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Ricardian model

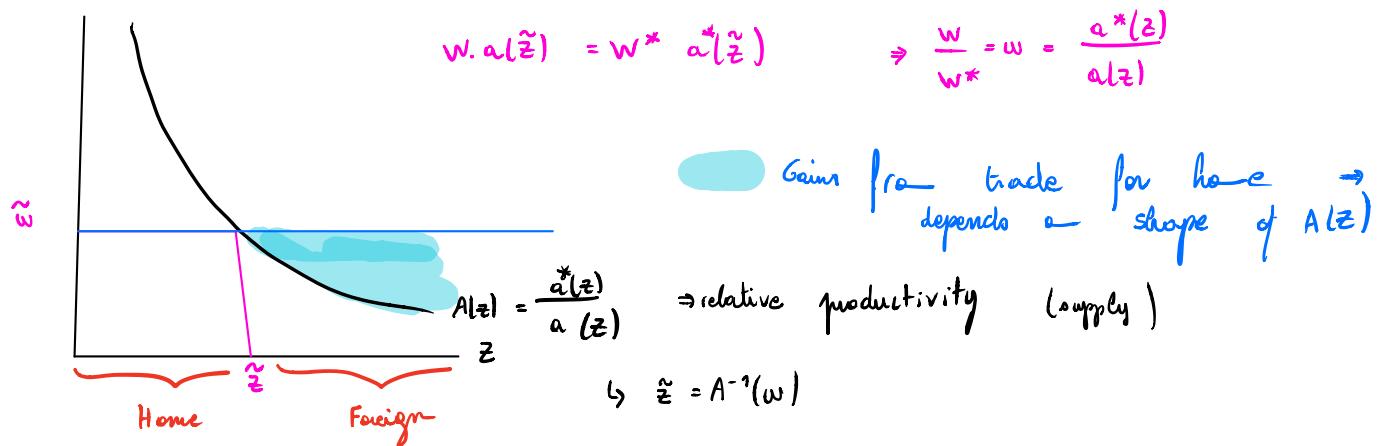
- multiple goods produced with one factor
- CRS is the product of each good
  - ↳  $a_{ij}$  for good  $i$ , country  $j$ :
  - trade bc  $a_{ij} \neq a_{ij'}$

⇒ trade bc ≠ TFP across countries



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Gains from trade

Cobb Douglas price index

$$w = 1$$

$$\ln\left(\frac{w}{l}\right) = \ln w - \int_0^1 b(z) \ln \frac{1}{a(z)} dz \approx \ln\left(\frac{w}{p}\right) \rightarrow \text{real wage}$$

$$\int_0^1 b(z) \ln a(z) dz \quad \text{vs} \quad \int_0^{\bar{z}} b(z) \ln a(z) dz + \int_{\bar{z}}^1 b(z) \ln w^* a^*(z) dz$$

$$\int_{\bar{z}}^1 b(z) \ln a(z) dz \quad \text{vs} \quad \int_{\bar{z}}^1 b(z) \ln w^* a^*(z) dz$$

$$\rightarrow \int_{\bar{z}}^1 b(z) \cdot \ln\left(\frac{A(z)}{w}\right) dz$$

$\hookrightarrow \ln(A(z)) \leq \bar{w}$ , = at the cutoff, < for  $z \in (\bar{z}, 1]$

$$\int_{\bar{z}}^1 b(z) dz \geq \underbrace{\int_{\bar{z}}^1 b(z) \ln\left(\frac{A(z)}{w}\right) dz}_{\text{subtract stg bigger}}$$

⇒ gains from trade depend on relative factor prices technology (shape  $A(z)$ )

## Comparative statics to prep growth

↳ Good switches nominal price ratio

$$\frac{w^* \alpha^*(z)}{w \alpha(z)}$$

$$\left. \begin{array}{l} w \\ w' \\ w^* \\ w^{*'} \end{array} \right\} \text{prices}$$

↳ new real consumer price of the good:

$$\frac{\frac{w^* \alpha^*(z)}{w} / w'}{w \alpha(z) / w} = \underbrace{\frac{w^*}{w'}}_{\frac{1}{1-\bar{\omega}}} \cdot \frac{\alpha^*(z)}{\alpha(z)} \cdot A(z)$$

# Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods

By R. DORNBUSCH, S. FISCHER, AND P. A. SAMUELSON\*

This paper discusses Ricardian trade and payments theory in the case of a continuum of goods. The analysis thus extends the development of many-commodity, two-country comparative advantage analysis as presented, for example, in Gottfried Haberler (1937), Frank Graham (1923), Paul Samuelson (1964), and Frank W. Taussig (1927). The literature is historically reviewed by John Chipman (1965). Perhaps surprisingly, the continuum assumption simplifies the analysis neatly in comparison with the discrete many-commodity case. The distinguishing feature of the Ricardian approach emphasized in this paper is the determination of the competitive margin in production between imported and exported goods.

The analysis advances the existing literature by formally showing precisely how tariffs and transport costs establish a range of commodities that are not traded, and how the price-specie flow mechanism does or does not give rise to movements in relative cost and price levels.

The formal *real* model is introduced in Section I. Its equilibrium determines the relative wage and price structure and the efficient international specialization pattern. Section II considers standard comparative static questions of growth, demand shifts, technological change, and transfers. Extensions of the model to nontraded goods, tariffs, and transport costs are then studied in Section III. Monetary considerations are introduced in Section IV, which examines the price-specie mechanism under stable parities, floating exchange rate regimes, and also questions of unemployment under sticky money wages.

\*Massachusetts Institute of Technology. Helpful comments from Ronald W. Jones are gratefully acknowledged. Financial support was provided by a Ford Foundation grant to Dornbusch, NSF GS-41428 to Fischer, and NSF 75-04053 to Samuelson.

## I. The Real Model

In this section we develop the basic real model and determine the equilibrium relative wage and price structure along with the efficient geographic pattern of specialization. Assumptions about technology are specified in Section IA. Section IB deals with demand. In Section IC the equilibrium is constructed and some of its properties are explored. Throughout this section we assume zero transport costs and no other impediments to trade.

### A. Technology and Efficient Geographic Specialization

The many-commodity Ricardian model CRS assumes constant unit labor requirements ( $a_1, \dots, a_n$ ) and ( $a_1^*, \dots, a_n^*$ ) for the  $n$  commodities that can be produced in the home and foreign countries, respectively. The commodities are conveniently indexed so that relative unit labor requirements are ranked in order of diminishing home country comparative advantage,

$$a_1^*/a_1 > \dots > a_i^*/a_i > \dots > a_n^*/a_n$$

where an asterisk denotes the foreign country.

In working with a continuum of goods, we similarly index commodities on an interval, say  $[0, 1]$ , in accordance with diminishing home country comparative advantage. A commodity  $z$  is associated with each point on the interval, and for each commodity there are unit labor requirements in the two countries,  $a(z)$  and  $a^*(z)$ , with relative unit labor requirement given by

$$(1) \quad A(z) \equiv \frac{a^*(z)}{a(z)} \quad A'(z) < 0$$

The relative unit labor requirement function in (1) is by strong assumption continuous

and by construction (ranking or indexing of goods), decreasing in  $z$ . The function  $A(z)$  is shown in Figure 1 as the downward sloping schedule.

Consider now the range of commodities produced domestically and those produced abroad, as well as the relative price structure associated with given wages. For that purpose we define as  $w$  and  $w^*$  the domestic and foreign wages measured in *any* (common!) unit. The home country will efficiently produce all those commodities for which domestic unit labor costs are less than or equal to foreign unit labor costs. Accordingly, any commodity  $z$  will be produced at home if

$$(2) \quad a(z)w \leq a^*(z)w^* \quad \text{produce at home if cheaper}$$

Thus

$$(2') \quad \omega \leq A(z)$$

where (3) defines the parameter  $\omega$ , fundamental to Ricardian analysis,

$$(3) \quad \omega = w/w^*$$

This is the ratio of our real wage to theirs (our "double-factoral terms of trade"). It follows that for a given relative wage  $\omega$  the home country will efficiently produce the range of commodities

$$(4) \quad 0 \leq z \leq \tilde{z}(\omega)$$

where taking (2') with equality defines the borderline commodity  $z$ , for which

$$(5) \quad \tilde{z} = A^{-1}(\omega) \quad \text{threshold}$$

$A^{-1}(\cdot)$  being the inverse function of  $A(\cdot)$ . By the same argument the foreign country will specialize in the production of commodities in the range

$$(4') \quad \tilde{z}(\omega) \leq z \leq 1$$

The minimum cost condition determines the structure of relative prices. The relative price of a commodity  $z$  in terms of any other commodity  $z'$ , when both goods are produced in the home country, is equal to the ratio of home unit labor costs:

$$(6) \quad P(z)/P(z') = wa(z)/wa(z') \\ = a(z)/a(z'); \\ z \leq \tilde{z}, z' \leq \tilde{z}$$

The relative price of home produced  $z$  in terms of a commodity  $z''$  produced abroad is by contrast

$$(7) \quad P(z)/P(z'') = wa(z)/w^*a^*(z'') \\ = \omega a(z)/a^*(z''); \\ z < \tilde{z} < z''$$

In summarizing the supply part of the model we note that any specified relative real wage is associated with an efficient geographic specialization pattern characterized by the borderline commodity  $\tilde{z}(\omega)$  as well as by a relative price structure. (The pattern is "efficient" in the sense that the world is out on, and not inside, its production-possibility frontier.)

### B. Demand

On the demand side, the simplest Mill-Ricardo analysis imposes a strong homothetic structure in the form of J. S. Mill or Cobb-Douglas demand functions that associate with each  $i$ th commodity a constant expenditure share,  $b_i$ . It further assumes identical tastes for the two countries or uniform homothetic demand.

By analogy with the many-commodity case, which involves budget shares

$$b_i = P_i C_i / Y \quad b_i = b_i^*$$

$$\sum_1^n b_i = 1$$

directe

We therefore prescribe for the continuum case a given  $b(z)$  profile:

$$(8) \quad b(z) = P(z)C(z)/Y > 0 \\ b(z) = b^*(z)$$

$$\int_0^1 b(z) dz = 1$$

continuum

where  $Y$  denotes total income,  $C$  demand for and  $P$  the price of commodity  $z$ .

Next we define the fraction of income spent (anywhere) on those goods in which the home country has a comparative advantage:

$$(9) \quad \vartheta(\tilde{z}) \equiv \int_0^{\tilde{z}} b(z) dz > 0 \\ \vartheta'(\tilde{z}) = b(\tilde{z}) > 0$$

where again  $(0, \tilde{z})$  denotes the range of commodities for which the home country enjoys a comparative advantage. With a fraction  $\vartheta$  of each country's income, and therefore of world income, spent on home produced goods, it follows that the fraction of income spent on foreign produced commodities is

$$(9') 1 - \vartheta(\tilde{z}) = \int_{\tilde{z}}^1 b(z) dz$$

$$0 \leq \vartheta(z) \leq 1$$

*RHS: what home producers get  
LHS: what they spend on factors = wL  
common to both?*

C. Equilibrium Relative Wages and Specialization

To derive the equilibrium relative wage and price structure and the associated pattern of efficient geographic specialization, we turn next to the condition of market equilibrium. Consider the home country's labor market, or equivalently the market for domestically produced commodities. With  $\tilde{z}$  denoting the *hypothetical* dividing line between domestically and foreign produced commodities, equilibrium in the market for home produced goods requires that domestic labor income  $wL$  equals world spending on domestically produced goods:

$$(10) \quad \frac{wL}{\text{domestic labor income}} = \vartheta(\tilde{z}) \left( \frac{wL}{\text{value exports}} + \frac{w^* L^*}{\text{value imports}} \right)$$

Equation (10) associates with each  $\tilde{z}$  a value of the relative wage  $w/w^*$  such that market equilibrium obtains. This schedule is drawn in Figure 1 as the upward sloping locus and is obtained from (10) by rewriting the equation in the form:

$$(10') \quad \omega = \frac{\vartheta(\tilde{z})}{1 - \vartheta(\tilde{z})} (L^*/L) = B(\tilde{z}; L^*/L)$$

where it is apparent from (9) that the schedule starts at zero and approaches infinity as  $\tilde{z}$  approaches unity.

To interpret the  $B(\ )$  schedule we note that it is entirely a representation of the demand side; and in that respect it shows that if the range of domestically produced goods were increased at constant relative wages, demand for domestic labor (goods) would increase as the dividing line is shifted —at the same time that demand for foreign

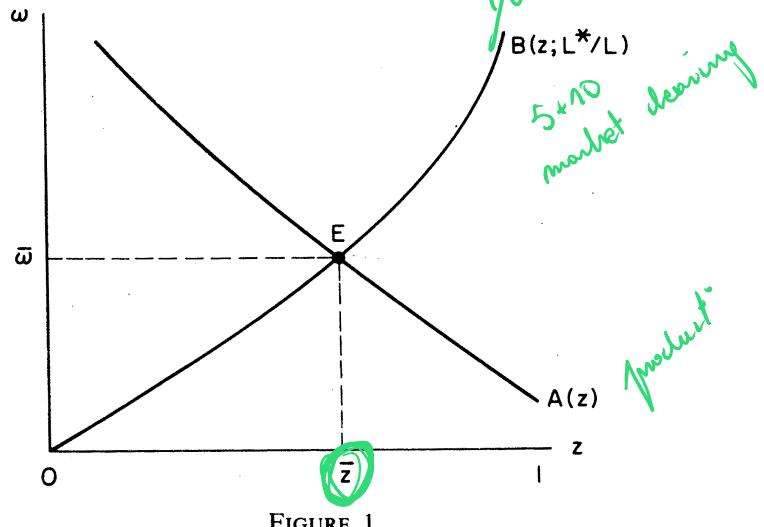


FIGURE 1

labor (goods) would decline.<sup>1</sup> A rise in the domestic relative wage would then be required to equate the demand for domestic labor to the existing supply.

An alternative interpretation of the  $B(\ )$  schedule as the locus of trade balance equilibria uses the fact that (10) can be written in the balance-of-trade form:

$$(10'') \quad [1 - \vartheta(\tilde{z})] wL = \vartheta(\tilde{z}) w^* L^*$$

This states that equilibrium in the trade balance means imports are equal in value to exports. On this interpretation, the  $B(\ )$  schedule is upward sloping because an increase in the range of commodities hypothetically produced at home at constant relative wages lowers our imports and raises our exports. The resulting trade imbalance would have to be corrected by an increase in our relative wage that would raise our import demand for goods and reduce our exports, and thus restore balance.

The next step is to combine the demand side of the economy with the condition of efficient specialization as represented in equation (5), which specifies the competitive margin as a function of the relative wage. Substituting (5) in (10') yields as a solution the unique relative wage  $\bar{\omega}$ , at which the world is efficiently specialized, is in bal-

<sup>1</sup>Throughout this paper we refer to "domestic" goods as commodities produced in the home country rather than to commodities that are nontraded. The latter we call "nontraded" goods.

anced trade, and is at full employment with all markets clearing:

$$(11) \quad \bar{\omega} = A(\bar{z}) = B(\bar{z}; L^*/L)$$

The equilibrium relative wage defined in (11) is represented in Figure 1 at the intersection of the  $A(z)$  and  $B(z)$  schedules.<sup>2</sup> Commodity  $\bar{z}$  denotes the equilibrium borderline of comparative advantage between commodities produced and exported by the home country ( $0 \leq z \leq \bar{z}$ ), and those commodities produced and exported by the foreign country ( $\bar{z} \leq z \leq 1$ ).

Among the characteristics of the equilibrium we note that the equilibrium relative wages and specialization pattern are determined by technology, tastes, and relative size (as measured by the relative labor force).<sup>3</sup> The relative price structure associated with the equilibrium at point  $E$  is defined by equations (6) and (7) once (11) has defined the relative wage  $\bar{\omega}$  and the equilibrium specialization pattern  $\bar{z}(\bar{\omega})$ .

The equilibrium levels of production  $Q(z)$  and  $Q^*(z)$ , and employment in each industry  $L(z)$  and  $L^*(z)$ , can be recovered from the demand structure and unit labor requirements once the comparative advantage pattern has been determined.

We note that with identical homothetic tastes across countries and no distortions, the relative wage  $\bar{\omega}$  is a measure of the well-

being of the representative person-laborer at home relative to the well-being of the representative foreign laborer.

## II. Comparative Statics

The unique real equilibrium in Figure 1 is determined jointly by tastes, technology, and relative size,  $L^*/L$ . We can now exploit Figure 1 to examine simple comparative static questions.

### A. Relative Size

Consider first the effect of an increase in the relative size of the rest of the world. An increase in  $L^*/L$  by (10) shifts the  $B(z)$  trade balance equilibrium schedule upward in proportion to the change in relative size and must, therefore, raise the equilibrium relative wage at home and reduce the range of commodities produced domestically. It is apparent from Figure 2 that the domestic relative wage increases *proportionally less* than the decline in domestic relative size.

The rise in equilibrium relative wages due to a change in relative size can be thought of in the following manner. At the initial equilibrium, the increase in the foreign relative labor force would create an excess supply of labor abroad and an excess demand for labor at home—or, correspondingly, a trade surplus for the home country. The resulting increase in domestic relative wages serves to eliminate the trade surplus while

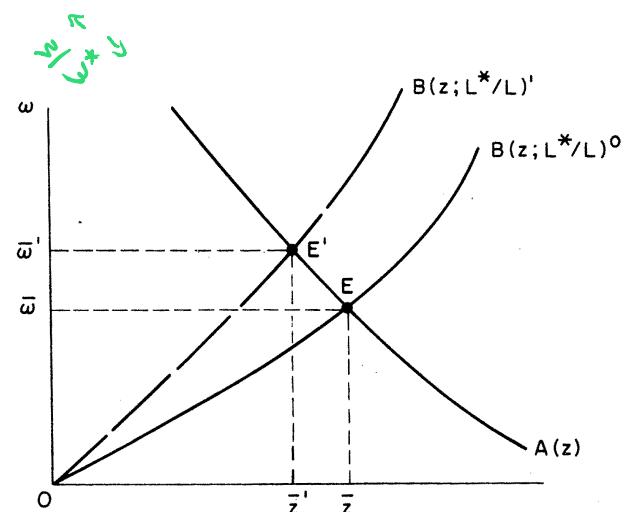


FIGURE 2

<sup>2</sup>See the Appendix for the relation of the diagram to previous analyses.

<sup>3</sup>The construction of the  $B(z)$  schedule relies heavily on the Cobb-Douglas demand structure. If, instead, demand functions were identical across countries and homothetic, an analogous schedule could be constructed. In the general homothetic case, however, a set of relative prices is required at each  $z$  to calculate the equivalent of the  $B(z)$  schedule; the relative prices are those that apply on the  $A(\bar{z})$  schedule for that value of  $z$ . In this case the independence of the  $A(z)$  and  $B(z)$  schedules is obviously lost. In the general homothetic case there is still a unique intersection of the  $A(z)$  and  $B(z)$  schedules. For more general nonhomothetic demand structures, it is known that an equilibrium exists; but even in the case of two Ricardian goods there may be *no* unique equilibrium even though there will almost always be a finite number of equilibria. See Gerard Debreu and Stephen Smale. Extensions of our analysis with respect to the demand structure and the number of countries are developed in unpublished work by Charles Wilson.

at the same time raising relative unit labor costs at home. The increase in domestic relative unit labor costs in turn implies a loss of comparative advantage in marginal industries and thus a needed reduction in the range of commodities produced domestically.

The welfare implications of the change in relative size take the form of an unambiguous improvement in the home country's real income and (under Cobb-Douglas demand) a reduction in real income per head abroad. We observe, too, that from the definition of the home country's share in world income and (10), we have

$$(12) \quad wL/(wL + w^* L^*) = \vartheta(\bar{z})$$

It is apparent, as noted above, that a reduction in domestic relative size in raising the domestic relative wage (thereby reducing the range of commodities produced domestically) must under our Cobb-Douglas demand assumptions lower the home country's share in total world income and spending—even though our per capita income rises.

### B. Technical Progress

To begin with, we are concerned with the effects of uniform technical progress. By equation (1), a uniform proportional reduction in foreign unit labor requirements implies a reduction in  $a^*(z)$  and therefore a proportional downward shift of the  $A(z)$  schedule in Figure 1. At the initial relative wage  $\bar{\omega}$ , the loss of our comparative advantage due to a reduction in foreign unit labor costs will imply a loss of some industries in the home country and a corresponding trade deficit. The resulting induced decline in the equilibrium relative wage serves to restore trade balance equilibrium, and to offset in part our decline in comparative advantage.

The net effect is therefore a reduction in domestic relative wages, which must fall proportionally short of the decline in relative unit labor requirements abroad. The home country's terms of trade therefore improve as can be noted by using (7) for any two commodities  $z$  and  $z''$ , respectively, produced at home and abroad:

$$(13) \quad \hat{P}(z) - \hat{P}(z'') = \hat{\omega} - \hat{a}^*(z'') > 0$$

where a "hat" denotes a proportional change. Domestic real income increases, as does foreign real income.<sup>4</sup> The range of goods produced domestically declines since domestic labor, in efficiency units, is now relatively more scarce.

An alternative form of technical progress that can be studied is the international transfer of the least cost technology. Such transfers reduce the discrepancies in relative unit labor requirements—by lowering them for each  $z$  in the relatively less efficient country—and therefore flatten the  $A(z)$  schedule in Figure 1. It can be shown that such harmonization of technology must benefit the innovating low-wage country, and that it may reduce real income in the high-wage country whose technology comes to be adopted. In fact, the high-wage country must lose if harmonization is complete so that relative unit labor requirements now become identical across countries and all our consumer's surplus from international trade vanishes.<sup>5</sup>

### C. Demand Shifts

The case with a continuum of commodities requires a careful definition of a demand shift. For our purposes it is sufficient to ask: What is the effect of a shift from high  $z$  commodities toward low  $z$  commodities? It is apparent from Figure 2 that such a shift will cause the trade balance equilibrium schedule  $B( )$  to shift up and to the left. It follows that the equilibrium domestic rela-

<sup>4</sup>The purchasing power of foreign labor income in terms of domestically produced goods is  $w^* L^*/w a(z) = L^*/a(z)\bar{\omega}$  and in terms of foreign goods  $L^*/a^*(z)$ . The fact that foreigners' real income per head rises is guaranteed by our Cobb-Douglas demand assumption. In the general homothetic case, a balanced reduction in  $a^*(z)$  can be immiserizing abroad if the real wage falls strongly in terms of all previously imported goods; however, the balanced drop in  $a^*(z)$  in the general homothetic case always increases our real wage.

<sup>5</sup>Complete equilibration of unit labor requirements implies that the  $A( )$  schedule is horizontal at the level  $\omega = A(z) = 1$ . In this case geographic specialization becomes indeterminate and inessential.

tive wage will rise while the range of commodities produced by the home country declines. Domestic labor is allocated to a narrower range of commodities that are consumed with higher density while foreign labor is spread more thinly across a larger range of goods.

Welfare changes cannot be identified in this instance because tastes themselves have changed. It is true that domestic relative income rises along with the relative wage. Further we note that since  $\bar{\omega}$  rises, the relative well-being of home labor to foreign labor (reckoned at the new tastes) is greater than was our laborers' relative well-being (reckoned at the old tastes).

#### D. Unilateral Transfers

Suppose foreigners make a continual unilateral transfer to us. With uniform homothetic tastes and no impediments to trade, neither curve is shifted by the transfer since we spend the transfer *exactly* as foreigners would have spent it but for the transfer. The new equilibrium involves a recurring trade deficit for us, equal to the transfer, but there is no change in the terms of trade. As Bertil Ohlin argued against John Maynard Keynes, here is a case where full equilibration takes place solely as a result of the spending transfers. When we introduce nontraded goods below, Ohlin's presumption will be found to require detailed qualifications, as it also would if tastes differed geographically.

### III. Extensions of the Real Model

Extensions of the real model taken up in this section concern nontraded goods, tariffs, and transport costs. The purpose of this section is twofold. First we establish how the exogenous introduction of nontraded goods qualifies the preceding analysis. Next we turn to a particular specification of tariffs and transport costs to establish an equilibrium range of endogenously determined nontraded goods as part of the equilibrium solution of the model. Transfers are then shown to affect the equilibrium

relative price structure and the range of goods traded.

#### A. Nontraded Goods

To introduce nontraded goods into the analysis we assume that a fraction  $k$  of income is everywhere spent on internationally traded goods, and a fraction  $(1 - k)$  is spent in each country on nontraded commodities. With  $b(z)$  continuing to denote expenditure densities for traded goods, we have accordingly

$$(14) \quad k \equiv \int_0^1 b(z) dz < 1$$

where  $z$  denotes traded goods.<sup>6</sup> As before the fraction of income spent on domestically exportable commodities is  $\vartheta(z)$ , except that  $\vartheta$  now reaches a maximum value of  $\vartheta(1) = k$ .  $(10'') \quad [1 - \vartheta(\bar{z})]wL = \vartheta(\bar{z})w^*L^*$

Equation (1) remains valid for traded goods, but the trade balance equilibrium condition in  $(10'')$  must now be modified to:

$$(15) \quad [1 - \vartheta(\bar{z}) - (1 - k)]wL = \vartheta(\bar{z})w^*L^*$$

since domestic spending on imports is equal to income less spending on *all* domestically produced goods including nontraded commodities. Equation (15) can be rewritten as

$$(15') \quad \omega = \frac{\vartheta(\bar{z})}{k - \vartheta(\bar{z})} (L^*/L)$$

where  $k$  is a constant and therefore independent of the relative wage structure.

We note that (15') together with (5) determines the equilibrium relative wage and efficient geographic specialization,  $(\bar{\omega}, \bar{z})$ . Further it is apparent that (15') has exactly the same properties as (10') and that accordingly a construction of equilibrium like that in Figure 1 remains appropriate. The equilibrium relative wage again depends on

<sup>6</sup>We can think of the range of nontraded goods as another  $[0, 1]$  interval with commodities denoted by  $x$  and expenditure fractions on those goods given by  $c(x)$ . With these definitions we have  $\int_0^1 c(x) dx = 1 - k$ , a positive fraction.

relative size, technology, and demand conditions. In this case demand conditions explicitly include the fraction of income spent on traded goods:

$$(11') \quad \bar{\omega} = \frac{\vartheta(\bar{z})}{k - \vartheta(\bar{z})} \frac{L^*}{L} = A(\bar{z})$$

This nicely generalizes our previous equilibrium of (11) to handle exogenously given nontraded goods.<sup>7</sup>

Two applications of the extended model highlight the special aspects newly introduced by nontraded goods. First consider a shift in demand (in each country) toward *nontraded* goods. To determine the effects on the equilibrium relative wage we have to establish whether this shift is at the expense of high or low  $z$  commodities. In the former case the home country's relative wage increases while in the latter case it declines. If the shift in demand in each country is uniform so that  $b(z)$  is reduced in the same proportion for all  $z$  in both countries, then the relative wage remains unchanged.

Consider next a transfer received by the home country in the amount  $T$  measured in terms of foreign labor. As is well known, and already shown, with identical homothetic tastes and *no* nontraded goods, a transfer leaves the terms of trade unaffected. In the present case, however, the condition for balanced trade, inclusive of transfers, becomes:

$$(16) \quad T = (k - \vartheta)[\omega L + T] - \vartheta[L^* - T]$$

or, in equilibrium,

$$(16') \quad \bar{\omega} = \frac{1 - k}{k - \vartheta(\bar{z})} (T/L) + \frac{\vartheta(\bar{z})}{k - \vartheta(\bar{z})} (L^*/L)$$

It is apparent from (16') that a transfer receipt by the home country causes the trade balance equilibrium schedule in Figure 1 to shift upward at each level of  $z$ . Accordingly, the equilibrium domestic rela-

<sup>7</sup>Diagrams much like Figures 1 and 2 again apply: the descending  $A(z)$  schedule is as before; and now the new rising schedule looks much as before. As before, a rise in  $L^*/L$  and a balanced drop in  $a^*(z)$  will raise  $\bar{\omega}$  and lower  $\bar{z}$ .

tive wage increases and the range of commodities produced domestically is reduced. The steps in achieving this result are, first, that at the initial relative wage only a fraction of the transfer is spent on imports in the home country, while foreign demand for domestic goods similarly declines only by a fraction of their reduced income. The resulting surplus for the home country has to be eliminated by, second, an increase in the domestic relative wage and a corresponding improvement in the home country's terms of trade.<sup>8</sup>

The analysis of nontraded goods therefore confirms in a Ricardian model the "orthodox" presumption with respect to the terms of trade effects of transfers.<sup>9</sup>

### B. Transport Costs: Endogenous Equilibrium for Nontraded Goods

The notion that transport costs give rise to a range of commodities that are nontraded is established in the literature and is particularly well stated by Haberler (1937). In contrast with the previous section we shall now endogenously determine the range of nontraded commodities as part of the equilibrium. We assume, following the "iceberg" model of Samuelson (1954), that transport costs take the form of "shrinkage" in transit so that a fraction  $g(z)$  of commodity  $z$  shipped actually arrives. We further impose the assumption that  $g = g(z)$  is identical for all commodities and the same for shipments in either direction.

The home country will produce commodities for which domestic unit labor cost falls short of foreign unit labor costs adjusted for shrinkage, and we modify (2') accordingly:

$$(17) \quad wa(z) \leq (1/g) w^* a^*(z)$$

or  $\omega \leq A(z)/g$

<sup>8</sup>At constant relative wages the current account worsens by  $[(1 - k - \vartheta) + \vartheta]dT = (1 - k)dT$  which is less than the transfer, since it is equal to the fraction of income spent on nontraded goods.

<sup>9</sup>The pre-Ohlin orthodox view of Keynes, Taussig, Jacob Viner and other writers is discussed in Viner (1937) and Samuelson (1952, 1954). A recent treatment with nontraded goods is Ronald Jones (1975).

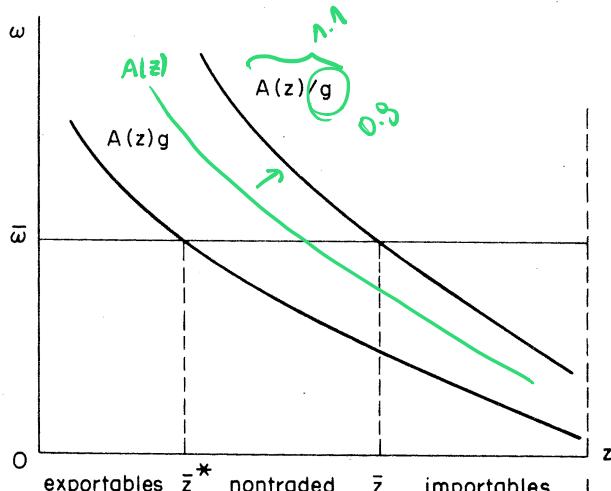


FIGURE 3

Similarly the foreign country produces commodities for which foreign unit labor cost falls short of adjusted unit labor costs of delivered imports:

$$(18) \quad w^*a^*(z) \leq (1/g)w_a(z)$$

$$\text{or} \quad A(z)g \leq \omega$$

In Figure 3 we show the adjusted relative unit labor requirement schedules  $A(z)/g$  and  $A(z)g$ . It is apparent from (17) and (18) that for any given relative wage the home country produces and exports commodities to the left of the  $A(z)g$  schedule, both countries produce as nontraded goods commodities in the intermediate range, and the foreign country produces and exports commodities in the range to the right of  $A(z)/g$ .

To determine the equilibrium relative wage we turn to the trade balance equilibrium condition in (19)—together with (20) and (21)—which is modified to take account of the endogenous range of nontraded goods:

$$(19) \quad (1 - \lambda)wL = (1 - \lambda^*)w^*L^*$$

The variable  $\lambda$  is the fraction of home country income spent on our domestically (or home) produced goods—exportables and nontraded—and  $\lambda^*$  is the share of foreigners' income spent on goods they produce. Both  $\lambda$  and  $\lambda^*$  are endogenously determined because the range of goods produced in each country depends on the relative wages.

$$(20) \quad \lambda(g\omega) \equiv \int_0^{\bar{z}} b(z)dz \quad \lambda'(g\omega) < 0$$

$$\lambda^*(\omega/g) \equiv \int_{\bar{z}}^1 b(z)dz \quad \lambda^{**}(\omega/g) > 0$$

The dependence of  $\lambda(\cdot)$  and  $\lambda^*(\cdot)$  on the variables specified in (20) and the respective derivatives follow from (21) below.

The limits of integration  $\bar{z}$  and  $\bar{z}^*$  are derived from the conditions for efficient production in (17) and (18) by imposing equalities and so defining the borderline commodities. Thus, in Figure 3,  $\bar{z}$  is the borderline between domestic nontraded goods and imports for the home country, and  $\bar{z}^*$  denotes the borderline between foreign nontraded goods and the home country's exports:

$$(21) \quad \bar{z}^* = A^{-1}(\omega/g) \quad d\bar{z}^*/d(\omega/g) < 0$$

$$\bar{z} = A^{-1}(g\omega) \quad d\bar{z}/d(g\omega) < 0$$

Of course, equilibrium  $\bar{z}$  and  $\bar{z}^*$  are yet to be determined by the interaction of technology and demand conditions.

From (21) an increase in the relative wage reduces the range of commodities domestically produced and therefore raises the fraction of income spent on imports. Abroad the converse holds. An increase in the domestic relative wage increases the range of goods produced abroad and therefore reduces the fraction of income spent on imports. It follows that we can solve:

$$(19') \quad \bar{\omega} = \frac{1 - \lambda^*(\bar{\omega}/g)}{1 - \lambda(g\bar{\omega})} (L^*/L)$$

$$\equiv \varphi(\bar{\omega}; L^*/L, g) \quad \partial\varphi/\partial\bar{\omega} < 0$$

for the unique equilibrium relative wage as a function of relative size and transport costs:

$$(22) \quad \bar{\omega} = \bar{\omega}(L^*/L, g)$$

Because (19')'s right-hand side declines as  $\bar{\omega}$  rises, a rise in  $L^*/L$  must still raise  $\bar{\omega}$ ; a rise in  $g$  can shift  $\bar{\omega}$  in either direction, depending on the  $B(z)$  and  $A(z)$  profiles.

The equilibrium relative wage in (22), taken in conjunction with (21), determines the equilibrium geographic production pattern,  $\bar{z}$  and  $\bar{z}^*$ . Since the range of nontraded

goods  $\bar{z}^* \leq z \leq \bar{z}$  depends in this formulation on the equilibrium relative wage, it is obvious that shifts in given parameters will shift the range of nontraded commodities. Thus, a transfer that raises the equilibrium relative wage at home causes previously exported commodities to become nontraded, and previously nontraded commodities to become importables.

### C. Tariffs

We consider next the case of zero transport cost but where each country levies a uniform tariff on imports at respective rates  $t$  and  $t^*$ , with proceeds rebated in lump sum form. This case, too, leads to cost barriers to importing, and to a range of commodities that are not traded, with the boundaries defined by:

$$(23) \quad \bar{z} = A^{-1} \left( \frac{\omega}{1+t} \right)$$

$$\text{and } \bar{z}^* = A^{-1}(\omega(1+t^*))$$

From (23) it is apparent that the presence of tariffs in either or both countries must give rise to nontraded goods because in this case  $\bar{z} \neq \bar{z}^*$ .

The trade balance equilibrium condition at international prices becomes, in place of (19),

$$(24) \quad (1 - \lambda)Y/(1 + t) = (1 - \lambda^*)Y^*/(1 + t^*)$$

where  $Y$  and  $Y^*$  denote incomes inclusive of lump sum tariff rebates. Using the fact that rebates are equal to the tariff rate times the fraction of income spent on imports, we arrive at the trade balance equilibrium condition in the form:<sup>10</sup>

$$(25) \quad \omega = \left( \frac{1 - \lambda^*}{1 - \lambda} \right) \frac{1 + t\lambda}{1 + t^*\lambda^*} (L^*/L)$$

where  $\lambda$  and  $\lambda^*$  are functions of  $(\omega, t, t^*)$ .

<sup>10</sup>Tariff rebates in the home country are equal to  $R = (1 - \lambda)Yt/(1 + t)$ . With  $Y = WL + R$  we therefore have  $Y = WL(1 + t)/(1 + \lambda t)$  as an expression for income inclusive of transfers. From equations (20) and (23) we have  $\lambda = \lambda[\omega/(1 + t)]$  and  $\lambda^* = \lambda^*[\omega(1 + t^*)]$ , having substituted the tariff instead of transport costs as the obstacle to trade.

The implicit relations (25) can be solved for the equilibrium relative wage as a function of relative size and the tariff structure:

$$(26) \quad \bar{\omega} = \bar{\omega}(L^*/L, t, t^*)$$

From (26) and (23) it is apparent now that the range of nontraded goods will be a function of both tariff rates. It is readily shown that an increase in the tariff improves the imposing country's relative wage and terms of trade. Furthermore, as is well known, when all countries but one are free traders, then one country can always improve its own welfare by imposing a tariff that is not too large.

A further question suggested by (26) concerns the effect of a uniform increase in world tariffs. Starting from zero, a small uniform increase in tariffs raises the relative wage of the country whose commodities command the larger share in world spending. This result occurs for two reasons. First, at the initial relative wage a larger share of spending out of tariff rebates falls on the goods of the country commanding a larger share in world demand. Second, the tariff induces new nontraded goods and therefore increases net demand for the borderline commodity of the country whose residents have the larger income, or equivalently, the larger share in world income.

If countries are of equal size as measured by the share in world income, such a uniform tariff increase has zero effect on relative wages, but of course reduces well-being in both places. Multilateral tariff increases, in this case, unnecessarily create some nontraded goods, and artificially raise the relative price of importables in terms of domestically produced commodities in each country exactly in proportion to the tariff.

### IV. Money, Wages, and Exchange Rates

In this section we extend the discussion of the Ricardian model to deal with monetary aspects of trade. Specifically we shall be interested in the determination of exchange rates in a flexible rate system, in the process of adjustment to trade imbalance under fixed rates, and in the role of wage sticki-

ness. The purpose of the extension is to integrate real and monetary aspects of trade.

### A. Flexible Exchange Rates

The barter analysis of the preceding sections is readily extended to a world of flexible exchange rates and flexible money wages. Assume a given nominal quantity of money in each country,  $M$  and  $M^*$ , respectively. Further, in accordance with the classical Quantity Theory, assume constant expenditure velocities  $V$  and  $V^*$ .<sup>11</sup> A flexible exchange rate, and our stipulating the absence of nonmonetary international asset flows, will assure trade balance equilibrium and therefore the equality of income and spending in each country. The nominal money supplies and velocities determine nominal income in each country:

$$(27) \quad WL = MV \text{ and } W^*L^* = M^*V^*$$

where  $W$  and  $W^*$  (now in capital letters) denote domestic and foreign money wages in terms of the respective currencies. Further, defining the exchange rate  $e$  as the domestic currency price of foreign exchange, the foreign wage measured in terms of domestic currency is  $eW^*$ , and the relative wage therefore is  $\omega \equiv W/eW^*$ .

From the determination of the equilibrium real wage ratio  $\bar{\omega}$  by our earlier "real" relations, we can now find an expression for the equilibrium exchange rates:

$$(28) \quad \bar{e} = (1/\bar{\omega})(\bar{W}/\bar{W}^*) = (1/\bar{\omega})(MV/M^*V^*)(L^*/L)$$

where (27') defines equilibrium money wages:

$$(27') \quad \bar{W} = MV/L$$

and

$$\bar{W}^* = M^*V^*/L^*$$

In this simple structure and with wage flexibility, we can keep separate the determinants of all equilibrium real variables from all monetary considerations. Money-

<sup>11</sup>This is a strong assumption since it makes spending independent of income and nonliquid assets even in the short run.

tary changes or velocity changes in one country will be reflected in equiproportionate changes in prices in that country and in the exchange rate in the fashion of the neutral-money Quantity Theory. However, a real disturbance, as (28) shows, definitely does have repercussions on the nominal exchange rate as well as on the real equilibrium.

Using the results of Section II, we see that an increase in the foreign relative labor force causes, under flexible exchange rates and given  $\bar{M}$  and  $\bar{M}^*$ , a depreciation in the home country's exchange rate as does uniform technical progress abroad. A shift in real demand toward foreign goods likewise leads to a depreciation of the exchange rate as well as to a reduction in real  $\bar{\omega}$ . A rise in foreign tariffs will also cause our currency to depreciate. Each of these real shifts is assumed to take place while  $(M, M^*)$  are unchanged and on the simplifying proviso that real income changes leave  $V$  and  $V^*$  unchanged.

### B. Fixed Exchange Rates

In the fixed exchange rates case we assume currencies are fully convertible at a parity pegged by the monetary authorities. In the absence of capital flows and sterilization policy, a trade imbalance is reflected in monetary flows. In the simplest metal money model, the world money supply is redistributed toward the surplus country at precisely the rate of the trade surplus. We assume that the world money supply is given and equal to  $\bar{G}$ , measured in terms of domestic currency. The rate of increase of the domestic quantity of money is therefore equal to the reduction in foreign money, valued at the fixed exchange rate  $\bar{e}$ :

$$(29) \quad \dot{M} = -\bar{e}\dot{M}^*$$

where  $\dot{M} \equiv dM/dt$ .

For a fixed rate world we have to determine in addition to the real variables  $\bar{\omega}$  and  $\bar{z}$ , the levels of money wages  $W$  and  $W^*$  as well as the equilibrium balance of payments associated with each short-run equilibrium. In the long run the balance of payments will be zero as money ends up *assume initial supply of money fixed but can convert from one currency to the other*

redistributed internationally to the point where income equals spending in each country. In the short run an initial misallocation of money balances implies a discrepancy between income and spending and an associated trade imbalance. To characterize the preferred rate of adjustment of cash balances in the simplest and most manageable way, we assume that spending by each country is proportional to money holdings.<sup>12</sup> On the further simplifying assumption that velocities are equal in each country,  $V = V^*$ ,<sup>13</sup> world spending is equal to

$$(30) \quad VM + eV^*M^* \equiv V\bar{G}$$

For the tastes and technology specified in Section I, world spending on domestically produced goods is given by

$$(31) \quad V\bar{G} \int_0^z b(z)dz \equiv \vartheta(\omega)V\bar{G}$$

$$\bar{z} = A^{-1}(\omega)$$

In equilibrium, world spending on our goods must equal the value of our full-employment income  $WL$ :

$$(32) \quad WL = \vartheta(\omega)V\bar{G}$$

Equilibrium requires, too, that world spending on foreign goods equals the value of foreign full-employment income:

$$(33) \quad \bar{e}W^*L^* = [1 - \vartheta(\omega)]V\bar{G}$$

Equations (32) and (33) express what would seem to be the *joint* determination of real and monetary variables. But, in fact, we could have taken the shortcut of recognizing that the real equilibrium is precisely that of the barter analysis developed in Section I. Dividing (32) by (33) and substitut-

<sup>12</sup>The assumption that spending is proportional to cash balances is only one of a number of possible specifications. Conditions for this expenditure function to be optimal are derived in Dornbusch and Michael Mussa. In general, expenditure will depend on both income and cash balances.

<sup>13</sup>In the long-run equilibrium, higher  $V$  than  $V^*$  leaves us with a smaller share of the world money stock than foreigners, but with nominal and real income *shares* in the two countries the same as when  $V = V^*$ .

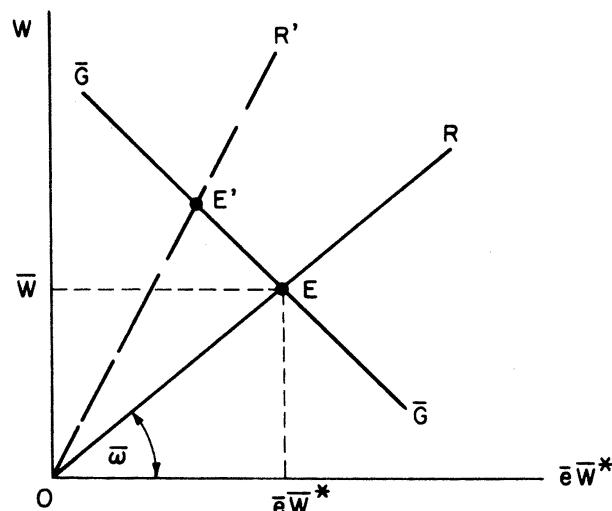


FIGURE 4

ing from (11) for the equilibrium relative wage  $\bar{\omega}$ , we can employ equations (32) and (33) to determine money wage levels.

The equilibrium determined by equations (32) and (33) can be analyzed in terms of Figure 4. The figure emphasizes the separation of real and monetary aspects of the equilibrium under our assumptions of traded goods only, and no distribution effects. From the ratio of (32) and (33) we obtain the equilibrium relative wage  $\bar{\omega}$  as a function of tastes and technology solely from the barter model. This equilibrium relative wage is plotted as the ray  $OR$  in Figure 4.

The equality of world income and spending

$$(30') \quad WL + \bar{e}W^*L^* = V\bar{G}$$

is shown as the downward sloping straight line  $\bar{GG}$ , which is drawn for given velocity, world quantity of money, and labor forces. Point  $E$  is the equilibrium where relative prices and the level of wages and prices are such that all markets clear. At a level of wages and prices higher than point  $E$ , there would be a world excess supply of goods, and conversely at points below  $E$ .

Figure 4 immediately shows some comparative static results. Thus a doubling of both countries' labor forces, from the analysis of the barter model, will leave the relative wage unaffected but will double

world output. Given unchanged nominal spending  $V\bar{G}$ , wages and prices will have to halve. This would be shown by a parallel shift of the  $\bar{G}\bar{G}$  schedule halfway toward the origin. A shift in demand toward the home country's output by contrast would rotate the  $OR$  ray to a position like  $OR'$  since it raises our relative wage. The ensuing monetary adjustment is then an increase in our money wage and money income and a decline in foreign wages, prices, and incomes (point  $E'$ ).

The real and nominal equilibrium at point  $E$  in Figure 4 is independent of the short- and long-run distribution of the world quantity of money. The independence of the real equilibrium derives from the uniform homothetic tastes. The independence of the nominal equilibrium is implied by identical velocities. What does, however, depend on the short-run distribution of world money is the transition periods' balance of payments. As in the absorption approach of Sidney Alexander (1952), we know this: when goods markets clear, the trade surplus or balance of payments  $\dot{M}$  of the home country is equal to the excess of income over spending, or:

$$(34) \quad \dot{M} = \bar{W}L - VM$$

With the nominal wage independent of the distribution of world money, equation (34) therefore implies that the trade balance monotonically converges to equilibrium at a rate proportional to the discrepancy from long-run equilibrium:<sup>14</sup>

$$(34') \quad \dot{M} = V(\bar{M} - M); \bar{M} = \vartheta(\bar{\omega})\bar{G}$$

The assumptions of this section were designed to render inoperative most of the traditional mechanisms discussed as part of

<sup>14</sup>Suppose  $V > V^*$  and our share of the world money supply is initially larger than our equilibrium share. Then, as we lose  $M$ , total world nominal income and nominal  $GNP$  falls. Always our share of nominal world  $GNP$  stays the same under the strong demand assumptions. Total world real output never changes during the transition; only regional consumption shares change. Therefore, both countries' nominal price and wage levels fall in the transition, but such balanced changes have no real effects on either the transient or the final real equilibrium.

the adjustment process: changes in the terms of trade, in home and/or foreign price levels, in relative prices of traded and nontraded goods (there being none of the latter), in double factorial terms of trade; and any discrepancies in the price of the same commodity between countries. The features of the adjustment process of this section rely on 1) identical, constant expenditure velocities, 2) uniform-homothetic demand, and 3) the absence of trade impediments. If velocities were constant but differed between countries, the absolute *levels* of money wages and prices, though not *relative* wages or prices, would depend on the world distribution of money. Relaxation of the uniform-homothetic taste assumption would make equilibrium relative prices a function of the distributions of spending. Finally, the presence of nontraded goods would, together with Ricardo's technology, provide valid justification for some of the behavior of relative prices and price levels frequently asserted in the literature; this behavior is studied in more detail in the next section.

### C. The Price-Specie Flow Mechanism under More General Conditions

We now discuss the adjustment process to monetary disequilibrium and enquire into the price effects associated with a redistribution of the world money supply when there are nontraded goods. Common versions of the Hume price-specie flow mechanism usually involve the argument that in the adjustment process, prices decline along with the money stock in the deficit country, while both rise in the surplus country. There is usually, too, an implication that the deficit country's terms of trade will necessarily worsen in the adjustment process and indeed have to do so if the adjustment is to be successful.

Section IVB demonstrated that the redistribution of money associated with monetary imbalance need have no effects on real variables (production, terms of trade, etc.) and on nominal variables other than the money stock and spending. While this is

clearly a very special case, it does serve as a benchmark since it establishes that the monetary adjustment process would be effective even in a one-commodity world.

To approach the traditional view of the adjustment process more clearly and provide formal support for that view, we consider an extension to the monetary realm of our previous model involving nontraded goods. We return to the assumption that a fraction  $(1 - k)$  of spending in each country falls on nontraded goods, and accordingly equations (32) and (33) become:

$$(32') \quad WL = \vartheta(\omega) V\bar{G} + (1 - k)\gamma V\bar{G}; \\ \gamma \equiv M/\bar{G}$$

$$(33') \quad \bar{e}W^*L^* = [k - \vartheta(\omega)]V\bar{G} \\ + (1 - \gamma)(1 - k)V\bar{G}$$

These hold both in final equilibrium, and in transient equilibrium where specie is flowing. Equations (32') and (33') imply that the equilibrium relative wage does depend on the distribution of the world money supply. Solving these equations for the equilibrium relative wage we have:

$$(35) \quad \bar{\omega} = \bar{\omega}(\gamma) \quad \frac{\partial \bar{\omega}}{\partial \gamma} > 0$$

An increase in the home country's initial share in the world money supply  $\gamma$  raises our relative wage.

Using this extended framework, we can draw on the analysis of the transfer problem in Section II to examine the adjustment that follows an initial distribution of world money between the two countries that differs from the long-run equilibrium distribution.

Suppose our  $M$  is initially excessive, say from a gold discovery here. Assume also that the gold discovery occurred when the world was in long-run equilibrium with the previous world money stock. As a result of our excess  $M$ , we spend more than our earnings, incurring a balance-of-payments deficit equal to the rate at which our  $M$  is flowing out. In effect, the foreign economy is making us a real transfer to offset our deficit. As seen earlier, we, the deficit country, are devoting some of our excess spend-

ing to nontraded goods, shifting some of our resources to their production at the expense of our previous exports. We not only export fewer types of goods, but also import more types, and import more of each ( $\bar{\omega}$  rises and  $\bar{z}$  falls).

During the transition, while the real transfer corresponding to our deficit is taking place, our terms of trade are more favorable than in the long-run state. The new gold raises both their  $W^*$  and our  $W$ , but in addition, our  $W$  is up relative to their  $W^*$ . Therefore the price level of goods we continue to produce is up relative to the price level of goods they continue to produce. This is true both for our nontraded goods and for our exportables. The prices of goods we produce rise relative to the prices of goods they produce in proportion to the change in relative wages.

Thus the price levels in the two countries have been changed differentially by the specie flow and implied real transfer. But that does not mean that any traded good ever sells for different prices in two places. In fact the divergence in weighted average (consumer) price levels is due to nontraded goods. The price level will rise in the gold-discovering country relative to the other country the greater is the share of nontraded goods in expenditure,  $1 - k$ . It is a bit meaningless to say, "What accomplished the adjustment is the relative movements of price levels for nontraded goods in the two countries," since we have seen that the adjustment can and will be made even when there are no such nontraded goods. It is meaningful to say, "The fact that people want to direct some of their expenditure to nontraded goods makes it necessary for resources to shift in and out of them as a result of a real transfer, and such resource shifts take place only because the terms of trade (double-factoral and for traded goods) do shift in the indicated way."

The adjustment process to a monetary disturbance is stable in the sense that the system converges to a long-run equilibrium distribution of money with balanced trade. To appreciate that point, we supplement equations (32') and (33') with (34) that con-

tinues to describe the monetary adjustment process. We note, however, that now  $W$  and  $W^*$  are endogenous variables whose levels in the short run do depend on the distribution of the world money supply. A redistribution of money toward the home country would raise our spending and demand for goods, and reduce foreign spending and demand. As before, spending changes for traded goods offset each other precisely so that the net effect is an increase in demand for nontraded goods at home and a decline abroad. As a consequence our wages will rise and foreign wages decline. Therefore, starting from full equilibrium, a redistribution of money toward the home country will create a deficit equal to

$$(36) \quad d\dot{M}/dM = -V(1 - \delta) \quad 0 \leq \delta < 1$$

where  $\delta$  is the elasticity of our nominal wages with respect to the quantity of money and is less than unity.<sup>15</sup> Equation (36) implies that the price-specie flow mechanism is stable.

It is interesting to observe in this context that the presence of nontraded goods in fact *slows down* the adjustment process by comparison with a world of only traded goods (contrary to J. Laurence Laughlin's turn of the century worries). As we saw before, with all goods freely tradeable, wages are independent of the distribution of money, and accordingly  $\delta = 0$ . Further we observe that the speed of adjustment depends on the relative size of countries. Thus the more equal countries are in terms of size, the slower tends to be the adjustment process.

In concluding this section we note that nontraded goods (and/or localized demand) are essential to the correctness of traditional insistence that the adjustment process necessarily entails absolute and re-

lative price, wage, and income movements. They are, of course, in no way essential to the existence of a stable adjustment process, nor is there at any time a need for a discrepancy of prices of the same commodity across countries in either case.<sup>16</sup>

A final remark concerns the adjustment to real disturbances such as demand shifts or technical progress. It is certainly true that whether the exchange rate is fixed or flexible, real adjustment will have to take place and cannot be avoided by choice of an exchange rate regime. So long as wages and prices are flexible, it is quite false to think that fixed parities "put the whole economy through the wringer of adjustment" while in floating rate regimes "only the export and import industries have to make the real adjustment." It is true, however, that once we depart from flexible wages and prices there may well be a preference for one exchange rate regime over another. The next section is devoted to that question.

#### D. Sticky Money Wages

The last question we address in this section concerns the implications of sticky money wages. For a given world money supply, *downward* stickiness of money wages implies the possibility of unemployment. We assume upward flexibility in wages, once full employment is attained.

We start with a fixed exchange rate  $\bar{e}$ . The relation between wages and the world quantity of money is brought out in Figure 5. Denote employment levels in each country, as opposed to the labor force, by the new symbols  $\bar{L}$  and  $\bar{L}^*$ , respectively; denote nominal incomes by  $Y$  and  $Y^*$ . The equality of world income and spending is again shown by the  $\bar{G}\bar{G}$  schedule, the equation of which now is

$$(37) \quad V\bar{G} = Y + \bar{e}Y^* \equiv \bar{W}\bar{L} + \bar{e}\bar{W}^*\bar{L}^*$$

<sup>15</sup>The value of  $\delta$  can be calculated from equations (32') and (33') to be

$$\delta \equiv (1 - k) \frac{\gamma(1 - \gamma)}{\gamma(1 - \gamma) + \vartheta\epsilon}$$

where  $\epsilon$  is the elasticity of the share of our traded goods in world spending,  $\epsilon \equiv -\vartheta'\omega/\vartheta > 0$ . The elasticity  $\delta$  is evaluated at the long-run equilibrium where  $\gamma \equiv \vartheta/k$ . If  $A'(z)$  falls slowly,  $\epsilon$  will be large.

<sup>16</sup>The continuum Ricardian technology is special in that there can be no range of goods both imported and produced at home. Therefore, the cross elasticity of supply between nontraded goods and exports must be greater than the zero cross elasticity between nontraded goods and imports. Consequently, a transfer must shift the terms of trade (for goods and factors) in the stated orthodox way, favorably for the receiver.

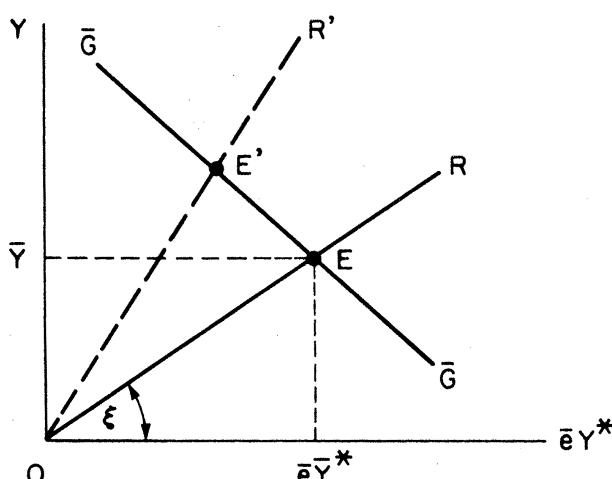


FIGURE 5

where  $\bar{W}$  and  $\bar{W}^*$  are the fixed money wages set at too high sticky levels. The schedule is drawn for given money wages, a given world quantity of money, and a pegged parity for  $\bar{e}$ . The ray  $OR$  now is predetermined by the given sticky relative wage  $\bar{\omega} = \bar{W}/\bar{e}\bar{W}^*$ . From equations (32) and (33) the ratio of money incomes  $Y/\bar{e}Y^*$  is just a function of the relative wage now given exogenously by rigid money wages and the exchange rate:

$$(38) \quad Y/\bar{e}Y^* = \frac{\vartheta(\omega)}{1 - \vartheta(\omega)} \equiv \xi(\bar{W}/\bar{e}\bar{W}^*)$$

$$\xi'(\omega) < 0$$

Point  $E$  is the nominal equilibrium where by assumption the world quantity of money is insufficient relative to wage rates to ensure full employment. Although that equilibrium is one with unemployed labor, it is efficient in other respects. Specifically, geographic specialization follows comparative advantage as laid out above, but now labor employed adjusts to sticky wage patterns of specialization.

Employment levels  $\bar{L}$  and  $\bar{L}^*$  now are determined by (39)

$$(39) \quad \bar{L} = \bar{Y}/\bar{W}, \quad \bar{L}^* = \bar{e}\bar{Y}^*/\bar{W}^*$$

where  $\bar{Y}$  and  $\bar{Y}^*$  are the equilibrium levels of nominal income determined by equations (37) and (38) or by point  $E$  in Figure 5.

Consider now the impact of a foreign increase in money wages. The effect of the im-

plied reduction in our relative wages and the resulting increase in our relative income are shown in Figure 5 by the rotation from  $OR$  to  $OR'$ .

The new equilibrium is at  $E'$  where our money income and employment have risen while income and employment decline abroad. Thus an increase in the foreign wage rate, by moving the terms of trade against us, shifts comparative advantage and employment toward the home country. The extent to which the home country benefits from the adverse terms of trade shift in terms of employment will depend on both the substitutability in demand and the elasticity of the  $A(z)$  schedule in Figure 1. We observe, too, that the move from  $E$  to  $E'$  will bring about a transitory balance-of-payments surplus. Given the initial distribution of money and hence of spending, the foreign decline in income and the increase at home implies that we will spend less than our income and therefore have a trade surplus. This surplus persists until money is redistributed to match the new levels of income at  $E'$ .

Next we move to flexible exchange rates. Under flexible rates an increase in the foreign money wage  $\bar{W}^*$ , given money supplies in each country, will similarly have real repercussion effects on relative prices and employment at home. Now employment in each country is determined by money supplies and prevailing wages:

$$(39') \quad \bar{L} = V\bar{M}/\bar{W}; \quad \bar{L}^* = V\bar{M}^*/\bar{W}^*$$

Given the employment levels thus determined, we know from the analysis of the earlier barter model that there is a unique relative wage at which the trade balance achieves equilibrium. The higher is  $\bar{M}^*/\bar{W}^*$ , the higher will be employment abroad—and, therefore, the higher will be our relative wage  $\bar{\omega}$ . It is thus apparent that an increase in the foreign money wage,  $\bar{W}^*$ , will reduce employment abroad. Employment declines only in proportion to the increase in wages and thus declines by less than it would under fixed exchange rates when specie is lost abroad.

We saw in the barter model that a reduc-

tion in effective foreign labor causes a decline in our relative wage, but that the decline in our relative wage falls proportionately short of the foreign reduction in labor. Now, at the initial exchange rate, the increase in foreign wages reduces our relative wage and their employment in the same proportion. The decline in our relative wage is therefore excessive. Domestic goods are underpriced and the exchange rate appreciates to *partly* offset the gain in cost competitiveness. The net effect is therefore a decline in our relative wage and an appreciation of our exchange rate (a decline in  $e$ ) that falls short of the foreign increase in wages. Since our terms of trade unambiguously deteriorate without any compensating gain in employment, it must be true that welfare declines at home. Abroad, the loss in employment is offset by a gain in the terms of trade, but there too the net effect is a loss in welfare under our strong Mill-Ricardo assumption.

The adjustment to money wage disturbances under fixed and flexible rates differs in several respects. Under fixed rates employment effects are transmitted, while under flexible rates they are bottled up in the country initiating the disturbance. Under fixed rates the terms of trade move one for one with money wage, while under flexible rates exchange rate movements partly offset increases in the foreign money wage rate.

The difference between fixed and flexible rates in relation to the adjustment process is further brought out by an example of a real disturbance. Consider a shift in world demand toward our goods. Under fixed rates the resulting increase in our relative income will, from (38), move us in Figure 5 from  $E$  to  $E'$ . Employment rises at home and falls abroad. Demand shifts are fully reflected in employment changes. Under flexible rates, by contrast, with given wages and money, a demand shift has no impact on employment—as we observe from (39). At the initial exchange rate the demand shift would give rise to an excess demand for our goods and to an excess supply abroad. Domestic income and employment would tend to rise while falling abroad. The resulting trade

surplus causes our exchange rate to appreciate until the initial employment levels and therefore trade balance equilibrium are restored. The demand shift is fully absorbed by a change in the terms of trade and a shift in competitive advantage that restores demand for foreign goods and labor.

Real and nominal equilibria are thus seen to be uniquely definable in our continuum model with constant-velocity spending determinants. The difference between sticky and flexible wage rates under fixed exchange rates is understandable as the difference between (a) having the crucial relative wage  $\bar{\omega}$  be imposed in the sticky wage case with employments having then to adjust; or (b) having the full employments be imposed and  $\bar{\omega}$  having to adjust. Under floating exchange rates, sticky nominal wages impose employment levels in each country and the crucial relative wage  $\bar{\omega}$  then adjusts to those employment levels.

## APPENDIX

### *Historical Remark*

Figure 1 seems to be new. G. A. Elliott (1950) gives a somewhat different diagram, one that makes explicit the meaning of Marshall's 1879 "bales" (which, by the way, happen to work only in the two-country constant labor costs case). In terms of the present notations, Elliott plots for the U.S. offer curve the following successive points traced out for all  $\omega$  on the range  $[0, \infty]$ : on the vertical axis is plotted our total real imports valued in foreign labor units ("our demand for bales of their labor," so to speak), namely,

$$\int_z^1 [P^*(z)/w^*] C(z) dz = \int_z^1 a^*(z) C(z) dz$$

and on the horizontal axis, our total real exports valued in home labor units ("our supply of bales of labor to them"), namely,

$$\begin{aligned} \int_0^z [P(z)/w] [Q(z) - C(z)] dz = \\ L - \int_0^z a(z) C(z) dz \end{aligned}$$

It is to be understood that  $\tilde{z}$  is a function of  $\omega$ , namely the inverse function  $A^{-1}(\omega)$ ; also that  $C(z)$  are the amounts demanded as a function of our real income  $L$  and of the  $P(z)/W$  function defined for each, namely  $\min[\omega a(z), a^*(z)]$ . Because we have a continuum of goods, we avoid Elliott's branches of the offer curve that are segments of various rays through the origin. The reader will discern by symmetry considerations how the foreign offer curve is plotted in the same  $(L, L^*)$  quadrant, by varying  $\omega$  to generate the respective coordinates

$$\left[ \int_0^{\tilde{z}} a(z) C^*(z) dz, \right. \\ \left. L^* - \int_{\tilde{z}}^1 a^*(z) C^*(z) dz \right]$$

Our model forces the Elliott-Marshall diagram to generate a *unique* solution under uniform-homothetic demand. Unlike our Figure 1, the Elliott diagram can handle the general case of nonhomothetic demands in the two countries; but then, as is well known, multiple solutions are possible, some locally stable and some unstable. The price one pays for this generality is that, as Edgeworth observed, the Marshallian curves are the end products of much implicit theorizing, with much that is interesting having taken place offstage.

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