NBER WORKING PAPER SERIES

FACTOR TRADE AND GOODS TRADE

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Working Paper No. 999

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

October 1982

The research reported here is part of the NBER's research programs in International Studies and project in Productivity (World Economy). Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #999
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ABSTRACT

Previous work by Dixit and Woodland on the effect of inter-country factor endowment differences on goods trade is extended to include simultaneous factor trade and goods trade. The goods trade pattern with factor trade is compared to that without factor trade. It is for instance shown that goods trade and factor trade may be substitutes or complements, depending upon whether traded and nontraded factors are "cooperative" or "non-cooperative." The asymmetry between the effects of differences in endowments of traded and differences in endowments of nontraded factors is emphasized.

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Revised September 1982

FACTOR TRADE AND GOODS TRADE*

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1. Introduction

The standard factor proportions theory of international trade examines how intercountry differences in factor proportions determine the pattern of international trade, in the extreme situation when all goods are internationally mobile but all factors of production are trapped behind national borders. For the classic 2 x 2 x 2 Heckscher-Ohlin-Samuelson model, the relation between factor endowments and goods trade is summarized in the Heckscher-Ohlin Theorem: Under some conditions a country exports the good that is intensive in the use of its abundant factor. The theory has now been much developed beyond this simplest case, and several generalizations of the Heckscher-Ohlin-Theorem to an arbitrary number of goods and factors have been presented.[1] A recent very elegant treatment is due to Dixit and Woodland (1982).

In the real world there is, however, international movement not only of goods but also of some factors of production, for instance migration of workers and professionals as well as foreign direct investment. Although there exists a literature on various aspects of factor mobility and the pattern of trade,[2] there does not to my knowledge exist a more systematic and general analysis of how intercountry differences in factor endoments determine trade in both goods and factors, and in particular how the pattern of trade in goods is modified when there is trade in factors compared to when there is not. The purpose of this paper is to provide such an analysis, by extending the Dixit and Woodland (1982) analysis to include trade in factors.

We shall hence deal with trade in both goods and factors. With regard to trade in factors, we shall assume that factor owners are not internationally mobile but remain in their home countries, repatriate the income from the factors they employ abroad, and consume this income in the home country.

It is well known that if trade in goods results in factor price equalization across countries, factor trade is in a sense redundant and would simply create a continuum of different trade patterns at the same goods and factor prices. We shall avoid such trivial examples of trade in factors, and instead deal with situations where goods trade does not equalize factor prices in the absence of factor trade.

In general, in competitive non-distorted situations trade between countries depends on differences in preferences, technology and factor endowments. To isolate the effect of factor endowments, Dixit and Woodland (1982) consider a world consisting of two countries, called the home and the foreign country, which initially are identical with respect to preferences, technology and factor endowments. The countries will have the same autarky equilibrium, assuming that it is unique. If trade in goods is opened up between the two countries, it is clear that the trade equilibrium will be one of zero trade, where goods and factors are priced as in the autarky equilibrium. Then a marginal change is made in the factor endowments of the home country, so as to create a situation with intercountry differences in factor endowments. At unchanged prices there will then be excess demand or supply of goods, prices will adjust, and a new trade equilibrium will be established with non-zero trade in goods between the countries. Now, if, before the change in home country endowments, trade both in goods and in some factors is opened up, the initial equilibrium will be the same with zero trade in goods and factors. The change in home country endowments will however then result in a different equilibrium with generally non-zero trade in both goods and factors. With this method we can examine how the change in endowments determines these trade patterns with and without trade in factors.

The paper is organized as follows. Section 2 briefly presents Dixit and Woodlands (1982) model and restates their generalization of the Heckscher-Ohlin Theorem, for the case with no international factor mobility. We modify their analysis by considering compensated factor endowment changes, to be specified below, which allows us to concentrate on the production side, and to avoid assumptions of constant returns to scale and homothetic preferences.

Section 3 introduces trade in factors on a general level. Section 4 compares more closely the goods trade pattern with and without factor trade and discusses whether factor trade is a substitute or a complement to goods trade, and whether factor trade may reverse goods trade. Section 5 deals with gains from factor trade, and Section 6 summarizes the results and presents some concluding remarks.

2. Factor endowments and goods trade

In this section we present the model of Dixit and Woodland (1982) and restate one of their results about the effect on factor endowments on goods trade in the absence of factor mobility. Their model and this result will be the starting point for the subsequent analysis. Our presentation differs somewhat from that of Dixit and Woodland in that we do not assume constant returns to scale and homothetic preferences; on the other hand we consider only compensated factor endowment changes (to be specified below). We also add a diagrammatic illustration to their result. The presentation will be brief; for further discussion we refer to Dixit and Woodland (1982).

We consider an open economy that produces m + 1 goods, indexed $i = 0,..,m$, all of which are traded. It has a well-behaved convex technology (not necessarily with constant returns to scale and not necessarily with no joint production), and uses n primary factors in fixed supply, indexed $j = 1,..,n$. Its demand for goods is represented by a well-behaved strictly quasi-concave utility function, not necessarily homothetic. Let good 0 be the numeraire with price $p_o = 1$, and let the positive m-vector p denote the prices of goods $i = 1,..,m$, the non-numeraire goods. Let the non-negative m-vector v denote the economy's factor endowments. Assuming competitive conditions, production efficiency, flexible factor prices and full employment of factors, the equilibrium of the economy can be represented by the budget constraint

(2.1) $E(1, p, u) = G(1, p, v)$,

stating that expenditure, given by a standard twice differentiable expenditure function $E(1, p, u)$ of goods prices and the welfare level u, equals national product, given by a standard twice differentiable national product function $G(1, p, v)$. Equation (2.1) expresses the welfare level as an implicit function $u = H(1, p, v)$ of goods prices and factor endowments. We define net export of non-numeraire goods as the difference between output and consumption, which by standard properties of the expenditure and national product function can be written as the m-vector $x = G_p(1, p, v) - E_p(1, p, u)$, where $y = G_p = (\partial G/\partial p_1,..,\partial G/\partial p_m)$ and $c = E_p = (\partial E/\partial p_1,..,\partial E/\partial p_m)$ is output and consumption, respectively, of non-numeraire goods. (Derivatives will be denoted by subindices throughout.) Positive components of x correspond to export, negative to import. Net export of good 0 is $x_o = \partial G/\partial p_o - \partial E/\partial p_o$, but by Walras' Law we need not explicitly deal with net export of good 0 in the analysis below. By substituting the welfare level $u = H(1, p, v)$ that solves (2.1), we get the net export function for non-numeraire goods,

(2.2) $x(p, v) = G_p(p, v) - E_p(p, H(p, v))$,

where we for convenience suppress the price of the numeraire.

The assumption of single-valued and differentiable supply functions, that is that the expenditure and national product functions are twice differentiable, is crucial for the analysis that follows. For the case with constant returns to scale and no joint production, we hence implicitly assume that the number of factors is at least as large as the number of goods, $n \geq m + 1$.[3]

We next consider a two-country world, with the home country having a net export function $x(p, v)$ and the foreign country having the net export function $x^*(p, v^*)$, where v^* denotes the foreign country's factor endowments. (A "*" superscript will refer to the foreign country throughout.) A trade equilibrium, where goods are internationally traded but factors are not, is given by the condition that the two countries' net exports sum to zero, i.e.,

$$(2.3) \quad x(p^t, v) + x^*(p^t, v^*) = 0,$$

from which condition the trade price vector p^t can be solved.[4] Assume now that the two countries have identical preferences and identical technologies. Hence their net export functions are identical. Furthermore, assume that their factor endowments are identical, i.e. $v = v^*$. It is then clear that the trade price equals the price in autarky for the two countries, and that there is no trade between them in the trade equilibrium, i.e. $x = x^* = 0$.

To find how differences in factor endowments determine the pattern of trade in goods, we now let factor endowments change by the n-vector dv in the home country. We say that the home country is relatively <u>abundant</u> (scarce) in factor j ($j = 1,..,n$) if and only if dv_j is positive (negative). This change in endowments will, at constant trade prices, give rise to a world excess supply of non-numeraire goods equal to $x_v dv$, the post multiplication of the (mxn) matrix $x_v = [\partial x_i/\partial v_j]$ of endowment effects on net export at constant prices with the column n-vector dv.

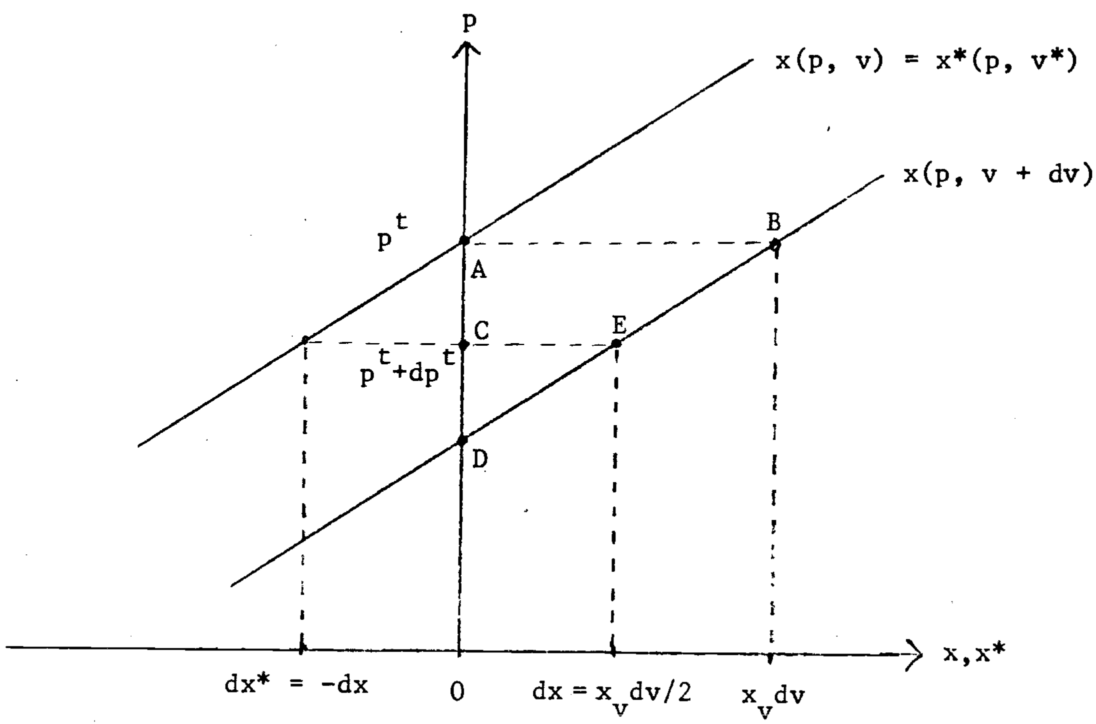
From the symmetry of the two countries follows that trade prices will adjust such that each country absorbs half of the initial excess supply. Hence, the home country's net export in the new trade equilibrium, dx, will simply be half the initial excess supply,[5]

$$(2.4) \quad dx = x_v dv/2 \ .$$

These results are readily illustrated in the two-good case (m = 1), as shown in Fig. 1. The curve through A shows the home and foreign countries' identical net export function for the single non-numeraire good, before the endowment change. The initial zero-trade equilibrium (and autarky equilibrium) is given by A. The net export function is upward sloping in the neighbourhood of the zero-trade equilibrium since production is non-decreasing and consumption non-increasing in the price of the non-numeraire goods (there is no terms of trade effect on welfare with zero trade and hence only a pure substitution effect on consumption).[6]

The change in factor endowments in the home country shifts its net export curve horizontally, giving rise to a world excess supply of goods AB at the initial prices (assumed positive in the figure). The trade price adjusts to point C where the two countries' net exports are of equal size but of opposite signs. Then they have each absorbed half of the initial excess supply. The equilibrium net export of the home country after the change in endowments is CE, half the initial world excess supply at constant prices AB. We also note that the change in the trade price AC is half the change in the price if the home country had been in autarky, AD.[7]

Fig. 1



Let us next examine the initial excess supply $x_v dv$ more closely. Differentiating (2.1) and (2.2) at constant prices, gives[8]

(2.5) $x_v dv = G_{pv} dv - C_Y w dv.$

Here the (mxm) matrix $G_{pv} = [\partial^2 G/\partial p_i \partial v_j] = [\partial y_i/\partial v_j]$ is the matrix of Rybczynski derivatives, that is the endowment effects on output at contant prices. The (column) m-vector C_Y is the vector of income derivatives $[\partial C_i/\partial Y]$ of the Marshallian demand functions $[C_i(p, Y)]$ for the goods (where Y denotes income). The expression wdv denotes the inner product $\Sigma_j w_j dv_j$ of factor prices and the change in factor endowments. The first term in (2.5) is the Rybczynski effect on production, the second term is the effect on consumption of the change in income due to the change in endowments. Let us consider what we call <u>compensated</u> changes in the factor endowments, that is changes which fulfill wdv = 0 and hence have no direct effect on the income of the home country. This means that we in a sense restrict the countries to be of the same size, in spite of having different factor endowments. There will hence be no income effects on consumption, and we need not assume homotheticity.[9] Then the effect on consumption in (2.5) is zero, and the initial excess supply is simply equal to the Rybczynski effect. Since net export equals half the initial excess supply, we have the final result

(2.6) $dx = G_{pv} dv/2.$

<u>For compensated factor endowment changes, net export is simply half the Rybczynski effect on production.</u>

One way to interpret this result, in line with Dixit and Norman (1980), is to take the elements of the Rybczynski matrix G_{pv} to represent generalized factor intensities: Good i is said to be intensive (non-intensive) in its use of factor j if and only if $\partial^2 G/\partial p_i \partial v_j$ is positive (negative). With this interpretation of the Rybczynski matrix, we may interpret (2.6) as expressing that the home country tends to export goods that are intensive in abundant factors. In this sense, (2.6) is a generalization of the Heckscher-Ohlin Theorem. Put differently, this definition of intensities is the one required for us to be able to say that a country exports goods that are intensive in its abundant factors.

The definition is consistent with the standard 2 x 2 x 2 Heckscher-Ohlin model, since the Rybczynski effect on the capital intensive good (defined by cost share, capital/labor ratio, or autarky wage/rental ratio) is positive (negative) for capital (labor) increases.

The appropriate definition of factor intensities in a general model is a somewhat controversial issue in international trade theory. Clearly, the Rybczynski derivatives are in general not in a one-to-one relation to intensities measured as, say, cost shares in production, but depend not only on elasticities of substitution (as in the sector specific factors model) but on the specification of the full general equilibrium of the model. Different definition of factor intensities are further discussed in Dixit and Norman (1980), Ethier (1982a,b), Jones and Neary (1982), and Jones and Scheinkmann (1977).[10]

3. Factor trade and goods trade

In the previous section we restated the case when there is international trade in goods but not in factors. In this section we shall extend the Dixit and Woodland model to allow trade between the two countries in some factors, and examine how differences in factor endowments in that case determine the trade pattern for both goods and factors.

Before introducing trade in factors, let us consider the two countries' factor prices when there is trade in goods but not in factors. Suppose there is factor price equalization between the two countries in the new trade equilibrium, after the change in the home country's factor endowments. That is, factor prices are (locally) independent of factor endowments (for the endowment changes considered), and factor prices depend only on goods prices. With factor price equalization, it is well-known that trade in factors is redundant, in the sense that goods prices, factor prices, consumption, and welfare are not affected. Only an indeterminacy in the pattern of production and trade between countries is created. To avoid such trivial cases of factor trade, we now explicitly assume that there is a subset of factors for which there is no (local) factor price equalization, and hence for which the endowment effects on factor prices are non-zero.[11]

Let us then introduce trade in a subset of the factors for which there is no factor price equalization. We shall use the same approach as Kemp (1969), Neary (1980) and Woodland (1982). It has the advantage of treating goods and traded factors symmetrically. We decompose the factor endowment n-vector v into two subvectors, $v = (k, \ell)$, where the non-negative n_k-vector k denotes endowments of traded factors, the non-negative n_ℓ-vector ℓ denotes endowments of nontraded factors, and where $n = n_k + n_\ell$. Let the corresponding factor price vectors be r and w. We let the non-negative n_k-vector $\tilde{k}$ denote traded factors used in production at home, and let the n_k-vector z given by $z = k - \tilde{k}$ denote net export of traded factors, the difference between endowments and domestic use of traded factors. Positive components correspond to export, negative to import of traded factors. For convenience we shall henceforth call traded factors "capital", non-traded factors "labor", and the prices r of traded factors "rentals".

For goods prices and rentals given in the world market, the production side of the home country can be represented by the modified twice differentiable national product function defined as

$$(3.1) \quad \tilde{G}(p, r, k, \ell) = \max \{G(p, \tilde{k}, \ell) + r(k - \tilde{k}): \tilde{k} \geq 0\},$$

the maximum over the sum of Gross Domestic Product, $G(p, \tilde{k}, \ell)$, where $\tilde{k}$ is capital used at home, and net factor payments from abroad, $r(k - \tilde{k})$, the value of the export of capital. Hence the modified national product function gives Gross National Product of the country. Henceforth, we shall indeed call $G(p, v)$ the <u>domestic</u> product function, and $\tilde{G}(p, r, v)$ the <u>national</u> product function. The optimal stock of capital used at home will be a function $\tilde{k}(p, r, \ell)$ of goods prices, rentals, and labor endowments that fulfills the first-order condition

(3.2) $G_k(p, \tilde{k}(p, r, \ell), \ell) = r,$

i.e. the marginal value product of capital equals the rental (we assume an interior solution). We note that capital used at home is independent of capital endowments, depending instead on the rentals.

For the case when there is only one capital good ($n_k = 1$), the production side can be illustrated as in Fig. 2. The curve showing the value of the marginal (domestic) product of capital $G_k(p, r, \tilde{k}, \ell)$ is downward sloping,[12] and shows for a given r the corresponding use of capital at home $\tilde{k}(p, r, \ell)$. Net export of capital, z, is given by the difference between endowments k and capital used at home, and can be read off leftwards on the $\tilde{k}$-axis from the endowment point k.

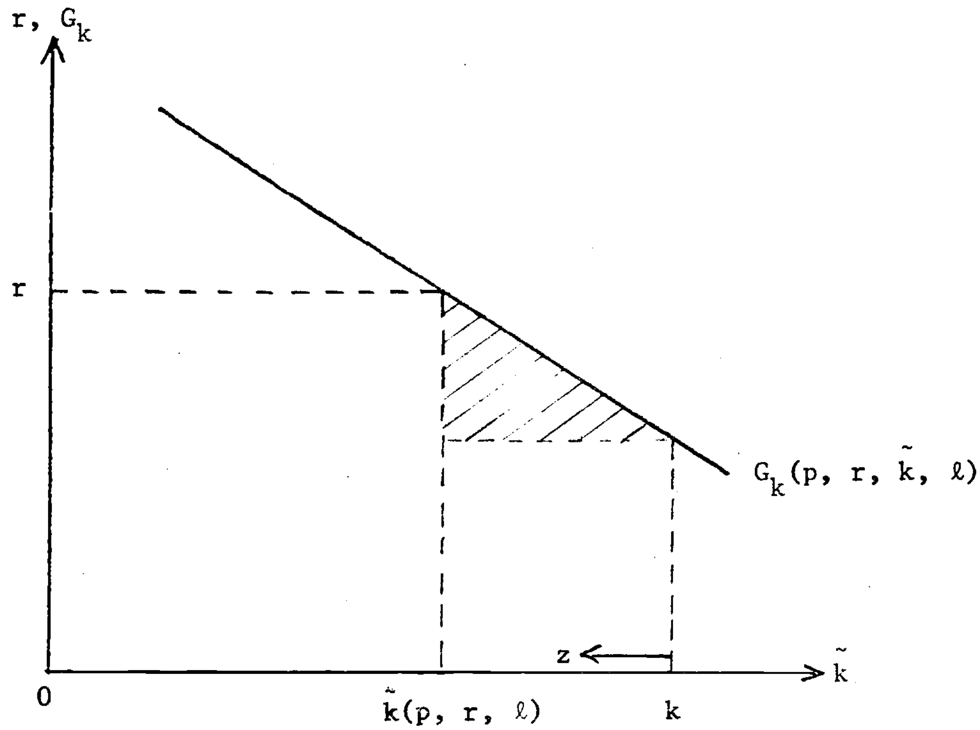
An equilibrium for the home country with trade in both goods and capital can then be represented by the budget constraint $E(p, u) = \tilde{G}(p, r, v)$, letting the national product function replace the domestic product function in (2.1). This gives the welfare level as an implicit function $u = \tilde{H}(p, r, v)$ of goods prices, rentals, and factor endowments. Net export of goods and capital will be given by the functions

$$(3.3) \quad \begin{aligned} \tilde{x}(p, r, v) &= \tilde{G}_p(p, r, v) - E_p(p, \tilde{H}(p, r, v)) \text{ and} \\ z(p, r, v) &= \tilde{G}_r(p, r, v) = k - \tilde{k}(p, r, \ell). \end{aligned}$$

We assume these functions are well defined and differentiable. If there are constant returns to scale and no joint production, we hence assume that the number of nontraded factors is at least as large as the number of traded goods and factors.

With two countries, a trade equilibrium will be represented by the world market equilibrium conditions

Fig. 2



$$(3.4)\quad \begin{aligned} &x(p^t, r^t, v) + x^*(p^t, r^t, v^*) = 0 \quad \text{and} \\ &z(p^t, r^t, v) + z^*(p^t, r^t, v^*) = 0, \end{aligned}$$

stating that world net export of goods and capital is zero. The initial equilibrium, with identical countries and identical endowments, will of course have zero trade in both goods and capital and the same goods prices and rentals as if the countries were in autarky. Consider next the effect on the equilibrium of a change dv in the endowments of the home country. At unchanged goods prices and rentals, there will be an excess supply of goods $\tilde{x}_v dv$ and of capital $z_v dv$. By analogy with the case with trade in goods only, the symmetry between the countries inplies that they will each absorb half of this excess supply of goods and capital. It follows that the remaining half of the excess supply will be the home country's net export of goods and capital. Hence its trade in goods and capital will be given by

$$(3.5)\quad \begin{aligned} &d\tilde{x} = \tilde{x}_v dv/2 \quad \text{and} \\ &dz = z_v dv/2. \end{aligned}$$

Let us next examine what determines the initial excess supply of goods and capital. We first look at the excess supply of capital, $z_v dv$. From (3.3) and (3.5) we get

$$(3.6)\quad dz = \tilde{G}_{rv} dv/2 = (dk - \tilde{k}_\ell d\ell)/2,$$

where the $(n_k x n_\ell)$ matrix $\tilde{k}_\ell = [\partial \tilde{k}_h/\partial \ell_j]$ denotes the derivatives of capital used at home with respect to labor endowments, at constant goods prices and rentals. The interpretation of (3.6) is clear. The initial excess demand of capital consists of the change in capital endowments, dk, minus the change in capital used at home due to the change in labor endowments, $\tilde{k}_\ell d\ell$. It follows that the properties of the labor endowments effect on capital used at home, $\tilde{k}_\ell$, will be crucial in determining net export of capital.

Let us then look behind the initial excess supply of goods, $\tilde{x}_v dv$. Assuming compensated changes in factor endowments, that is that $r dk + w d\ell = 0$, we first get, by differentiating (3.3) and substituting in (3.5), in complete analogy with (2.6),

$$(3.7)\quad d\tilde{x} = \tilde{G}_{pv} dv/2 = \tilde{G}_{p\ell} d\ell/2 = (G_{p\ell} d\ell + G_{pk}\tilde{k}_\ell d\ell)/2,$$

where we have used (3.1) and noted that $\tilde{G}_{pk} = 0$, since output $\tilde{y} = \tilde{G}_p$ will depend on rentals rather than capital endowments. The $G_{p\ell} d\ell$ term on the right hand side of (3.7) is the labor Rybczynski effect, due to the change in labor endowments. The term $G_{pk}\tilde{k}_\ell d\ell$ on the right hand side is the capital Rybczynski effect, due not to the change in capital <u>endowments</u> dk, but to the change in capital <u>used at home</u> $\tilde{k}_\ell d\ell$.

From this analysis we draw the following conclusion for the case when there is trade both in capital and goods: Differences in capital endowments between the countries have a direct effect on net export of capital, but no effect at all on net export of goods. Differences in labor endowments have an indirect effect on net export of capital due to the effect on capital used at home. With regard to net export of goods, differences in labor endowments have a direct labor Rybczynski effect, and an indirect capital Rybczynski effect, the latter due to the effect on capital used at home.

Hence, at first it seems that the intuitive and easily interpreted generalization of the Heckscher-Ohlin theorem in (2.6) for trade in goods only does no longer hold when there is trade in capital. Differences in capital endowments then do not at all affect net export of goods, and differences in labor endowments affect net export of goods in a somewhat complicated way. It appears that it cannot be said, for instance, that the home country tends to export goods that are relatively intensive in the use of its relatively abundant kinds of labor. Thus, the relation between differences in factor endowments and trade in goods seem to be considerably weakened if there is trade in some factors.

Let us however look further into these matters, still on a rather general level, to see whether we can balance these somewhat pessimistic conclusions. Let us treat trade in goods and factors symmetric, and look at the full generalized Rybczynski matrix of the national product function $\tilde{G}(p, r, v)$, exploiting (3.6) and (3.7),

$$(3.8) \quad \begin{bmatrix} \tilde{G}_{pk} & \tilde{G}_{p\ell} \\ \tilde{G}_{rk} & \tilde{G}_{r\ell} \end{bmatrix} = \begin{bmatrix} 0 & G_{p\ell} + G_{pk}\tilde{k} \\ I & -\tilde{k}_{\ell} \end{bmatrix}$$

where I is the $(n_k \times n_k)$ identity matrix. Let us call these generalized Rybczynski effects <u>total</u> Rybczynski effects. The total Rybczynski effect $\tilde{G}_{pk}$ on goods of traded factors (capital) is zero, reflecting that differences in endowments of traded factors do not affect goods net export. The total Rybczynski effect $\tilde{G}_{p\ell}$ on goods of nontraded factors (labor) is given by the cumbersome expression $G_{p\ell} + G_{pk}\tilde{k}_{\ell}$ in terms of direct Rybczynski effects of the domestic product function. It takes into account the indirect effects via the change in capital used, k_{ℓ}. It is a total Rybczynski effect in the same way as we get a total Rybczynski effect on net output in a standard Heckscher-Ohlin model with intermediate inputs. If we are bold and identify these total Rybczynski effects with total generalized factor intensities, we can, in complete analogy with the no factor trade case, indeed interpret (3.7) as expressing that, with factor trade, a country will export goods that are intensive (in this total sense) in its abundant nontraded factors. In this sense the Heckscher-Ohlin Theorem still holds. Put differently, if we like the Heckscher-Ohlen Theorem to hold with trade in factors, generalized factor intensities <u>have</u> to be defined in this way.

The total Rybczynski effect $\tilde{G}_{rk}$ on net output of traded factors of endowments of traded factors is of course the unit matrix, since they stand in a one-to-one relation. Equivalently, traded factor <u>service</u> j is of course intensive in its use of the <u>endowments</u> of traded factor j, but not in other traded factors. The total Rybczynski effect $\tilde{R}_{r\ell}$ on net output of traded factors of nontraded factors is given by $-\tilde{k}_{\ell}$, minus the effect on traded factors used. This can again be interpreted as indicators of generalized factor intensity, and we may accordingly again tautologically interpret (3.6) as expressing that a country will export those factors who are intensive in their abundant factor endowments. We shall however refer to the sign pattern of the $(n_k \times n_{\ell})$ matrix $\tilde{k}_{\ell}$ as indicating 'cooperativeness'

($\partial k_h/\partial \ell_j > 0$) and 'noncooperativeness' ($\partial k_h/\partial \ell_j < 0$) between capital and labor. This will be further discussed in next section.[13]

4. <u>The trade pattern with and without factor trade</u>

Let us compare more closely the trade pattern with and without factor trade. Let us consider the two goods case ($m = 1$) for which net export x of the single non-numeraire good 1 is a scalar. With no trade in factors, net export of good 1 is $dx = (G_{pk}dk + G_{p\ell}d\ell)/2$ by (2.6); whereas with trade in capital, net export of goods and capital is $d\tilde{x} = (G_{pk}\tilde{k}_\ell d\ell + G_{p\ell}d\ell)/2$ and $dz = (dk - \tilde{k}_\ell d\ell)/2$ by (3.7) and (3.6). It follows that the difference between net export of good 1 with and without trade in capital is

$$(4.1) \quad d\tilde{x} - dx = G_{pk}(- dz)/2,$$

that is, the capital Rybczinski effect due to net import $-dz$ of capital.

Let us consider the situation when the compensated differences in factor endowments are such that the home country is abundant in (all kinds of) capital and scarce in (all kinds of) labor. Let us also assume that good 1 is intensive in the use of (all kinds of) capital. Hence

$$(4.2) \quad dk > 0, \quad d\ell < 0 \quad \text{and} \quad G_{pk} > 0.$$

We now assume that capital and labor are <u>cooperative</u>,[14] in the sense that an increase in labor endowments at constant goods prices and rentals implies an increase in capital used at home, that is, the matrix $\tilde{k}_\ell$ has all entries positive,

$$(4.3) \quad \tilde{k}_\ell > 0.$$

Under these assumptions it follows from (3.6) that when there is trade in capital, the home country exports capital, since its endowments of capital are larger, and its use of capital at home is smaller. Furthermore, from (4.1) we see that net export of the capital intensive good 1 is smaller when capital is exported. Hence, under the assumption that capital and labor are cooperative, we get the intuitive result that when there is trade in capital, the capital intensive home country exports those directly and exports less of capital intensive goods than when capital is not traded,

$$(4.4)\quad d\tilde{x} < dx \quad \text{and} \quad dz > 0.$$

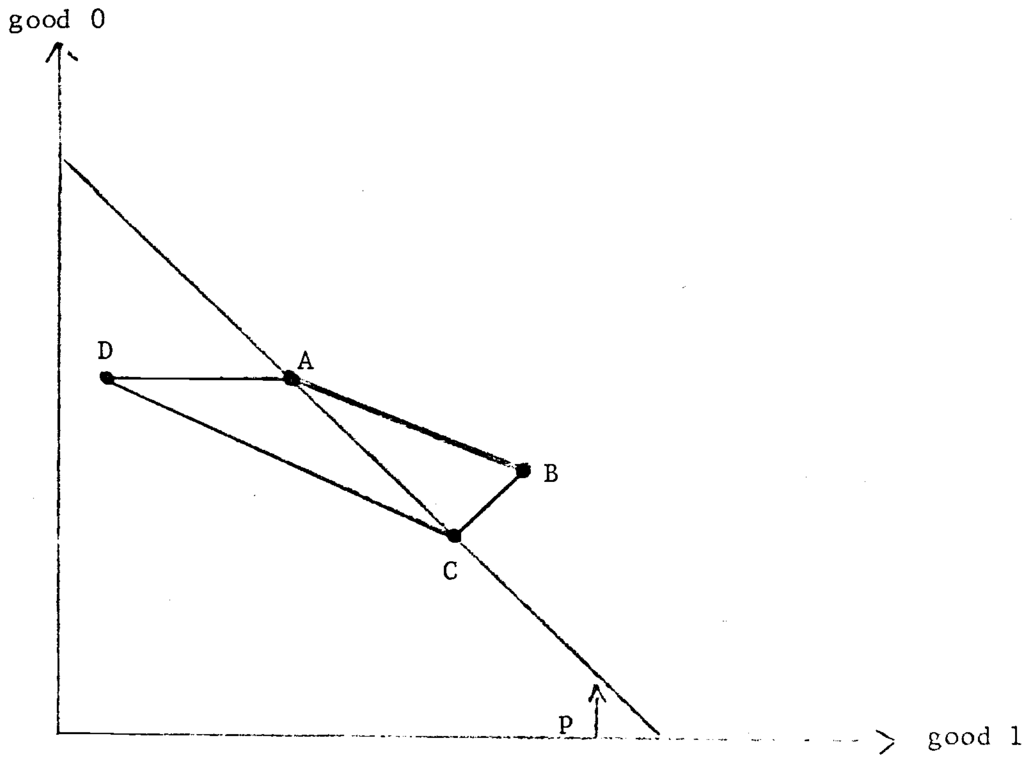
It appears that factor trade and goods trade here are <u>substitutes</u> in the sense that export of capital intensive goods is replaced with export of capital, and the goods trade volume might fall.[15]

Thus trade in capital may decrease the capital abundant country's export of capital intensive goods. But can trade in capital <u>reverse</u> the trade in goods? That is, can it be the case that a capital intensive country exports capital intensive goods if capital is not traded, but exports capital and imports capital intensive goods if capital goods are traded? The answer is yes, as the following example shows:

Consider the standard specific-factors model with two goods and three factors.[16] Let good 1 be produced by capital and labor, and let good 0 be produced by land and labor. Labor is hence the non-specific factor. Let the home country be relatively abundant in capital ($dk > 0$) and relatively scarce in labor ($d\ell < 0$), whereas the home and foreign countries' endowments of land are the same.

If there is trade in goods only, the home country will export good 1 and import good 0 as illustrated in Fig. 3.[17] The initial zero trade equilibrium of the home country is at A, where consumption and production coincide. The increase in capital ($dk > 0$) increases output of good 1 ($G_{pk} > 0$) and decreases output of good 0 ($\partial(\partial G/\partial p_o)/\partial k < 0$), at constant goods prices. Production shifts southeast to B. The compensated decrease in labor ($d\ell < 0$) decreases output of both goods ($G_{p\ell} > 0$, $\partial(\partial G/\partial p_o)/\partial \ell > 0$)[18] and shifts the production point southwest to C, back to the budget line at constant prices through A. Consumption remains at A. Hence, initial excess supply of the two goods is the vector from A to C, and net export of the two goods in the new trade equilibrium will be half that vector. What will the trade pattern be with trade in capital? The Rybczinski effect of capital on good 1 is positive, and capital and labor are cooperative.[19] Hence (4.2) and 4.3) hold, as does (4.4). Capital will be exported, and net export of good 1 will be smaller. But indeed net export of good 1 will be negative. For, noting in (3.7) that the Rybczinski effect of labor $G_{p\ell}$ on good 1 is positive, we realize that there is an initial <u>negative</u> excess supply of good 1, first because the home country has less labor ($G_{p\ell} d\ell < 0$), and second, because capital and labor are cooperative, it will use less capital ($\tilde{k}_\ell d\ell < 0$ and $G_{pk}\tilde{k}_\ell d\ell < 0$). Hence, the net export of capital will shift the production point northwest from C to somewhere west of A. However, the new production point will indeed be due west of A, at D, where there is zero

Fig. 3



excess supply of good 0. This can be understood as follows. The shift from A to D represents the excess supply of goods at constant goods price <u>and</u> rental, from the change in endowments. For a constant rental, the labor wage is constant, and for a constant wage, the land rent in sector 0 is constant. Hence, since the endowment of land does not change, neither does output of good 0. The net export vector in the new trade equilibrium with trade in capital will be half the vector from A to D, involving neither input nor export of good 0. We summarize our findings as

$$(4.5)\quad d\tilde{x} < 0 < dx, \quad d\tilde{x}_o = 0 > dx_o, \quad \text{and} \quad dz > 0.$$

With trade in capital, the capital abundant country exports capital, starts importing the capital intensive good it was exporting without capital trade, and ceases to import the other good. The goods trade pattern is indeed reversed.

Suppose now that capital and labor are <u>non-cooperative</u>, in the sense that (all elements of the matrix) $\tilde{k}_\ell$ are negative,

$$(4.6)\quad \tilde{k}_\ell < 0,$$

that is, more of labor at constant prices and rentals decreases the use of capital. It follows that a country abundant in capital and scarce in labor may either export or import capital, since both endowment and use of capital is initially larger. Hence, net export of capital intensive goods may be either larger or smaller with trade in capital. Let us give an example of an economy where indeed export of capital intensive goods <u>increases</u> with capital trade:

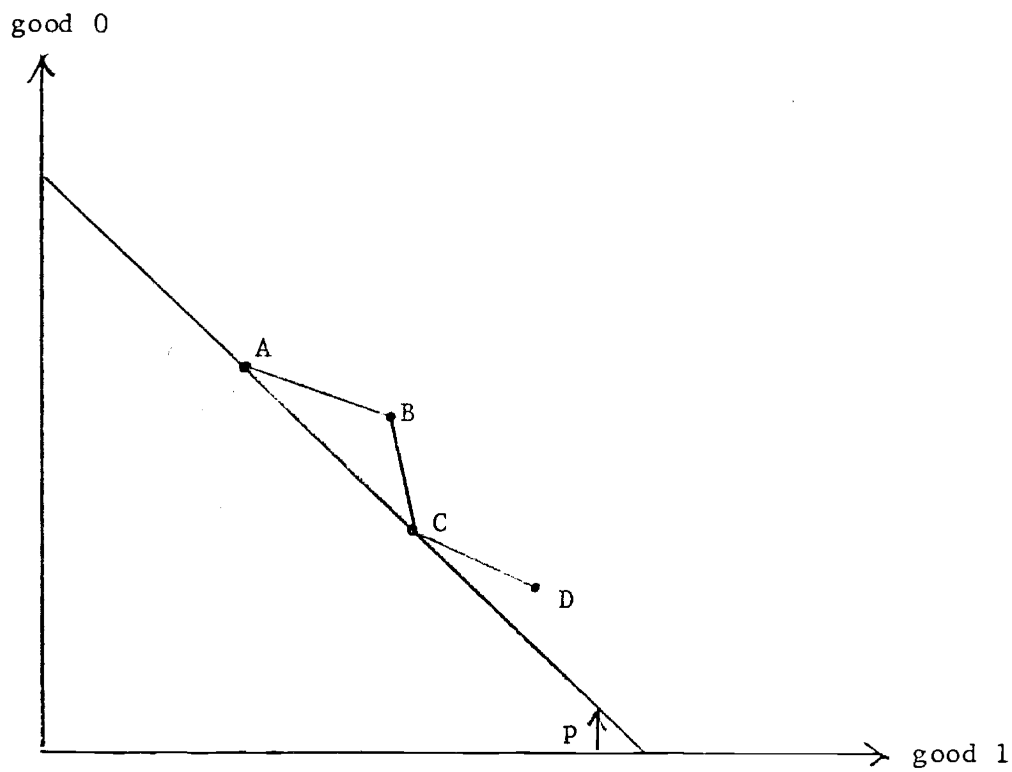
We consider again the specific-factors model mentioned above, but now the nontraded factor denoted by ℓ refers to the sector 0-specific factor land (rather than the non-specific labor as in the previous example). Let the home country be abundant in capital and scarce in land, whereas it has the same endowment of labor as the foreign country. With no trade in capital, the home country will export good 1, as shown in Fig. 4. The increase in capital shifts production from A southeast to B, at constant goods prices, and the compensated decrease in land shifts production futher southeast to C, back to the budget line through A.

With trade in capital, we first note that capital and land are non-cooperative, so capital use will indeed increase with less land. Can the increase in capital use dominate the increase in capital endoments, and hence lead to an initial excess demand for capital? Yes, at constant goods prices and capital rentals, land rents and labor wages are constant, and factor proportions in the two sectors do not change. Full employment of labor then requires that the proportional change in the use of capital $\hat{\tilde{k}}$ and land $\hat{\ell}$ fulfill $\lambda_1\hat{\tilde{k}} + \lambda_o\hat{\ell} = 0$, where λ_i is the share of labor employed in sector i, i = 0,1. Since the compensated endowment changes fulfill $\theta_k\hat{k} + \theta_\ell\hat{\ell} = 0$, where θ_k and θ_ℓ are the initial shares of capital and land income in national product, we can express (3.6) as

$$(4.7) \quad dz = [(\theta_\ell/\theta_k) - (\lambda_o/\lambda_1)](k/\ell)\ (-d\ell/2).$$

We see that a necessary and sufficient condition for capital to be imported is that the relative labor employment shares

Fig. 4



(λ_o/λ_1) exceeds the relative income shares (θ_ℓ/θ_k), which is equivalent to the cost share of capital in sector 1 to exceed the cost share of land in sector 0 $(\theta_{k1} > \theta_{\ell o})$.[20] Under these conditions, the production point moves further southeast from C to D. In the new trade equilibrium, net export of goods will be half the vector from A to D. The capital abundant home country will import capital, and export more of the capital intensive good 1 and import more of good 0. In this sense trade in capital is here complementary to trade in goods.

Let us also say something about the case when the two countries' endowments differ only with respect to (the vector of) the traded capital, but not with respect to the non-traded labor ($dk \neq 0$, $d\ell = 0$). For compensated factor endowment changes we have $rdk = 0$, hence there must be at least two different capital goods, and the vector dk has both positive and negative components. It follows from (2.6) that net export of goods without trade in capital is given by $dx = G_{pk}dk/2$, whereas with trade in capital net export of goods by (3.7) is zero, $d\tilde{x} = 0$. Net export of capital by (3.6) will be $dz = dk/2$. In this case, trade in capital completely replaces trade in goods (there will also be zero trade in the numeraire good), and trade in capital is in this sense complementary to trade in goods. The trade in capital simply offsets the endowment differences, with no change in production relative to the pre-endowment change situation. Capital trade is balanced, with simultaneous export and import of different capital goods. This is a straightforward example of so called "cross-hauling", recently discussed in a different context by Jones, Neary and Ruane (1982).[21]

When countries differ only with respect to endowments of traded factors, we can also say something general about uncompensated endowment changes. Assume that the endowment change fulfills $rdk > 0$, for instance that the home country has more of all capital goods. Differentiating (3.3) to express (3.5) and the analogue of (2.5), we get (since $\tilde{G}_{pk} = 0$)

$$(4.7) \qquad d\tilde{x} = -C_Y \, rdk/2,$$

where C_Y is the vector of marginal propensities to consume non-numeraire goods. If all goods are normal, it follows that the home country will import all goods, and export capital goods according to $dz = dk/2$.[22]

Let us finally mention the case when the countries differ only with respect to endowments of nontraded labor ($dk = 0$, $d\ell \neq 0$, $wdr = 0$). With no trade in capital, net export of non-numeraire goods is $dx = G_{p\ell}d\ell$, with trade in capital $d\tilde{x} = \tilde{G}_{p\ell}d\ell$. In the former case it is the labor Rybczynski effects for the domestic product function ('direct' intensities) that matter, in the latter the same effects for the national product function ('total' intensities). The difference is $d\tilde{x} - dx = G_{pk}\tilde{k}_\ell d\ell$ due to the change in use of capital, and net export of capital $dz = -\tilde{k}_\ell d\ell$ is determined by that change only.[23]

5. Gains from factor trade

Are there welfare gains from introducing factor trade in addition to goods trade? We would expect trade in factors to improve world overall welfare by improved world production efficiency, but it does not necessarily follow that every individual country will improve its welfare.[24] For it may very well be the case that factor trade leads to adverse goods terms of trade effects which may dominate and imply a net welfare deterioration for a country.[25] This is completely in accordance with the standard Gains from Trade Theorem, which says that for each country some trade is better than none, but trade in more commodities (goods and/or factors) is not necessarily better than trade in fewer.

In our case, we can however verify that factor trade is beneficial for both the home and foreign country. The reason is than here goods prices are the same whether or not there is trade in goods. This is because of the symmetry between the two countries. When the net export dz of capital occurs between the home country and foreign country, production changes by $G_{pk}(-dz)$ and $G^*_{pk}(dz)$ in the home and foreign country, respectively. Due to the symmetry between the countries, these production changes cancel ($G_{pk} = G^*_{pk}$) and there is no change in world production and world excess supply, and hence no effect on goods prices.[26]

Since there is zero trade initially, there is no first order effect on welfare of a change in prices. The effect on welfare consists of second order effects only. Those can be separated into a consumption substitution effect, which is the same with and without capital trade since the change in goods prices is the same, and a production substitution effect, the increase in national product. With factor trade, the latter contains an extra term, corresponding to a standard triangle in Fig. 2. Let the marginal value productivity schedule G_k

be drawn for the post trade prices $p^t + dp^t$, and let the rental r correspond to the equilibrium post factor trade world rental (the change from the rental before the endowment change is equal to half the change in the home country's autarky rental). Then the shaded triangle in Fig. 2 measures the increase in national product due to factor trade.[27]

6. Summary and concluding remarks

We first considered the case with goods trade but no factor trade, by restating one of Dixit and Woodland's (1982) results. Considering compensated factor endowment differences only, we saw that net export of goods is half the Rybczynski effect on production of the endowment change, since it is half the initial excess supply of goods. By the controversial identification of Rybczynski effects with generalized factor intensities, this result can be interpreted as saying that a country exports goods intensive in its abundant factors, and hence as a generalization of the Heckscher-Ohlin Theorem to many goods and factors. In any case, whether or not this definition of intensity is accepted, there is a rather clearcut effect on endowments on trade.

When we introduced factor trade in addition to goods trade, we found that differences in endowments of traded factors have a direct effect on net export of factors, but no effect whatsoever on net export of goods. Differences in endowments of nontraded factors have an indirect effect on trade in factors, via their effect on domestic use of traded factors. Differences in endowments of nontraded factors have a direct Rybczynski effect on net export of goods. In addition, they have an indirect effect via the effect on use of traded factors and the traded factors Rybczynski effect. Hence, the relation between goods trade and differences in factor endowment is weakened by the existence of factor trade. In particular, the effect of endowments of nontraded factors on the use of traded factors, that is whether traded and nontraded factors are "cooperative" or "noncooperative", is of crucial importance. In general, with factor trade it cannot be said that a country exports goods that are intensive in the use of abundant factors. Nor can it be said that a country exports goods that are intensive in the use of abundant nontraded factors. It all depends on the cooperative/non-cooperative properties of traded and nontraded factors. Nevertheless, as we have seen the different effects on net export of goods are still transparent.

Although the relation between differences in factor endowments and goods trade is weakened with factor trade, we however realize that the relation between differences in factor <u>use</u> and goods trade is the same as when there is no factor trade. That is, a country will export goods that are intensive in the use of factors that are intensively used in the country. In this sense, we can say that the Heckscher-Ohlin theorem generalizes to a situation with factor trade, if it is interpreted as referring to differences in factor use rather than endowments owned. Since, however, use of traded factors is endogenously determined, there is of course no causal relation between goods trade and differences in factor use. For empirical work, it seems that domestic factor use rather than total endowments of factors owned should be used in tests of the Heckscher-Ohlin theorem when there is factor trade. This is probably exactly what most empirical work has been doing. But, as we have seen, no causal relationship is tested this way.

These somewhat pessimistic conclusions could be somewhat modified by the observation that with factor trade, net export of goods and factors will be half of the total Rybczynski effects (taking into account the endogenous change in use of traded factors) on both goods and traded factors of the endowment differences. If these total effects are identified with intensities, we could say that a country exports goods that are 'total-intensive' in abundant nontraded factors. But the relation between the total Rybczynski effects and the direct ones depend on the cooperativeness between traded and nontraded factors.

When explicitly comparing the goods trade pattern with and without factor trade, we found that if capital and labor are cooperative, and capital is traded, a capital abundant country would export capital directly, and export less capital intensive goods than when capital is not traded. Hence, factor trade and goods trade are then in a sense substitutes, as in Mundell (1957). In a specific example, we could even show that capital export might make a country import capital intensive goods, and hence reverse the goods trade.

If capital and labor are non-cooperative, we could show that a capital abundant and labor scarce country might import capital and increase its export of capital intensive goods. In that case goods trade and factor trade are complementary, as in Markusen (1981).[28]

We also showed that in our case there are unambiguous gains for both countries from introducing factor trade, since no adverse goods price changes result.

Let us finally comment on Dixit and Woodland's (1982) method of local analysis around the zero trade equilibrium, together with our assumption of compensated endowment differences. There are some obvious advantages: The results are easily derived with straightforward calcusus, and they are transparent and easily interpreted. There is no need to assume either constant returns to scale and no joint production, or homotheticity of preferences. Also, the results are exact in the sense of giving explicit expressions, rather than the correlations that one otherwise gets (see Deardorff (1980, 1982), Dixit and Norman (1980), Woodland (1981) and Ethier (1982a, b)).

The disadvantages of the method are equally obvious: The results strictly apply only within a neighbourhood of the zero trade equilibrium, and, in our case, for factor endowment differences that are compensated. The single-valuedness and differentiability assumption on supply implicitly restricts the number of goods and traded factors not to exceed the number of nontraded factors (when "all" factors are included, such that there are constant returns to scale).

It seems rather likely that under the assumptions of constant returns to scale, no joint production, and homothetic preferences, most results would hold globally, although their derivation may be less transparent and straightforward. This is one area for future research.

Footnotes

* Several people have contributed very helpful comments to this paper. I especially would like to thank Alan Deardorff, Avinash Dixit, Elhanan Helpman, Bill Ethier, Harry Flam, Gene Grossman, Henrik Horn, Ron Jones, Paul Krugman, Peter Neary, Torsten Persson, Assaf Razin and Alan Woodland. The usual caveat applies, of course. A much different version with a different title was presented to the Workshop on Production and Trade in a World with Internationally Mobile Factors of Production, financed by the Bank of Sweden Tercentenary Foundation and held at the IIES, August 4-15, 1980, and to a Tel-Aviv University Department of Economics Seminar. A previous version with the same title was presented to the Workshop in International Economics, August 9-13, 1982, organized by the Stockholm School of Economics and the IIES. Partial support from the Bank of Sweden Tercentenary Foundation and the Torsten and Ragnar Söderberg Foundation is gratefully acknowledged.

1. For a recent survey, see Ethier (1982b).

2. See, for example, Mundell (1957), Chipman (1971), Jones and Ruffin (1975), Ferguson (1978), Jones (1980), Neary (1980), Markusen (1981) and Jones and Neary (1982).

3. If there are constant returns to scale but joint production, the number of factors must be at least as large as the number of 'activities'.

4. We assume that autarky and trade equilibria are unique.

5. Dixit and Woodland (1982), assuming constant returns to scale and homothetic preferences, and that the foreign country is k times larger than the home country, get the result $dx = x_v dv[k/(1 + k)]$.

6. The (m x m) matrix of the price derivatives of the net export function, x_p, is negative definite in the neighborhood of the autarky equilibria.

7. By differentiating $x(p^a, v) = 0$ we get the autarky price change $dp^a = x_p^{-1} x_v dv$. By differentiating (2.3) we get the change in the trade price $dp^t = x_p^{-1} x_v dv/2 = dp^a/2$, where we have used $x_p = x_p^*$. It follows that the net export in the new trade equilibria is $dx = x_p dp^t + x_v dv = x_v dv/2$, by substituting dp^t, which proves (2.4).

8. We have $x_v dv = G_{pv} dv - (E_{pu}/E_u)E_u du$. But $E_{pu}/E_u = C_Y$ and $E_u du = G_v dv = wdv$.

9. Note that differentiating (2.1) gives the income equivalent welfare effect $E_u du = xdp + wdv$. The first term is the terms of trade effect, which is zero with initial zero trade. By assuming that the second term, the direct effect on welfare of the endowment change, is also zero, we have no (first order) welfare effect at all.

10. The definition of intensities by Rybczynski derivatives can lead to some apparent paradoxes, which however may be interpreted as emphasizing the general equilibrium nature of the definition. Consider the model in Gruhen and Corden (1970), where three goods, wool, grain and textiles, are produced with three factors, land,

labor and capital. Wool and grain use land and labor, and the land/labor ratio is higher for wool than for grain. Textiles use labor and capital. At constant goods prices, an increase in capital withdraws labor from wool and grain production (at constant factor prices). Production of land intensive wool then increases, and it appears that wool is capital intensive although no capital is actually used in its production. Production of labor intensive grain goes down. Suppose capital is injected until the economy is specialized in wool and textile production: Further increases in the capital stock now decreases wool production (at increased wages), and it appears that wool is now capital non-intensive. (I owe this point to Paul Krugman.)

Dixit and Woodland (1982) define net export of good i to be intensive in factor j if and only if $\partial x_i(p, v)/\partial v_j > 0$, hence including also in general the consumption response in the definition. Dixit and Norman (1980) motivate their definition of generalized factor intensities by referring to the Stolper-Samuelson derivatives $\partial w_j/\partial p_i$ which are identical to the Rybczinski derivatives $\partial y_i/\partial v_j$.

Note that if (2.6) is written in terms of relative change as $dx_i/y_i = \Sigma_j \gamma_{ij}(dv_j/v_j)$, i = 1,..,m, where $\gamma_{ij}=v_j(\partial y_i/ \partial v_j)/y_i$ is the Rybczynski elasticity of good i with respect to factor j, these Rybczynski elasticities can be used as indices of generalized factor intensities. Since they are unit-free, they make possible statement such that good i is more intensive in the use of factor j than good g is in factor h. Diewert (1974) introduced the notion of an 'elasticity of intensity' via the Rybczynski/Stolper-Samuelson elasticities. In the 'even' case with constant returns to scale, no joint production, and as many goods as factors, the matrix of Rybczynski elasticities is the inverse of the matrix of cost shares.

Dixit and Woodland (1982), assuming constant returns to scale, homothetic preferences and non-restricted factor endowment changes, derives the relation $\partial x_i/\partial v_j = (\gamma_{ij} - \theta_j)y_i/v_j$, where θ_j is the share of factor j in national income. In their phraseology, the excess supply of good i will be intensive in its use of factor j, and therefore good i will be exported when the endowment of factor j increases, if the Rybczynski elasticity γ_{ij} exceeds the income share θ_j. They note that for arbitrary factor endowment changes the relation between γ_{ij} and θ_{ij} is important. The production effect has to be strong enough to overcome the effect on demand of the additional factor income before an excess supply can emerge.

11. With no trade in factors the change in home and foreign factor prices from the initial zero trade equilibrium is $dw = G_{vp}dp^t + G_{vv}dv$ and $dw^* = G^*_{vp}dp^t$. The difference is $dw - dw^* = G_{vv}dv$, where we use $G_{vp} = G^*_{vp}$. Assuming no factor price equalization for some factors is then equivalent to assuming that endowments influence prices of those factors.

12. The $(n_k x n_k)$ matrix of second order derivatives with respect to capital $G_{kk} = [\partial^2 G/\partial k_h\, \partial k_j]$ is negative semidefinite since the revenue function by convexity of the technology is concave in capital. We assume that it is negative definite and invertible, which is a necessary condition for the capital-used-at-home function $\tilde{k}(p, r, \ell)$ to be differentiable. For the case with only one capital good, G_{kk} is a negative scalar, and the value or marginal product of capital is decreasing in capital.

13. We note that we could extend Dixit and Woodlands (1982) model with trade in goods but not in factors, to include initial endowments of goods. Let the home country's goods endowments be given as the non-negative (m+1)-vector (ω_o, ω), where ω_o is the endowments of the numeraire good, and the m-vector ω is the endowments of non-numeraire goods. Net export of numeraire goods would be given by $\bar{x}$ (p, v, ω_o, ω) $= \bar{G}_p (p, v) - E (p, \bar{H} (p, v, \omega_o, \omega)) + \omega$. Assuming compensating factor and goods endowment differences between the home and foreign countries, $wdv + \omega_o + pd\omega = 0$, net export in an equilibrium with trade in goods only would be given by $d\bar{x} = (\bar{G}_{pv} dv + d\omega)/2$. That is, net trade in goods is half the Rybezynski effect $\bar{G}_{pv}$ dv plus half the goods endowment difference $d\omega$. In particular, endowment differences in one good has no effect on trade in other goods. This is analogous to our result that endowment differences in traded factors have no effect on trade in goods. Indeed, we may of course interpret our traded factors as one kind of traded goods in Dixit and Woodland's model, and our non-traded factors as their factors, to get a complete analogy between our case with some traded factors and the goods-endowment augmented Dixit and Woodland model. (Our total Rybczynski effects $[\tilde{G}_{p\ell}{}^T, \tilde{G}_{r\ell}^T]^T$ (T denotes transpose) would be identified with the Rybczynski effect $\bar{G}_{pv}$ above, etc.) (I owe this point to Elhanen Helpman.)

14. According to Elhanan Helpman, this is the terminology used in Hebrew. The definition of cooperation is different from the usual definition of complementarity/substitutability via the conditional input demand functions. Any established English terminology covering this case is unknown to me (technical complementarity?). Jones and Scheinkman (1977) define "friendship"

between a good i and a factor j as meaning $\partial w_j/\partial p_i > 0$, that is in terms of the elements of the matrix G_{vp}. In Ruffin (1981) friendship between factors is defined in terms of the effect on the price of factor h of a change in the quantity of factor j, that is in our case in terms of the elements of the matrix of derivatives $[\partial r_h/\partial \ell_j] = G_{k\ell}$. In our case, we have $\tilde{k}_\ell = - G_{kk}^{-1} G_{k\ell}$. Hence our definition of cooperation in terms of the elements of $\tilde{k}_\ell$ is not exactly equal to Ruffin's definition of friendship, except for the case of one capital good ($n_k = 1$), when G_{kk} is a negative scale.

15. We note that there may not be an unambiguous measure of the volume of goods trade when there are more than two commodities (good and/or factors) traded, or when the goods trade is not balanced.

16. Caves (1971) discusses the specific factor model with factor mobility. See also Jones and Neary (1982).

17. The diagrammatic illustration was suggested by Ron Jones.

18. We note that the Rybczynski derivative with respect to the non-specific factor labor is positive for both goods in the specific factors model. Hence both goods are intensive in the use of labor, according to the Dixit and Norman (1980) way of defining generalized factor intensities.

19. In the specific-factors model, an increase in the endowments of the non-specific factor (labor) increases the price of both specific factors (capital and land), at constant endowments of the

latter. With capital being the only traded factor, this means that capital and labor are cooperative (cf. footnote 13).

20. We have $\theta_{\ell}/\theta_{k} = \{[\theta_{\ell o}/(1 - \theta_{\ell o})]\lambda^{o}\}/\{[\theta_{k1}/(1 - \theta_{k1})]\lambda_{1}\}$.

21. In the goods-endowment augmented Dixit and Woodland model referred to in footnote 13, compensated differences between countries in goods endowments only would simply result in offsetting trade of these goods at unchanged prices.

22. I owe this observation to Alan Woodland.

23. Jones and Neary (1982, Sect. 4) have independently noted that mobility and goods trade may be both complements and substitutes with the sector-specific model, and that trade may be reversed by factor mobility. They give the following example: "Suppose the home country has a larger [non-specific] labor force and that this causes it to export the first commodity in a two-commodity setting. In free trade the wage rate at home will be lower and the returns to both types of specific capital will be higher than abroad. Whether subsequent international capital mobility would reduce or expand commodity trade depends upon which type of capital is mobile. If type-1 capital is mobile, the flow into the home country serves to expand commodity trade, whereas if type-2 capital is mobile, home exports of commodity 1 will fall, instead. Indeed, in the latter case the pattern of commodity trade could get reversed with the flow of type-2 capital into the home country. Of course if labor is internationally mobile instead, an outward flow of

labor from the home country would restore relative endowment balance between countries and all [commodity] trade would vanish." (Footnotes deleted.)

24. We discuss the countries' aggregate welfare only, and do not consider the welfare distribution between various groups, different factor owners, say, within a country.

25. Cf. Bhagwati (1982).

26. Alternatively we know that the change in goods trade prices due to the endowment change is half the change in autarky goods prices, regardless of whether there is both goods and factor trade or factor trade only.

27. With no factor trade, the welfare gain from the price change dp^t is proportional to $(dp^t)^T(-E_{pp})dp^t/2 + (dp^t)^T G_{pp} dp^t/2$ (superscript T denotes transpose). The first term is the consumption substitution effect, the second the production substitution effect. Both are positive since E_{pp} is negative definite and G_{pp} positive definite. If then trade in capital is introduced, there is no additional first-order change in goods prices. (There is a second order change, but that will give a third-order change in the consumption substitution term above and can safely be disregarded.) The additional increase in national product is $(d\tilde{r})^T \tilde{G}_{rr} d\tilde{r}/2$, where $d\tilde{r}$ is the change in rentals from the level of home rentals with no factor trade <u>and</u> goods trade to the world market level

of rentals with both factor trade and goods trade, and $\tilde{G}_{rr}$ is evaluated at the goods prices $p^t + dp^t$. It can be shown that $\tilde{G}_{rr} = - \tilde{k}_r = - G_{kk}{}^{-1}$, hence the term is indeed the shaded triangle in Fig. 2.

28. Markusen (1981) argues that when the basis for trade is something other than differences in relative factor endowments, factor trade and goods trade tend to be complements, and that these are substitutes only for factor proportions models. As we have seen factor trade and goods trade can be complements also in factor proportion models.

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