THE KOREAN ECONOMIC REVIEW
Volume 8, Number 1, Summer 1992.

MEASUREMENT OF THE FACTOR CONTENT OF TRADE WITH TRADE BARRIERS

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I. INTRODUCTION

The empirical inadequacy of the Heckscher-Ohlin-Vanek (HOV) model of international trade has been an issue of contention at least since the Leontief paradox. Recently interest in this issue has been stimulated by Leamer's (1980) explanation that Leontief's (1954) celebrated results are not really inconsistent with a multifactor version of the Heckscher-Ohlin (HO) model with factor price equalization everywhere. Despite the abundance of literature purporting to test the HOV model in some fashion, howerver, empirical results have continued to solidify the evidence of major departures from this model and thus to cast doubt on the overall validity and usefulness of the HO theory.[1]

One reason for the failure of the HOV model may simply be that factor prices are not equalized due to the substantial trade barriers and/or large differences in factor endowments between countries. This paper explores this possibility by extending tests of the factor content version of the HO model with enequal factor prices.

Helpman (1984) has recently derived restrictions on the factor content of bilateral trade as functions of differences in international factor prices, which can be tested with post-trade data. The only assumptions required for his results are the same constant-returns-to-scale technology, perfect competition, and free trade across countries. As intermediate goods are not explicitly considered in his model, however, one potential problem with the test is how to empirically measure the factor content embodied in traded goods. We thus extend Helpman's factor con-

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[1]See, for instance, Brecher and Choudhri (1982b, 1988), Maskus (1985), Staiger, Deardorff and Stern (1987), and Bowen, Leamer and Sveikauskas (1987).

tent version of the HO theory to a model which allows for the presence of intermediate goods. Once intermediate goods are in place, we can raies an important issue of whether the calculation of factor content should be based on only direct or gross (direct-plus-indirect)factor requirements.

Deardorff (1982) and Hamilton and Svensson (1983) have argued that gross factor requirements arw the appropriate determinants of trade pattern, on the grounds that they determine autarky prices. By contrast, Staiger (1986) has recently shown that direct (instead of gross) factor requirement should be used to measure factor content. Staiger's result stems from the fact that he derives restrictions on trade pattern implied by the post-trade equilibrium conditions rather than autarky variables. In these paper we find, however, that when trade in goods (including intermediate goods) is subject to trade barriers neither direct nor gross requirements necessarily provide a valid measure of factor content of trade.

Our objective in this paper is two fold: first, we develop the theoretically appropriate measure for use in empirical examination of HO predictions; second, we derive conditions on the pattern of factor content of trade that must be satisfied by the observed trade flows in a world with trade barriers.

The rest of this paper is organized as follows. In Section II we describe the theoretical structure of the model to develop a new measure of factor content of trade discussed above. We will refer to this measure as "home-gross" factor requirements. In Section III we discuss how the model may be extended in a number of directions to take account of different assumpions about the pattern of production and trade. We will establish that the home-gross factor requirements always provide an appropriate measure for use in evaluating the empirical implications of the HO model. Finally, we offer some concluding remadks in Section IV.

II. MODEL WITH TRADE BARRIERS

Consider a model with two countries, many factors, and goods produced under perfect competition with internationally identical and linearly homogeneous technology.[2] Assume for simplicity that intermediate goods are produced with primary inputs only.[3] Assume further that trade between two countries does not bring about factor price equalization. In this paper we focus on the case where trade in goods is subject to trade barriers (possibly zero in some caese). Trade barriers may consist of tariffs, non-tariff barriers which have tariff equivalents, or

[2]While the focus is on bilateral relationships, there is no restriction on the number of countries. The results below continue to apply to any pair of countries (or groups of countries) in a multicountry world.

[3]This assumption is made for simplicity. The relaxation of the assumption does not affect any of the results here. For general case see Kang (1991).

transport costs. We also allow for the possibility of prohibitive tariff or zero quota for some goods so that such goods are not traded. Under the above assumptions, we begin this section with a general case in which foreign traded intermediate goods as well as both traded and nontraded home intermediate goods are required to produce final goods.

Let the set of goods $N = (N_f, N_g)$, where N_f is a subset of N that includes all final goods and N_g is a subset of all goods that are intermediate goods. Specifically, we dendote foreign variable with an asterisk and leave home variable unstarred. Let 1 and 2 represent traded and nontraded goods, respectively. Then we define the unit production function for dood i by

$$f_i(d_i, g_i) = 1, \qquad \text{if} \quad i \in N_f \tag{1}$$

where d_i and $g_i = (g_{i1}, g_{i2}, g^*_{i1})$ represent, respectively, the vectors of primary factors and intermediate inputs used to produce one unit of gross output of good i at home country. If good i is an intermediate good, the g_i vector equals zero.

Letting w and $p = (p_1, p_2)$ denote the vectors of home prices of primary factor services and goods, respectively, the minimum unit cost function for good i is

$$c_i(w, p, p^*) = \min_{d_i,\, g_i} \{ d_i w + g_{i1} p_i + g_{i2} p_2 + g^*_{i1} p^*_1 \mid$$

$$f_i(d_i, g_{il}, g_{i2}, g^*_{i1}) = 1 \}, \; i \in N_f \tag{2}$$

By the assumption of unequal factor prices, w is not equal to w*. The protection afforded by trade barriers allows prices barriers, or simply "tariffs" on import good i (expressed as a proportion of price in foreign country), be s_i. For any traded good i this implies

$$p_i = p^*_i (1 + s_i), \; s_i \geqslant 0, \; i \in N \tag{3}$$

Since $c_j(w) = d_j w$ [and $c_j(w^*) = d^*_j w^*$] for intermediate good j according to (1) and $p_j = c_j(w)$ at a competitive equilibrium, $j \in N_g$, it follows that $g_i p = g_i D w$, $i \in N_f$, where $D = (d_{jm})$ is the primary input requirements matrix with the element d_{jm} representing amounts of primary factor m used directly to produce one unit of intermediate good j. Therefore we can rewrite (2) as

$$c_i(w, w^*) = \min_{\substack{d_i,\, e_{i1},\, e_{i2},\, e^*_{i1} \\ f_i(d_i, e_{i1}, e_{i2}, e^*_{i1}) = 1}} \{ d_i w + e_{i1} w + e_{i2} w + e^*_{i1} w^* \mid \}, \; i \in N_f \tag{4}$$

where $e_{ij} = g_{ij} D$ [and $e^*_{ij} = g^*_{ij} D^*$], $j = 1, 2$ is the vector of indirect factors em-

bodied in home (foreign) produced intermediate inputs per unit of final good i. Then the optimum choices of those inputs [d_i (w, w*), e_{i1} (w, w*), e_{i2} (w, w*), e^*_{i1} (w, w*)] are simply given by Shepard's lemma.

Now let $T^{ab} = (t_i^{ab})$, $i \in N_f$, stand for the vector of total imports of final goods by country a from country b. We define the vector of gross gactor content in the total imports by

$$T_v^{ab} \equiv T_d^{ab} + T_{e1}^{ab} + T_{e2}^{ab} + T_{ei*}^{ab} \tag{5}$$

where T_d^{ab} is the vector of primary factor embodied in the total imports; T_{e1}^{ab} [T_{ei*}^{ab}] is the vector of indirect factors embodied in the traded intermediate goods produced in country b (a) which are required to preduce the final imports; and T_{e2}^{ab} is the vector of indirect gactor embodied in country b's nontraded intermediate goods used in the productiom of the final imports such that

$$T_d^{ab} = \sum_i d_i^b (w^a, w^b)\, t_i^{ab}\,, \quad i \in N_f \tag{6}$$

$$T_{e1}^{ab} = \sum_i e_{i1}^b (w^a, w^b)\, t_i^{ab}\,, \quad i \in N_f \tag{7}$$

$$T_{e2}^{ab} = \sum_i e_{i2}^b (w^a, w^b)\, t_i^{ab}\,, \quad i \in N_f \tag{8}$$

$$T_{e1*}^{ab} = \sum_i e_{i1*}^b (w^a, w^b)\, t_i^{ab}\,, \quad i \in N_f \tag{7}$$

This measures the actual factor content of trade using exporter's input requirements (here country b).

Under these conditions country b will produce the final goods by purchasing some intermediate imputs from its home market and by importing others from abroad (here country a) and export them to country a. if we let g_{ij} represent the amount of import of ontermediate good j used in the production of one unit of final good i, the tariff at a rate s_j on the intermediate goods will generate tax revenue per unit of final good i by $\sum_j g_{ij}\, p_j^a\, s_j^b$, according to (3). In such a case a zero profit equilibrium condition together with (4) and (5) imply that

$$T^{ab}P^b = T_d^{ab}\, w^b + T_{e1}^{ab}\, w^b + T_{e2}^{ab}\, w^b + T_{e1*}^{ab}\, w^a + Q^b \tag{10}$$

where $Q^b = \sum_i \sum_j t_i^{ab}\, g_{ij}\, p_j^a s_j^b$ is the total tariff revenue collected by country b on the imports of intermediate goods from country a required to produce the final

goods.

Next consider the post-trade equilibrium factor price vectors in country a and in country b, w^a and w^b, satisfying

$$p_i^a \leqslant c_i^a(w^a, w^b), \qquad i \in N \tag{11}$$

Since $c_i^a(w^2, w^b)$ is minimum unit cost of good i in country a over the feasible input coefficients $[d_i^a(w^a, w^b), e_{i1}(w^2, w^b), e_{i2}^a(w^a, w^b), e_{i1*}^b(w^a, w^b)]$, when the vectors of factor prices are w^a and w^b, the cost minimization condition (4) implies that

$$\begin{aligned} T^{ab}p^a &\leqslant \sum_i c_i^a(w^a, w^b)\, t_i^{ab} \\ &= [\sum_i d_i^a(w^a, w^b)\, w^a + \sum_i e_{i1}^a(w^2, w^b)\, w^a + \sum_i e_{i2}^a(w^a, w^b)\, w^a \\ &\quad + \sum_i e_{il*}^b(w^a, w^b)\, w^b + \sum_i \sum_j g_{ij}\, p_j^b\, s_j^a]\, t_i^{ab}, \quad i \in N_f,\ j \in N_g \end{aligned} \tag{12}$$

Since intermediate goods are produced in the country that an produce them most cheaply in the trading equilibrium, the costs of foreign (here country b) intermediate goods would be higher if they were produced at home (here country a), implying

$$\begin{aligned} &\sum_i e_{i1*}^b(w^a, w^b)\, w^b + \sum_i \sum_j g_{ij}\, P_j^b\, s_j^a \leqslant \sum_i e_{i1}^{ba}(w^a, w^b)\, w^b, \\ &\qquad i \in N_f,\ j \in N_g \end{aligned} \tag{13}$$

where $e_{i1}^{ba}(w^a, w^b)$ represents the indirect requirements in the production of country b's intermediate goods if these goods were to be produced in country a. Since production technology is the same in the two countries, unit cost would be higher if country b's instead of country a's factor requirements were used to produce a good at country a's factor prices, implying

$$\begin{aligned} &[\sum_i d_i^a(w^a, w^b) + \sum_i e_{i1}^a(w^a, w^b) + \sum_i e_{i2}^a(w^a, w^b) + \sum_i e_{i1}^{ba}(w^a, w^b)]\, w^a \\ &\leqslant [\sum_i d_i^b(w^b, w^b) + \sum_i e_{i1}^b(w^a, w^b) + \sum_i e_{i2}^b(w^a, w^b) + \sum_i e_{i1*}^a(w^a, w^b)]\, w^a \\ &\qquad , i \in N_f \end{aligned} \tag{14}$$

Due to (13) and (14), (12) becomes

$$T^{ab}P^a \leqslant [\sum_i \delta_i^b (w^a, w^b)\, w^a + \sum_i e_{i1}^b (w^a, w^b)\, w^a + \sum_i e_{i2}^b (w^a, w^b)\, w^a$$

$$+ \sum_i e_{i1*}^a (w^a, w^b)\, w^a]\, t_i^{ab},\ i \in N_f \qquad (15)$$

From (6) through (9), this reduces to

$$T^{ab}p^a \leqslant T_d^{ab}\, w^a + T_{e1}^{ab}\, w^a + T_{e2}^{ab}\, w^a + T_{e1*}^{ab}\, w^a \qquad (16)$$

The combination of (10) and (16) yields the following condition which the factor content pattern of bilateral trade must satisfy in the presence of nontraded goods as well as trade barriers:

$$T_d^{ab}\, w^a + T_{e1}^{ab}\, w^a + T_{e2}^{ab}\, w^a + T_{e1*}^{ab}\, w^a \geqslant T^{ab}p^a$$

$$= T^{ab}p^b + T^{ab}(p^a - p^b)$$

$$= T_d^{ab}\, w^b + T_{e1}^{ab}\, w^b + T_{e2}^{ab}\, w^b +$$

$$T_{e1*}^{ab}\, w^a + Q^b + R^a \qquad (17)$$

where $R^a = T^{ab}(p^a - p^b)$ is the total tariff revenue collected by country a on the imports of final goods from country b. By rearranging (17), we have

$$\left[T_d^{ab} + T_{e1}^{ab} + T_{e2}^{ab} \right] (w^a - w^b) \geqslant Q^b + R^a \geqslant 0 \qquad (18)$$

Condition (18) is a restriction that relates international factor price differences to "home-gross" factor content of trade, consisting of both the direct factor inputs into traded final goods (here T^{ab}) and the direct factor inputs into the home (here country b) produced intermediate goods used in the production of the domestic final goods. Note that restrictions in terms of direct or gross factor requirements can not be derived from the model such that $T_d^{ab}(w^a - w^b)$ or $(T_d^{ab} + T_{e1}^{ab} + T_{e2}^{ab} + T_{e1*}^{ab})(w^a - w^b)$ exceeds some positive value. Thus restriction (18) establishes that only home-gross factor requirements are the theoretically appropriate measure of factor content of trade for the general model.

We provide a simple numerical example to highlight this proposition. Consider a two country (a and b), two factor (labor and capital), four good (one final good, one home traded intermediate good, one home nontraded intermediate good and one foreign traded intermediate good) HO world with the assumptions described in the model here. Suppose that vectors of post-trade factor prices in the two countries are given by

$w^a = [5 \quad 9]$ and $w^b = [10 \quad 6]$

where each first column is the wage rate, while each second column is the rental rate. Suppose further that one unit each of labor and capital, one unit each of home made intermediate goods (one traded and one nontraded), and one unit of a foreign traded intermediate good are required to produce one unit of a final good. On the other hand, one unit of home traded intermediate good is produced with two units of labor and eight units of capital, one unit of home nontraded intermediate good one unit of labor and five units of capital, and one unit of foreign traded intermediate good nine units of labor and two units of capital respectively. Then the direct inputs of labor and capital, for one unit of final good to be produced, will be required as follows

$$T_d^{ab\prime} = [1 \quad 1] \qquad T_{e1}^{ab\prime} = [2 \quad 8]$$

$$T_{e2}^{ab\prime} = [1 \quad 5] \qquad T_{e1*}^{ab\prime} = [9 \quad 2]$$

respectively, where primes denote transposes.

The trading equilibrium zero profit condition for competitive factor prices implies that[4]

$$T^{ab}P^b = T_d^{ab}w^b + T_{e1}^{ab}w^b + T_d^{ab}w^b{}_{e2} + T_{e1*}^{ab}w^a + Q^b$$

$$= \begin{bmatrix} 1 \\ 1 \end{bmatrix}[10 \quad 6] + \begin{bmatrix} 2 \\ 8 \end{bmatrix}[10 \quad 6] + \begin{bmatrix} 1 \\ 5 \end{bmatrix}[10 \quad 6] + \begin{bmatrix} 9 \\ 2 \end{bmatrix}[5 \quad 9] + Q$$

$$= 187 + Q^b$$

and

$$T^{ab}p^a \leqslant T_d^{ab}w^a + T_{e1}^{ab}w^a + T_{e2}^{ab}w^a + T_{e1*}^{ab}w^a$$

$$= \begin{bmatrix} 1 \\ 1 \end{bmatrix}[5 \quad 9] + \begin{bmatrix} 2 \\ 8 \end{bmatrix}[5 \quad 9] + \begin{bmatrix} 1 \\ 5 \end{bmatrix}[5 \quad 9] + \begin{bmatrix} 9 \\ 2 \end{bmatrix}[5 \quad 9] = 209$$

If $Q^b < 22$, then country b has a clear advantage in the production of the final good. Thus the final good will be exported from country b to country a.

[4]For simplicity it is assumed that only one unit of the final good is imported by country a from country b in the post-trade equilibrium.

The factor content of this trade flows can be calculated by employing each of the following different methods of measurement:

Case 1. Home-gross requirements: $[(T_d^{ab} + T_{e1}^{ab} + {}_{e2}^{ab})(w^a - w^b)]$

$$\begin{bmatrix} 1 + 2 + 1 \\ 1 + 8 + 5 \end{bmatrix} [5\text{-}10 \qquad 9\text{-}6] = 22 > 0$$

Case 2. Direct requirements: $[T_d^{ab}(w^a - w^b)]$

$$\begin{bmatrix} 1 \\ 1 \end{bmatrix} [5\text{-}10 \qquad 9\text{-}6] = -2 < 0$$

Case 3. Gross requirements: $[(T_d^{ab} + T_{e1}^{ab} + T_{e2}^{ab} + T_{e1*}^{ab})(w^a - w^b)]$

$$\begin{bmatrix} 1 + 2 + 1 + 9 \\ 1 + 8 + 5 + 2 \end{bmatrix} [5\text{-}10 \qquad 9\text{-}6] = -17 < 0$$

It is clear that the test of factor content of trade holds only in terms of "home-gross" factor requirements in the general case. However, if we use the same data to test restriction (18) but employ direct or gross factor requirements for $(T_d^{ab} + T_{e1}^{ab} + T_{e2}^{ab})$, then HO theorem may be incorrectly rejected.

III. RELATIONSHIP TO PREVIOUS RESULTS

In this section we discuss how the restriction derived in the presence of both nontraded goods and trade barriers may be extended in a number of directions to take account of different assumptions about the pattern of production and trade. We start by showing that if all goods are traded so that home and foreign prices differ by exactly the amount of tariffs, restriction (18) reduces to

$$(T_d^{ab} + T_{e1}^{ab})(w^a - w^b) \geqslant Q^b + R^a \geqslant 0 \tag{19}$$

Since $T_v^{ab} \equiv T_d^{ab} + T_{e1}^{ab} + T_{e1*}^{ab}$ in this case, it follows that the home-gross factor requirements are the appropriate determinants of the trade pattern.

We then demonstrate that the home-gross requirements test also holds when trade barriers are zero for all goods. In such a free trade world, if intermediate goods are not traded between countries, restriction (18) reduces to

$$(T_d^{ab} + T_{e2}^{ab})(w^a - w^b) \geqslant 0 \tag{20}$$

Since $T_v^{ab} \equiv T_d^{ab} + T_{e2}^{ab}$ in this case, it is easy to show that test of the Helpman final good model (1984), $T_v^{ab}(w^a - w^b) \geqslant 0$, extends to the use of gross (= home-gross) requirements. Note that in general home-gross requirements are different from both direct and gross requirements. In the above special case, however, home-gross requirements are the same as gross requirements by definition.

On the other hand, if such goods are freely traded between countries, Staiger (1986) has advocated that direct factor requirements should be used in determining the factor content of trade:

$$T_d^{ab}(w^a - w^b) \geqslant 0 \tag{21}$$

However, we can demonstrate, with the same assumptions as in Staiger, that depending on where intermediate goods are produced, the factor content of trade could be appropriately measured on the basis of either gross or direct factor requirements.[5] Note again that in this special case, the definition of home-gross requirements is the same as that of direct or gross requirements, respectively.

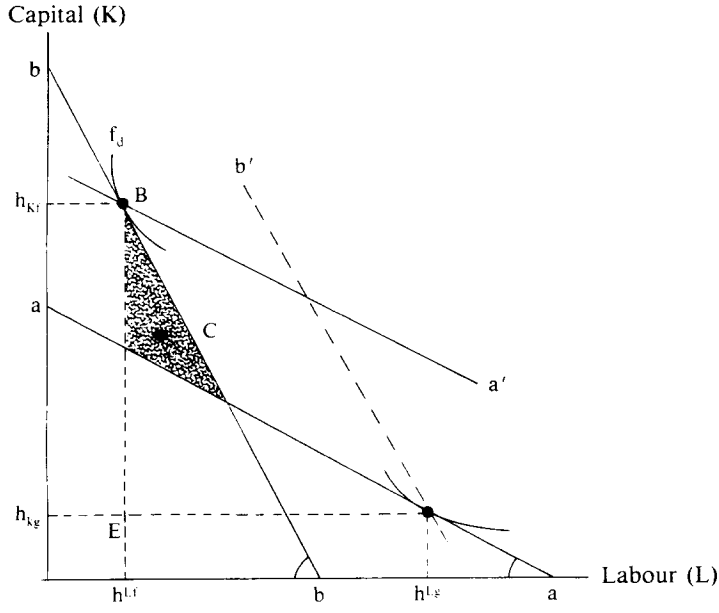
The intuition behind this results is reflected in the figure below where the free trade situation is depicted as the unit-value-added isoquants and unit-isocost lines in the two country and two factor case. In this figure the lines aa and bb are unit isocost lines representing the combination of factors which would cost one dollar in country a and in country b, respectively. The isoquants f_d and g_d are unit-value-added isoquants that represent the combination of primary factor inputs producing one dollar's worth of value added of the final good (h_{Kf}, h_{Lf} and the intermediate good (h_{Kg}, h_{Lg}), respectively. Given factor prices, the slopes of the unit isocost lines are determined. The condition for cost minimization implies that the unit isoquant. Under this condition country a produces the intermediate good at point A and exports it to country b, while country b produces a final good at point B by importing the intermediate good from country a.

Because the dotted isocost line a'a' that passes through point B lies clearly outside the unit isocost line aa, it implies that the cost of production of the final good would be higher if it was produced in country a than in country b. it also implies, by comparing the line bb with the line b'b', that the cost of production of the intermediate good would be higher if it was produced in country b than in country a. Since the isoquant f_d now stands for the combination of primary factor input producing one dollar's worth of value added of final good, direct requirements are relevant for the explanation of the factor content of trade.

Another way of viewing this example is to look at gross factor requirements. Since the coefficients (h_{Kg}, h_{Lg}, h_{Kf}, h_{Lf}) in the figure denote only primary factor requirements for producing one dollar's worth of value added, country b's com-

[5]A formal verification of this case if provided in Kang(1991).

Unit-Value-Added Isoquants



bination of factors used both directly and indirectly to produce this country's one dollar's worth of value added of final food must lie on the right of BE as well as above EA. If the gross (direct plus indirect) factor requirements lie somewhere in the shaded area, say point C where it lies below the line bb, implying the final good will be produced in country b but above the line aa, implying the final good will be not produced in country a, then gross factor requirements also are relevant.

IV. CONCLUDING REMARKS

We have derived the restrictions on the factor content of bilateral trade under various conditions. One interesting finding is that the admission of trade barriers into the model results in some positive value in the right hand side of restriction (18), as compared with the zero value in Helpman's factor content version of the Heckscher-Ohlin theorem. The positive value represents the cost (that is, price-distorting effects) of trade barriers between two countries. In deriving the restrictions we have assumed that intermediate goods are produced with primary factor inputs only. However, the model can be easily extended to allow for the possibility that all goods are used as intermediate inputs. Since restriction (18) depends on only post-trade data, it provides a feasible test that can be implemented empirically.

The other interesting finding is that neither direct nor gross factor requirements are relevant to explaining the factor content of trade flows in goods for the general case in which the model allows for the existence of both trade barriers and non-traded goods. We then have developed a new measure which is referred to as "home-gross" factor requirements. We have established that the home-gross factor requirements always provide a valid measure of factor content of trade. That is to say, the home-gross requirements test holds in a world with either free trade or trade barriers and with either freely traded or non-traded intermediate goods.

This result thus will offer an important theoretical foundation when we consider what should really be used in empirical tests of implications arising from the HO model.

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