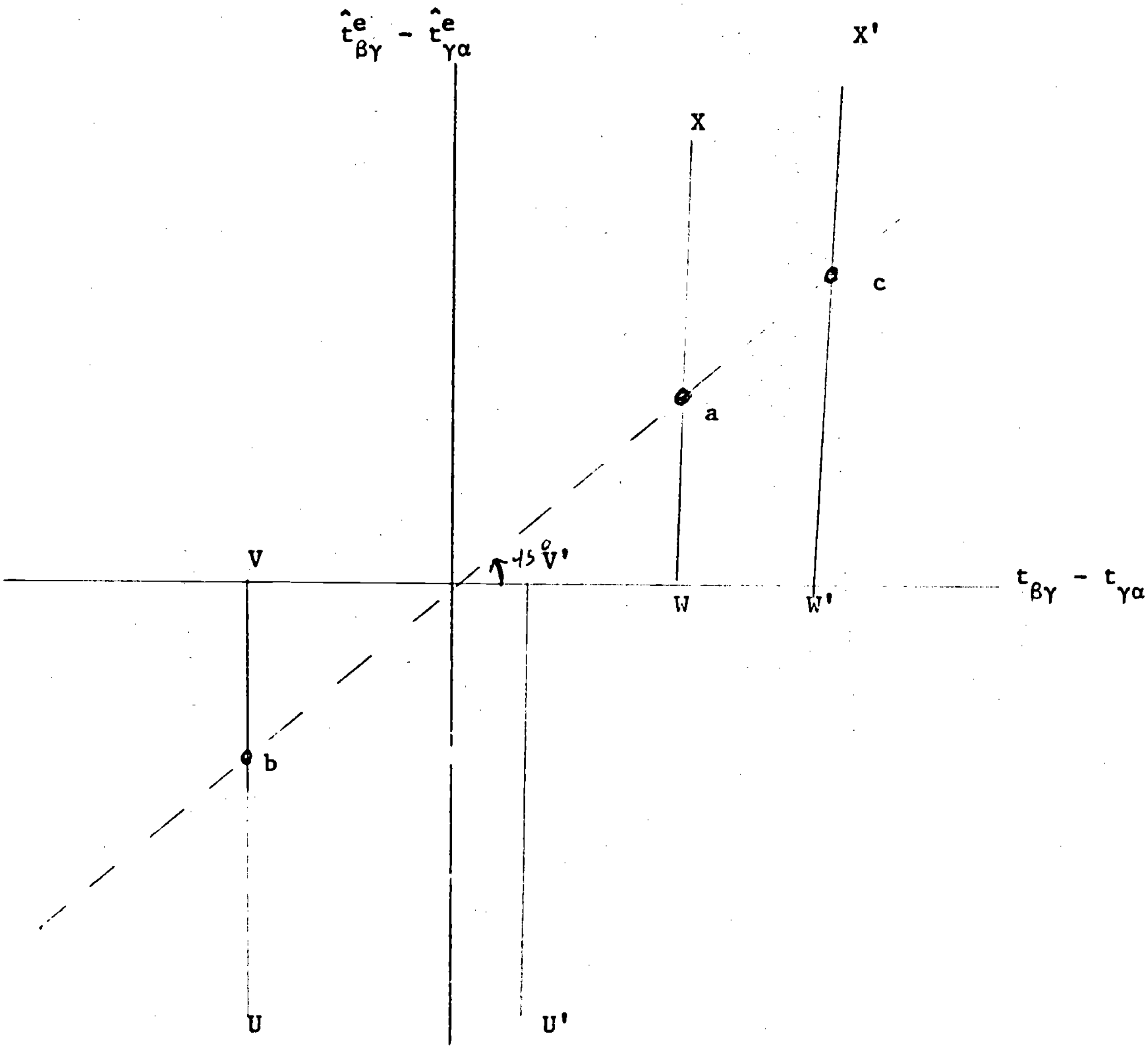

$t^e_{\beta\gamma} - t^e_{\gamma\alpha}$
X
a
45°
V
$t_{\beta\gamma} - t_{\gamma\alpha}$
0
W
b
U

Figure 9



$\hat{t}^{e}_{\beta\gamma} - \hat{t}^{e}_{\gamma\alpha}$
X'
X
c
a
V
45°
V'
W
W'
$t_{\beta\gamma} - t_{\gamma\alpha}$
b
U
U'

Figure 10

Beta. There need not, however, be two equilibria. If V were to shift to the right of the origin, the equilibrium with the Beta as vehicle currency would disappear; similarly, a leftward shift of W could eliminate the possible role of the Alpha. This provides a clue to how the structure of exchange might evolve over time, to which I will return in a moment.

First, however, let us consider another special case. Suppose that we can be certain that the Alpha will be the vehicle currency, so that the only question is whether indirect exchange will be partial or total. (A sufficient condition is R - I, T - I both greater than S in Figure 2, together with the assumption that we do not start from a position of total indirect exchange using the Beta or Gamma). Then we can focus on the difference between transaction costs in direct and indirect exchange,

$$(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) - (1 - t_{\beta\gamma}).$$

We need not draw the dynamic system in this case, since it will look just like that in Figure 9 except for a relabelling of the axes. Again there will be at most two stable equilibria, one corresponding to partial and the other to total indirect exchange. If country A is sufficiently predominant only total indirect exchange will be a stable equilibrium; if transaction costs do not fall enough with volume, only partial indirect exchange will be possible.

Let us consider, finally, how the structure of exchange might evolve over time. If the exchange structure is in stable equilibrium, the only things that can change that are changes in the technology of transactions or, more interestingly, in the structure of payments.[5] To see how changes in the structure of payments alter the exchange structure, let us return to the case illustrated in Figure 9, where the question is whether A's or B's currency will be the vehicle.

In Figure 10 we suppose that the system is initially in equilibrium at b, i.e., the Beta is the international medium of exchange. Over time, we suppose, A's role in world payments grows and B's shrinks. The effect is to shift both V and W right, say to V', W'. At the point at which V passes the origin (which is when T - I in Figure 2 becomes larger than S) the role of the Beta collapses, and the Alpha becomes the vehicle currency. Eventually the system reaches a new equilibrium at c, with the Alpha serving as the international medium of exchange. Interestingly, if the structure of payments were then to shift back to its original position, so that the lines U' V', W'X' shift back to UV, WX, there would nonetheless have been a permanent change in the structure of exchange from that implied by b to that implied by a.

This sequence of events suggests two important features of the dynamics of the exchange structure. The first is that the international monetary system is subject to "tipping"; gradual change in the underlying structure of payments can, when it reaches a critical point, lead to abrupt changes in the structure of exchange. The second feature is the way permanent changes can result from temporary events. If a country temporarily holds a dominant position in world payments which establishes its currency as an international medium of exchange, its currency may continue to play that role even after the commercial preeminence of the country has passed.

In this paper I have attempted to answer in a systematic way the rather subtle question of why some currencies have functioned as international media of exchange. The model set forth in this paper is, of course, highly simplified. Nonetheless, it gives results which look as if they have something to do with the actual experience of international monetary history. And the model shows that it is possible to deal in at least a rudimentary way with the role of transaction costs in international financial markets.

Notes

1/ Authors who have discussed the role of vehicle currencies, and stressed the parallel with the use of money in domestic exchange, include Kindleberger (1976), Swoboda (1968), McKinnon (1969), and Chrystal (1977). Discussions of transaction costs and the structure of exchange in closed economies include papers by Niehans (1969) and Jones (1976), as well as a distinguished tradition going back to Jevons (1875) and Menger (1892).

2/ A similar approximation is made by Jones (1976), who assumes in his model of domestic exchange that costs of trading have no effect on Walrasian market-clearing prices.

3/ Note that we are finding a value of D which would set $X_{\beta\gamma} = 0$ if the implied choices of direct vs. indirect exchange took place _without_ transaction costs.

4/ To the extent that the costs of transactions arise from the necessity of holding working balances in currencies, transaction costs will also depend on the holding costs. I.e., if the Beta is expected to depreciate, this would raise $t_{\beta\gamma}$ and $t_{\alpha\beta}$ relative to $t_{\gamma\alpha}$. This may be important in explaining how a vehicle currency, once established, can lose its special role, see footnote 5, below.

5/ Strictly speaking, an exchange structure could also be disrupted by changes in the perceived costs of holding working balances in different currencies, as already mentioned in footnote 4. Thus one way of interpreting Figure 10 is that a "loss of confidence" in the Beta raises $t_{\beta\gamma}$ relative to $t_{\gamma\alpha}$. This could lead to an unraveling of the Beta's role as vehicle. Notice that even if the loss in confidence is only temporary, it can still have a permanent effect on the structure of exchange.

Appendix: Clockwisdom and the Equilibrium Structure of Exchange

In Section II a concept of approximate equilibrium in the presence of transaction costs was developed and it was stated that:

(i) If $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) < (1 - t_{\beta\gamma})$, the approximate equilibrium will be one with $D = (1 - t_{\beta\gamma})/(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})$, and where the only indirect exchange is of Gammas for Betas;

(ii) If $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) \quad (1 - t_{\beta\gamma})$, D will be indeterminate in the range $(1 - t_{\beta\gamma})/(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})$ to $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})/(1 - t_{\beta\gamma})$, and all Beta-Gamma exchanges will take place indirectly. The purpose of this appendix is to demonstrate these propositions.

In making this demonstration, we can use two helpful aspects of the model already mentioned in the text. First, because of the budget constraints of the countries, it is sufficient to consider only one market, e.g. the $\beta\gamma$ market. Second, the excess demand for Gammas on the $\beta\gamma$ market is non-decreasing in D, since increases in D can never encourage a shift away from clockwise or towards counterclockwise indirect exchange. This means that if for D slightly less than D_0 we find $X_{\beta\gamma} < 0$, while for D slightly more than D_1 we find $X_{\beta\gamma} > 0$, <u>all</u> equilibrium values of D must lie in the range D_0 to D_1.

Let us begin by analyzing the choice between direct and indirect exchange. Consider the example of an exchange of Alphas for Gammas. In direct exchange, after transaction costs one could get $E_{\gamma\alpha}^{-1}(1 - t_{\gamma\alpha})$ Gammas per Alpha. In indirect exchange one could get $E_{\alpha\beta}E_{\beta\gamma}(1 - t_{\alpha\beta})(1 - t_{\beta\gamma})$ Gammas per Alpha. Clearly the breakpoint is $E_{\alpha\beta}E_{\beta\gamma}E_{\gamma\alpha} = D = (1 - t_{\gamma\alpha})/(1 - t_{\alpha\beta})(1 - t_{\beta\gamma})$. A similar exercise can be carried out for all such exchanges, yielding critical values of D, as shown in Table A-1. For entries below the diagonal in the table the value is that of the <u>minimum</u> D which will lead to indirect exchange; for entries above the diagonal it is the <u>maximum</u>.

Table A-1: Critical values of D for indirect exchange

Initial currency \ Final Currency	α	β	γ
α	———	$\frac{(1 - t_{\beta\gamma})(1 - t_{\gamma\alpha})}{(1 - t_{\alpha\beta})}$	$\frac{(1 - t_{\alpha\beta})(1 - t_{\beta\gamma})}{(1 - t_{\gamma\alpha})}$
β	$\frac{(1 - t_{\alpha\beta})}{(1 - t_{\beta\gamma})(1 - t_{\gamma\alpha})}$	———	$\frac{(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})}{(1 - t_{\beta\gamma})}$
γ	$\frac{(1 - t_{\gamma\alpha})}{(1 - t_{\alpha\beta})(1 - t_{\beta\gamma})}$	$\frac{(1 - t_{\beta\gamma})}{(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})}$	———

Given a value of D, together with information on the structure of transaction costs, we can determine for each type of exchange whether direct or indirect exchange is preferred. I will use a "+" to indicate a preference for indirect exchange, a "-" to indicate a preference for direct exchange, and a "0" to indicate indifference.

We can now proceed to cases. Recall that we have labelled countries so that $t_{\alpha\beta}$, $t_{\gamma\alpha}$ both less than $t_{\beta\gamma}$. Also, the underlying structure of payments is assumed to be that shown in Figure 2.

<u>Case 1</u>: $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) < (1 - t_{\beta\gamma})$. In this case it is immediately clear that $D = (1 - t_{\beta\gamma})/(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})$ corresponds to an equilibrium. Referring to Table A-1, we have a matrix of preferred exchanges

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & - \\ \gamma & - & 0 & \end{array}$$

Thus exchanges of Gammas for Betas may take place either directly or indirectly, which is consistent with an equilibrium of partial indirect exchange as illustrated in Figure 3. This equilibrium is unique. To see this, note that for a slightly higher D the matrix becomes

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & - \\ \gamma & - & + & \end{array}$$

which leads to $X_{\beta\gamma} = S - I > 0$; while for a slightly lower D we have the matrix

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & - \\ \gamma & - & - & \end{array}$$

which leads to $X_{\beta\gamma} = -I < 0$. The unique equilibrium exchange structure, then, is partial indirect exchange with the Alpha as vehicle.

Case 2: $(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha}) > (1 - t_{\beta\gamma})$. In this case, any value of D in the range from $D_0 = (1 - t_{\beta\gamma})(1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})$ to $D_1 = (1 - t_{\alpha\beta})(1 - t_{\gamma\alpha})/(1 - t_{\beta\gamma})$ will lead to a matrix of preferred exchanges

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & + \\ \gamma & - & + & \end{array}$$

This pattern, which means that all payments between B and C take place indirectly, corresponds to an equilibrium of total indirect exchange, as shown in Figure 4. This is the unique equilibrium structure although D is indeterminate. If D were slightly above D_1, the matrix of preferred exchanges would be

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & - \\ \gamma & - & + & \end{array}$$

which would produce an excess demand for Gammas of S − I on the $\beta\gamma$ market. If D were slightly below D_0, the matrix would be

$$\begin{array}{cccc} & \alpha & \beta & \gamma \\ \alpha & & - & - \\ \beta & - & & + \\ \gamma & - & - & \end{array}$$

which would produce an excess supply of S Gammas on the $\beta\gamma$ market. So the equilibrium structure of exchange must be total indirect exchange with the Alpha as vehicle.

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