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ABSTRACT

We consider a trade model combining a 2x2x2 Heckscher-Ohlin structure, monopolistic competition, transport costs, and multinational corporations. We demonstrate how the mix of national and multinational firms that operate in equilibrium depends on technology and on the division of the world endowment between countries. Multinationals are more likely to exist the more similar are countries in both relative and absolute endowments. Where multinationals exist they reduce the volume of trade and raise world welfare (although not necessarily that of both countries). They also reduce the agglomeration forces that arise when international factor mobility is allowed.

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1. Introduction: For many years, international differences in factor endowments were the basis of the dominant positive theory of international trade, and the simple two-good, two-factor, two-country Heckscher-Ohlin model served as the work-horse model to exposit and teach the basic theory. This model, involving perfect competition and constant returns to scale, was elegant in its technical simplicity, yet adaptable to a broad range of normative and positive questions. Developments provided by Dixit and Norman (1980) further increased the generality of basic factor-proportions theory and considerably clarified the problem of factor-price equalization (FPE), in particular by deriving a factor-price equalization set within a traditional Edgeworth box.[1]

An assault on the supremacy of Heckscher-Ohlin began in the 1980s. Researchers were motivated by the large volume of trade in similar products (dubbed intra-industry trade) between countries with similar endowments, facts seemingly at odds with the predictions of Heckscher-Ohlin theory. Elements of increasing returns to scale, imperfect competition, and product differentiation were added in order to generate predictions more in accordance with stylized facts.[2] It was possible to place this new theory "on top of" a basic Heckscher-Ohlin structure, generating a pattern of both intra-industry and inter-industry trade that depended on differences in relative factor endowments and in country sizes. Very similar countries are

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[1] The factor-price equalization set is a set of allocations of the world factor endowment between countries such that FPE occurs in a free-trade equilibrium. FPE is an extremely convenient property for analytical work because unit costs and unit factor requirements in production are equalized across countries.

[2] Important early references focussing on differentiated products include Krugman (1979,1980), and Ethier (1982). Models focussing on oligopoly and pro-competitive gains from trade include Brander and Krugman (1981) and Markusen (1981).

predicted to engage in large volumes of intra-industry trade, consistent with observed data. The most elegant exposition of this theory is found in Helpman and Krugman (1985), (henceforth HK).

At least two important problems remain, one empirical and one technical. The empirical problem is that the "new trade theory" generally neglects multinationals, yet direct investment stocks have been growing much more rapidly than trade between the high-income countries for the last two decades. This is illustrated in fig. 1.1 which plots the ratio of the stock of foreign direct investment to trade flows for the US-EU and the US-Japan. Each of the ratios has increased by more than 50% in the decade 1980-90, illustrating that firms are invading each others markets via direct investment rather than through exports.

The technical problem is that most analytical results in the literature have had to rely on restricting models to assumptions that generate factor-price equalization This restricts the range of parameter values and, much more importantly, precludes the use of the HK model in any context in which tariffs or trade costs are present. This in turn implies that the HK framework is not useful for any trade-policy analysis, for analyzing factor mobility, nor for most models of multinational firms.[3]

The purpose of this paper is provide a more general model of intra-industry, inter-industry, and multinational trade. We adopt the basic HK model with product differentiation

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[3]Helpman and Krugman (following Helpman, 1984) have a model of multinationals in which an MNE is a firm which geographically separates its headquarters and production activities. Since these activities use different factor proportions, differences in factor endowments across countries can generate this separation of activities and hence multinational firms even in an FPE equilibrium. Most other models of multinationals view MNEs as multiplant firms, which do not arise in equilibrium if trade costs are zero.

and monopolistic competition in one sector in an otherwise standard 2x2x2 Heckscher-Ohlin model. HK results are extended to allocations outside the FPE set and to positive transport costs thereby removing the "straightjacket of factor-price equalization" (Jones, (1971)). We allow firms in the differentiated-products sector the option of becoming multinationals by opening plants in both countries in addition to the usual option of exporting from a single plant in one country. Becoming multinational means incurring an additional fixed cost on the second plant, but gives a saving in transport costs. Our approach allows us to endogenize the production "regime" (the types of firms, multinational and/or national, which are active in equilibrium), and to fully characterize the volume of trade and incentives for factor mobility. The HK and Dixit-Norman models emerge as special cases of the general treatment.

Our first results relate to the effects of positive transport costs when multinationals are not present, generalizing the HK approach. Important difference to HK are as follows. (1) if countries have identical relative endowments but differ in size, there is inter-industry trade with the larger country being a net exporter in the increasing returns sector. (2) if countries are relatively similar, mobility of the factor used intensively in the increasing returns sector leads to divergence in endowments and to an increase in the volume of trade. The first result implies that country size is a source of comparative advantage and the second that commodity and factor trade are complements over some range of initial endowments. Neither result occurs in HK or in the Heckscher-Ohlin model.

The second set of results characterizes the dependence of the production regime on key parameters. These are the (1) the similarity of the two countries in economic size (absolute factor endowments), (2) the similarity of the two countries in relative factor endowments, (3) the level of trade costs, and (4) the ratio of multinational fixed costs to the fixed costs of a single-plant national firm. For given levels of (1) and (2), multinationals exist when the ratio of two-plant to one-plant fixed costs are relatively low and trade costs are relatively high. For given levels of (3) and (4), multinationals exist when the countries are relatively similar in both relative and absolute factor endowments.

The third set of issues we investigate is the effect of multinationals on endogenous variables of the model, including trade volumes and welfare. Comparing situations where multinationals occur with those where they are ruled out (by assumption) we find that multinationals (1) reduce trade volumes; (2) raise world welfare but possibly lower the welfare of the country which,in the absence of multinationals would have more national firms; (3) reduce the area of endowment space from which factor mobility leads to divergence of endowments and consequent agglomeration of activity.

The remainder of the paper is organised as follows. Section 2 sets out the details of the model. In section 3 we assume parameter values for technology such that multinationals do not exist, and work out the implications of trade costs in the HK model. Section 4 is the core of the paper, and finds conditions -- on technology and endowments -- which support different production regimes. Sections 5 - 6 draw out the implications of multinationals for trade volumes and welfare, and section 7 studies real factor incomes, factor mobility and agglomeration.

2. The model. The two countries are labelled 1 and 2, and country specific variables are subscripted i, j = 1, 2. Each country is endowed with quantities L_i and K_i of two factors, the

prices of which are w_i and r_i.

There are two production sectors. The z-sector is perfectly competitive and produces output which is freely tradable and will be used as numeraire. Denoting the quantity of z output in country i by z_i and its unit cost $c(w_i, r_i)$, z sector activity satisfies,

$$c(w_i, r_i) \leq 1, \quad z_i > 0, \quad \textit{complementary slack}, \quad i = 1,2. \tag{1}$$

The x-sector is imperfectly competitive, containing firms that produce differentiated products. We model product differentiation in the familiar Dixit-Stiglitz manner, so can form CES price indices in each country, and we denote these s_i. Consumer preferences between sectors are described by a homothetic expenditure function $e(1, s_i)\, u_i$, where u_i is utility. In equilibrium, income comes only from sale of factors, so the budget constraint takes the form,

$$e(1,\ s_i)u_i = w_i L_i + r_i K_i, \qquad i = 1, 2. \tag{2}$$

x-sector products can be supplied by national firms and by multinationals. National firms produce in a single country, but sell in both. The number of such firms in each country is n_i (i=1,2). Country i national firms set the same producer price p_i for sales in both markets, but iceberg trade costs of $t - 1$ per unit mean that consumer prices in home and export markets are p_i and tp_i respectively. The quantities each firm sells in its home and export market are denoted x_{ii} and x_{ij}.

Multinational firms produce and sell in both countries. We denote the number of such firms m, their prices in each market q_1 and q_2 (they do not incur trade costs but may face different marginal production costs in each location) and their sales volumes y_1 and y_2.

Since market i is supplied by n_i home firms, n_j foreign firms, and m multinationals, its price index for differentiated products takes the form,

$$s_i = \left[n_i p_i^{1-\epsilon} + n_j (tp_j)^{1-\epsilon} + m q_i^{1-\epsilon}\right]^{1/(1-\epsilon)}, \qquad i,j = 1,2,\ i \neq j, \tag{3}$$

wh

ere ϵ is the elasticity of substitution between varieties, $\epsilon > 1$. Using this in the expenditure function we can find the demand for each variety of differentiated product. Roy's identity gives,

$$x_{ii} = p_i^{-\epsilon} s_i^{\epsilon-1} E_i, \qquad x_{ij} = p_i^{-\epsilon} t^{1-\epsilon} s_i^{\epsilon-1} E_j, \qquad y_i = q_i^{-\epsilon} s_i^{\epsilon-1} E_i,$$
$$E_i \equiv (w_i L_i + r_i K_i)\, s_i e_s(1,s_i)/e(1,s_i). \tag{4}$$

E_i is country i expenditure on x-sector products in aggregate, and a subscript on a function denotes partial differentiation.

Technologies and profit maximisation of national and multinational firms are as follows. The profits of a single national firm in country i are,

$$p_i x_{ii} + p_i x_{ij} - b(w_i, r_i)[x_{ii} + x_{ij} + f] \tag{5}$$

where $b(w_i, r_i)$ is marginal production cost, and $b(w_i, r_i)f$ is fixed cost. Profit maximisation gives price,

$$p_i(1 - 1/\epsilon) = b(w_i, r_i) \tag{6}$$

where ϵ is the percieved elasticity of demand for a single variety. Entry and exit of firms ensures non-positive profits in equilibrium. As usual, this is a condition on firm scale, which takes the form,

$$f(\epsilon - 1) \geq x_{ii} + x_{ij}, \quad n_i \geq 0, \quad \textit{complementary slack.} \tag{7}$$

Total sales must reach level $f(\epsilon - 1)$, where the values of x_{ii} and x_{ij} come from demand equations, (4).

Multinational firms' profits take the form,

$$q_1 y_1 + q_2 y_2 - b(w_1, r_1)\left(y_1 + \alpha g\right) - b(w_2, r_2)\left(y_2 + (1 - \alpha) g\right) \tag{8}$$

where g is the fixed input requirement, proportion α of which is incurred in country 1 and (1-α) in country 2. We note three things about this definition of profits. First, production occurs in both countries so cost functions are evaluated at both country's factor prices; this assumes that multinationals draw on local factor markets for both labor and capital. Second, multinationals' fixed input requirement, g, differs from national firms' fixed input requirement, f; we shall assume g > f to capture fixed costs associated with running two plants. Third, share α of the fixed input requirement is incurred in country 1, and (1-α) in country 2; we shall assume that this division is equal to the division of output between countries, so $\alpha = y_1/(y_1 + y_2)$. Given that we have not distinguished multinationals according to their country of origin this seems the most natural assumption to make, and we shall look at alternative representations of multinationals' fixed costs at the end of section 4. Providing fixed costs are allocated before output levels are chosen multinationals' profit maximisation gives prices,

$$q_1(1 - 1/\epsilon) = b(w_1,r_1), \qquad q_2(1 - 1/\epsilon) = b(w_2,r_2). \tag{9}$$

These prices equal those set by national firms in their home markets, $q_i = p_i$. Multinationals' zero profit condition is,

$$g(\epsilon - 1) \geq y_1 + y_2, \qquad m \geq 0. \tag{10}$$

where values of y_1 and y_2 come from equations (4). Comparing multinationals with national firms, multinationals face the disadvantage of higher fixed costs, but the advantage of avoiding transport costs.

To complete characterization of equilibrium we need only specify factor market clearing. This takes the form,

$$L_i = z_i c_w(w_i,r_i) + n_i\left[x_{ii}+x_{ij}+f\right]b_w(w_i,r_i) + my_i\left[1+\frac{g}{y_1+y_2}\right]b_w(w_i,r_i) \tag{11}$$

$$K_i = z_i c_r(w_i,r_i) + n_i\left[x_{ii}+x_{ij}+f\right]b_r(w_i,r_i) + my_i\left[1+\frac{g}{y_1+y_2}\right]b_r(w_i,r_i) \tag{12}$$

The three terms on the right hand side give factor demands associated with z-sector production, and with national and multinational x-sector production.

There are three sorts of x-sector firms in the model -- national firms from each country and multinational firms -- and it is generally not the case that all types are active in equilibrium. We look first (section 3) at the case in which no multinationals exist, because their fixed cost disadvantage, g/f, is large relative to their transport cost savings. In section 4 we find the critical condition for multinationals to exist, and the region of endowment space in which they are active.

3. Production with national firms. If there is completely free trade and no multinationals then the model is that of HK. The pattern of inter-industry trade is as in the Heckscher-Ohlin model and if the x-sector is operating in both countries there is also intra-industry trade in differentiated products produced by national firms. As usual in a Heckscher-Ohlin framework, factor price equalisation occurs in a subset of endowment space of full dimension. This is illustrated in figure 3.1. In this and subsequent figures the x-sector is assumed capital intensive and rays O_1z and O_1x have gradient equal to the labor/ capital ratios in each sector (parameter details underlying this and other figures are given in the appendix). The parallelogram is the diversification set, i.e. the set of endowments in which both industries are active in both countries. With free trade, the diversification set is also the factor price equalisation set (FPE set).

Outside the diversification set the configuration is similar to that described by Dixit and Norman (1980). If economy 1 is very labor abundant then $n_1 = 0$, and if 2 is very capital abundant, then $z_2 = 0$. The dividing line between these regions is line AB. North-east of this line economy 2 is not large enough to produce world demand for x-sector output, so we have $n_1, n_2 > 0$; south-west of the line economy 1 is not large enough to produce world demand for z, so we have $z_1, z_2 > 0$.

Now consider transport costs which are strictly positive ($t > 1$), but low enough that it is not profitable for multinational firms to enter. How does this change the picture? The equilibrium location of the industries must always satisfy two sorts of conditions. The first are factor market conditions, stating that the industries must generate factor demands sufficient to employ the factor supplies in each economy. The second are product market conditions, stating that supply of output must equal demand in each economy.

If trade is completely free, as in Fig 3.1, then the product market conditions are relaxed. World supply must equal world demand for each product, but -- from the point of view of the product market -- the location of production is immaterial, as output can be transported costlessly to supply either market. This is the basis of traditional models of trade, as well as HK. Providing trade is completely costless, the division of industries between countries is determined by factor market, not product market considerations.

If trade is costly, then we have to think not only of how each industry demands factors, but also how it supplies each market. Positive trade or transport costs cause firms' sales to be skewed towards the home market, so relocating an x-sector firm not only changes factor demand in each country, but also changes the supply of output. This means that it is possible for the division of industries between countries to be determined by product market considerations alone. This occurs in a model with a single factor of production and no factor endowment basis for trade (eg Venables (1985)).

To see what happens when both factor market considerations (full employment of both factors in both countries) and product market conditions (output supply equals demand in both countries) operate, we start by constructing the FPE set which, as we shall see, is of reduced dimension.[4] To construct the FPE set, first note that if national firms are active in both

[4]We shall construct the set of endowments which support FPE in terms of the numeraire. The effects of international differences in the price indices s_i are analysed in section 7.

countries then, using demand equations (4), we can express the zero profit conditions (7) as

$$f(\epsilon - 1) = p_i^{-\epsilon} s_i^{\epsilon - 1} E_i + t^{1-\epsilon} p_i^{-\epsilon} s_j^{\epsilon - 1} E_j, \qquad i,j=1,2,\ i \neq j. \tag{13}$$

We can solve these two equations to express the terms $s_i^{\epsilon-1} E_i$ in the following form:

$$s_i^{\epsilon-1} E_i = \frac{f(\epsilon - 1)\left[p_i^{\epsilon} - p_j^{\epsilon} t^{1-\epsilon}\right]}{1 - t^{2(1-\epsilon)}}, \qquad i,j = 1,2, \qquad i \neq j. \tag{14}$$

In the FPE set marginal production costs in the x-sector are the same in both countries, so $p_1 = p_2$, and we shall denote the common value $\bar{p}$. The x-sector price index (equation (3)) can therefore be expressed as,

$$s_i^{1-\epsilon} \bar{p}^{\epsilon} = n_i \bar{p} + n_j \bar{p} t^{1-\epsilon}. \tag{15}$$

From (14) and (15) we obtain

$$n_1 \bar{p} f(\epsilon - 1) = \frac{E_1 - t^{1-\epsilon} E_2}{1 - t^{1-\epsilon}}, \qquad n_2 \bar{p} f(\epsilon - 1) = \frac{E_2 - t^{1-\epsilon} E_1}{1 - t^{1-\epsilon}}. \tag{16}$$

The left hand sides of these equations are the value of x-sector output in countries 1 and 2. The equations say that location of the industry depends on the location of x-sector expenditures and on transport costs. If there are positive transport costs, ($1 > t^{1-\epsilon}$) then production will be skewed towards the location with the larger expenditure.

Expenditure, E_i, depends on factor endowments, since $E_i = \sigma(\bar{w} L_i + \bar{r} K_i)$, where σ is the share of the x-sector in consumption, $\sigma \equiv s_i e_s(1,s_i)/e(1,s_i)$. We shall assume Cobb-

Douglas preferences, so that σ is a constant. In the FPE set expenditure and hence the location of x-sector production is therefore a linear function of endowments.

Equation (16) captures the effect of product market access on industrial location. We also have the usual factor market considerations. Assuming that both the z- and x-sectors are operating in both countries and denoting technical coefficients at FPE factor prices by $\bar{b}_w$ etc, we can use factor market clearing conditions, (11) and (12), to derive,

$$n_1 \bar{p} f(\epsilon - 1) = \bar{b}\left(\frac{\bar{c}_w K_1 - \bar{c}_r L_1}{\bar{c}_w \bar{b}_r - \bar{b}_w \bar{c}_r}\right), \qquad n_2 \bar{p} f(\epsilon - 1) = \bar{b}\left(\frac{\bar{c}_w K_2 - \bar{c}_r L_2}{\bar{c}_w \bar{b}_r - \bar{b}_w \bar{c}_r}\right). \tag{17}$$

This says that the value of output in each country depends on factor endowments in each country and on technical coefficients.

Equations (16) and (17) give the product and factor market determinants of x-sector production. Requiring them both to be satisfied restricts endowments, and this restriction defines the FPE set. Eliminating n_1 (or n_2 -- the two pairs of equations are not independent) from these equations, noting that both expressions are linear in K_i and L_i and using world endowments $K = K_1 + K_2$ and $L = L_1 + L_2$ we can characterise the FPE set as a linear relationship between K_1 and L_1. The FPE set is no longer the full diversification set of figure 3.1, but instead a one-dimensional subspace of this set.[5]

The expression for the FPE set is straightforward, and we need only note that it includes the point at which the two economies are identical (the midpoint of the main diagonal

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[4] The Cobb-Douglas assumption is necessary for the FPE set to be linear, but not for it to be a one dimensional subspace of the endowment space.

of figure 3.1), is linear, and has gradient,

$$\frac{dL_1}{dK_1} = \frac{\bar{c}_w \bar{b}(1 - t^{1-\epsilon}) - \sigma\bar{r}\Delta(1 + t^{1-\epsilon})}{\bar{c}_r \bar{b}(1 - t^{1-\epsilon}) + \sigma\bar{w}\Delta(1 + t^{1-\epsilon})} = \frac{\bar{c}_w \bar{b}(1-\sigma) + \bar{b}_w \bar{c}\sigma - t^{1-\epsilon}(\bar{c}_w \bar{b} + \sigma r\Delta)}{\bar{c}_r \bar{b}(1-\sigma) + \bar{b}_r \bar{c}\sigma - t^{1-\epsilon}(\bar{c}_r \bar{b} - \sigma w\Delta)} \quad \mathbf{(18)}$$

where Δ is the determinant of the matrix of technical coefficients, $\Delta \equiv \bar{c}_w \bar{b}_r - \bar{b}_w \bar{c}_r > 0$, positive since the x- sector is capital intensive. (The two different forms given for the gradient are useful in different contexts, and can be derived from each other using homogeneity of the cost functions).

This is illustrated in Fig 3.2 in which the line segment *bc* is the part of the FPE set in the diversification set (this figure is constructed with the same parameters as fig. 3.1 except that $t = 1.2$). It goes through the midpoint of the endowment box and has gradient given by (18). The gradient of *bc* is less than that of the O_1O_2 diagonal, as illustrated in Fig 3.2. The intuition for this can be seen by considering a point below the O_1O_2 diagonal. At such a point country 1 is relatively well endowed with capital, and hence has relatively much x-sector production. If there are transport costs, this is consistent with FPE only if country 1 has relatively high demand for x products, i.e., the point is closer to O_2 than to O_1. *bc* must therefore cut the O_1O_2 diagonal from above, as illustrated.

This market access affect is powerful when transport costs are large, but weak as they become small. Reducing *t* therefore reduces the gradient of *bc*, rotating the FPE set clockwise around the central point, and at some value of *t* the FPE set is horizontal (see the first part of equation (18)). At still lower values of *t* the FPE set has negative gradient, and as we go to free trade ($t \to 1$) the gradient of the FPE set tends to the ratio of factor prices, $-\bar{r}/\bar{w}$.

Increasing t, we see that as $t \to \infty$ so bc goes to the O_1O_2 diagonal of the box, because under autarky there is FPE only if the endowment ratios of the two economies are equal. (This can be seen by letting $t \to \infty$ in the second part of equation (18) which then gives the ratio of world demand for labor to world demand for capital).

Our theoretical discussion has hinged on diversified production, with both sectors active in both countries. Figure 3.2 also traces out the continuation of the FPE set outside the region in which production is diversified. The entire FPE set is made up of the three segments, O_1b, bc, and cO_2.

Other lines on figure 3.2 are loci of endowments for which p_1/p_2 = constant. Thus, moving vertically up from the FPE set reduces country 1 production of x-sector output (a Rybczynski effect) raising p_1 relative to p_2.[6]

How does the pattern of trade vary in the endowment box? In figure 3.3 point M is the midpoint, and O_1bcO_2 is the FPE set as in fig. 3.2. Consider moving north-east from M along the main diagonal towards O_2. With trade costs this increases p_1/p_2 and, since the x-sector is capital intensive, means that $r_1 > r_2$ and $w_1 < w_2$. Country 1 therefore uses relatively labor intensive techniques, so must produce relatively much x-sector output (to fully employ both factors). With expenditure shares fixed by Cobb-Douglas preferences, country 1 must then be a net exporter of x-sector output.

Figure 3.3 illustrates this by the curve O_1MO_2 which is the locus of endowments along which there is no inter-industry trade. With zero transport costs this locus would be the main

[6] Although the ratio of p_1 and p_2 is constant along these lines, p_1 and p_2 are not.

diagonal of the box. Transport costs mean that size itself is a determinant of comparative advantage, as reflected in the fact that to the north-east of the midpoint of the box, M, the curve O_1MO_2 lies above the diagonal. This has the following implication. Above the FPE line, O_1bcO_2 we have $p_1 > p_2$ and, since the x sector is capital intensive, $r_1 > r_2$ and $w_1 < w_2$. In the region between O_1MO_2 and O_1bcO_2 we therefore have each country exporting the good intensive in the factor which is relatively expensive.

4. National and multinational firms: We are now in a position to establish circumstances under which multinational firms will operate. Two sorts of conditions have to be met. First, a necessary condition for the existence of multinationals is that trade costs, t, are sufficiently high relative to the fixed cost disadvantage of operating two plants, g/f. In this section we find this necessary condition by locating the boundary set of values of t and g/f at which all three types of firms can coexist.

Second, the presence of multinational firms depends not only on parameters t and g/f, but also on the division of the world endowment between countries. Multinational and national firms have different impacts on both factor market and product market equilibrium conditions -- whereas national firms only draw factors from a single country, multinationals draw them from both, and whereas national firms' sales are skewed towards their home market, multinationals' are not. This suggests that for some regions of endowment space production might be undertaken by national firms (from one country or the other), and in other regions by multinationals, or some combination of multinational and national firms. There are seven possible regimes (i.e. combinations of the three firms types in which at least one type is active), and as we move across endowment space we move across regimes. We shall see all seven possible regimes appearing as equilibria of the model.

Our first task is to find parameter values at which all three types of firms can coexist. We have already seen that the zero profit condition for national firms can be written as in equation (13). The analogous condition for multinational firms is,

$$g(\epsilon - 1) \geq y_1 + y_2 = p_1^{-\epsilon} s_1^{\epsilon-1} E_1 + p_2^{-\epsilon} s_2^{\epsilon-1} E_2. \tag{19}$$

If both types of national firms are active, we know that the terms $s_i^{\epsilon-1} E_i$ satisfy equations (14). Using this we can express the condition as:

$$g(\epsilon - 1) \geq y_1 + y_2 = \frac{f(\epsilon - 1)}{1 - t^{2(1-\epsilon)}} \left[2 - t^{1-\epsilon} \left(\left(\frac{p_2}{p_1} \right)^{\epsilon} + \left(\frac{p_1}{p_2} \right)^{\epsilon} \right) \right] \tag{20}$$

The right hand equation gives demand for a multinational's output, given that both countries' national firms are operative. We learn several things from the expression.

First, a firm's sales generally depend on expenditure in each market, E_i, and the number of other firms supplying each market, as summarised through the price indices, s_i. These variables are absent from equation (20), the reason being that if national firms from each country are operating, their numbers will adjust in accordance with expenditure levels in each country. Variations in E_1 and E_2 are met by adjustment in n_1 and n_2 and have no effect on a multinational's sales.

Second, relative costs in the two locations (and hence relative prices p_2/p_1) do affect the sales of multinationals. Figure 4.1 plots $y_1 + y_2$, as given by the right hand side of (20), as a function of p_2/p_1; the three curves correspond to different values of f and t. We see that $y_1 + y_2$ is a concave function of p_2/p_1 (symmetrically p_1/p_2) with maximum when $p_2 = p_1$. The reason is that with asymmetries in costs (implying $p_2 \neq p_1$) national firms in the low cost country have an advantage, and their entry reduces demand for a multinational's output, $y_1 + y_2$. Conversely, it is when costs are similar in the two countries that demand for a multinational's output is maximised.

We can now find the conditions on technology necessary for multinationals to coexist with national firms. The horizontal line on fig 4.1, $y_1 + y_2 = g(\epsilon - 1)$, gives the level of sales which a multinational must attain if it is to break even. The lowest curve in fig. 4.1 gives sales for a low value of f (relative to g), or a low value of t. This favors national firms relative to multinationals, and there is no ratio p_2/p_1 at which sales reach the level necessary for the multinational to break even. The equilibrium is therefore as we described it in section 3, with national firms active, but not multinational.

The middle curve in fig 4.1 is drawn with parameters satisfying the critical condition, (derived by setting $p_2 = p_1$ in (20)),

$$1 + t^{1-\epsilon} = 2f/g. \qquad \textbf{(21)}$$

If t and g/f satisfy (21) then all three types of firms coexist providing endowments lie in the FPE set identified in section 3, so $p_2 = p_1$. Multinationals and national firms will therefore coexist along the line segment *bc* of figure 3.2, (but not along the continuation of the FPE set to the right and left of these points as on these segments one of the economies has no x-sector production).

If g/f is smaller (t greater) than the critical value defined in (21), then we move to a higher curve in fig 4.1. There are two values of p_2/p_1 (labelled k and its reciprocal, $1/k$), which support the break even output level. If endowments are such that operation of national firms alone gives p_2/p_1 outside the interval $[1/k, k]$ then the equilibrium is as in section 3, with no multinationals active. At endowments supporting prices $p_2/p_1 = k$ and $p_2/p_1 = 1/k$ all three types of firms coexist; figure 3.2 illustrates such endowments (eg the lines $p_1 = 1.03p_2$, $p_1 = 0.97p_2$). What happens if endowments are such that with national firms alonep_2/p_1 is in the interval $(1/k, k)$? Multinationals would then make strictly positive profits $(y_1 + y_2 > g(\epsilon - 1))$, so the equilibrium must involve national firms from (at least) one country ceasing to be active, this changing the mapping from endowments to prices.

The full picture is given in figure 4.2. The figure is constructed with g/f just below the critical value defined by equation (21). (With t = 1.2 and ϵ = 5 the critical value is g/f = 1.349 and fig 4.2 has g/f = 1.34). Multinationals occur in the central area of the figure, in a region the shape of which is exactly as would be expected from fig. 3.2.

The right and left hand edges of the region in which multinationals are active are determined by specialisation; factor supply considerations are such that there is no x-sector production (and consequently no multinationals) in one of the countries. The upper and lower bounds are the edges of the region are where all three types of x producers are active, i.e. the factor endowments that support a goods price ratio p_2/p_1 solving equation (20). Moving above or below this central band of endowment space leads to large cost and price differences and, as we have already seen, this is to the advantage of national firms relative to multinationals.

The area in which multinationals are active contains five regions. The upper and lower edges are regions in which all three firm types are active. The central region has only multinationals active, and to the left (right) of this there are regions with multinationals and national firms in country 2 (country 1).

In the region with only multinationals there is no trade, and FPE occurs only on the main diagonal where the two countries have the same factor endowment ratios.[7] The shape of this region can be checked by setting $n_1 = n_2 = 0$ in the price indices (equation (3)), so $s_i = m^{1/(1-\epsilon)} p_i$. The zero profit condition for multinational firms (equation (19)) then becomes

$$m(\epsilon - 1)\frac{p_1}{E_1} = \frac{1}{g}\left[1 + \frac{E_2 p_1}{E_1 p_2}\right]. \tag{22}$$

With $n_1 = n_2 = 0$ profits of national firms must be non-positive, so rewriting condition (13) for national firms in countries 1 and 2 respectively gives inequalities,

$$m(\epsilon - 1)\frac{p_1}{E_1} \geq \frac{1}{f}\left[1 + t^{1-\epsilon}\frac{E_2 p_1}{E_1 p_2}\right], \qquad m(\epsilon - 1)\frac{p_1}{E_1} \geq \frac{1}{f}\left[t^{1-\epsilon} + \frac{E_2 p_1}{E_1 p_2}\right]. \tag{23}$$

Putting (22) and (23) together, the region with multinationals only is that in which $(E_2/E_1)(p_1/p_2)$ lies in the interval,

$$\frac{g/f - 1}{1 - t^{1-\epsilon}g/f} \leq \frac{E_2 p_1}{E_1 p_2} \leq \frac{1 - t^{1-\epsilon}g/f}{g/f - 1} \tag{24}$$

If multinationals exist all terms (numerators and denominators) in this expression are positive.

[7] The absence of trade in this region corresponds to our assumption that fixed costs are divided between a multinational's plants in proportion to their scale of operation, so that there is no trade in 'headquarter's services'. A separate headquarters fixed cost would generate such trade.

If g/f and t are at the critical values satisfying (21), then the right and left hand ends of the inequalities both equal unity, and the region with only multinationals reduces to the central point of the endowment box where $(E_2/E_1)(p_1/p_2) = 1$. At lower values of g/f a discrete width opens up between the inequalities. Thus, along the main diagonal (where $p_1 = p_2$) there is a range of relative country sizes (E_2/E_1) with only multinationals active. Moving below the main diagonal, country 1 has relatively more capital decreasing p_1/p_2. We see from (24) that in order to stay in the region with no multinationals there must be an increase in (E_2/E_1), i.e. an increase in the size of country 2 relative to country 1. This accounts for the slope of the multinationals only region; it must have positive gradient and be steeper than the main diagonal. Intuitively, the move below the main diagonal expands country 1 x-sector production (a Rybczynski effect). For this *not* to lead to entry of country 1 national firms, country 1 market size must be made smaller.

Reductions in g/f or increases in t favor multinationals, and have the effect of expanding the region of endowment space within which they exist. Figure 4.3 considers a lower fixed cost disadvantage of multinationals (g/f = 1.25 as compared to g/f = 1.34 in fig. 4.2). The expansion in the region of endowment space in which multinationals are active is as we would expect from the relative price contours of figure 3.2. Some intuition can be gained by considering a point left of centre and near the top of the endowment box. In fig. 4.2 this region has national firms from both countries -- country 1 x-sector firms are needed to produce sufficient x to meet world demand, even though country 1 is capital scarce and x production is high cost. This implies that this region is vulnerable to entry of multinationals, and this is what we see occuring in fig. 4.3.

Figures 4.2 and 4.3 show that as g/f is reduced, so multinationals exist over a larger area of endowment space. Raising t has a similar effect, although, as t increases the region with multinationals not only increases, but also rotates anti-clockwise. This corresponds to our discussion of the slope of the FPE set in section 3.

We have assumed so far that multionationals' fixed input requirements are divided between countries in proportion to sales. This has the advantage that the zero profit condition is simply that sales should equal the target level (equation (10)). A fuller description of fixed costs might specify plant specific fixed input requirements (call them h) and a firm or 'headquarters' input requirement (g - $2h$). Assuming that these all have the same factor intensity, that plant fixed costs have to be incurred in each country, but that headquarters' costs are mobile, profits are,

$$q_1 y_1 + q_2 y_2 - b(w_1,r_1)[y_1 + h] - b(w_2,r_2)[y_2 + h] - \min[b(w_1,r_1), b(w_2,r_2)][g - 2h]. \tag{25}$$

If both countries' national firms are active, and denoting $p_i = \min[p_1, p_2]$, we derive, analogously to (20),

$$g - 2h + h\left(1 + \frac{p_j}{p_i}\right) \geq \frac{f}{1 - t^{2(1-\epsilon)}}\left[1 + \frac{p_j}{p_i} - t^{1-\epsilon}\left(\left(\frac{p_j}{p_i}\right)^{\epsilon} + \left(\frac{p_i}{p_j}\right)^{\epsilon - 1}\right)\right] \tag{26}$$

This has the same critical value (equation (21)) and has zero or two roots according to whether g is above or below the critical value. As in the preceding case, we therefore have multinationals occuring in a band of endowment space defined by relative price ratios. Simulations confirm that the structure of regimes is qualitatively similar to that illustrated in figs 4.2 and 4.3. We work with the analytically simpler case -- fixed input requirements divided in proportion to output -- for the remainder of the paper.

5. The value of trade. HK provide an elegant analysis of the way in which the value of trade depends on endowments. They show that -- with free trade and within the FPE set -- the value of trade is maximised at the North-West and South-East corners of the FPE set. Differences in endowment ratios increase the amount of inter-industry trade, and similarity of income levels increases the value of intra-industry trade.

How are these results modified by transport costs and multinationals? Fig. 5.1 plots iso-value of trade lines over the endowment space. The figure is constructed from simulations (with $t = 1.2$, as in the preceding section), and lines are iso-trade value contours, ranging from *d* (highest) to *a* (lowest). The figure contains information for two cases; solid lines give trade value contours when multinationals are active ($g/f = 1.32$), and the combination of solid and dashed lines gives trade volumes when multinationals are, by assumption, inactive. When multinationals are inactive, the picture is similar to HK (but not identical, because of transport costs). Trade is maximised at points in the North-West and South-East of the box (these maxima lying outside the diversification set). Providing production is diversified trade volumes fall as countries' endowment ratios become more similar, but increase as countries become more similar in size.

The presence of multinationals unambiguously reduces trade values. This is unsurprising, but important in view of the empirical observations made in the introduction. As in HK, trade values fall as endowment ratios become more similar. However, the presence of multinationals reverses the effects of convergence in country size on trade volumes. For example, consider moving along the arrow in Fig. 5.1. Without multinationals (dashed contours), this raises trade volumes. If multinationals are allowed to exist then as countries converge in size, so an increasing share of world production is undertaken by multinationals. Multinationals substitute for intra-industry trade, so convergence of country size reduces the value of trade.

6. Costs and benefits of multinationals. A long standing question in the study of multinationals is whether or not their presence brings welfare gains. We can answer the question in the present framework by comparing the equilibrium in which multinationals are active with one in which -- by assumption -- they are inactive. The comparison allows us to see which national firms are displaced by multinationals, and calculate the welfare implications of this change in the composition of firms.

Simulation output indicates two results. First, world welfare is increased by the presence of multinationals. And second, the country which in the absence of multinationals has relatively more national firms, may experience a welfare loss with multinationals.[8]

The logic behind the second result can be seen from the following thought experiment. Suppose that we let dm multinationals replace dn_1 and dn_2 national firms, and we do this in such a way that total resources used in the x-sector are held constant. We value these

[8] The first result is an implication of Dixit and Stiglitz'z (1977) observation that in models of this type the equilibrium is constrained efficient, in the sense that given total resources devoted to the industry the equilibrium scale and number of firms is welfare maximising.

resources at constant prices and, for simplicity, let these be FPE prices. If the value of resources is unchanged then we must have

$$0 = f dn_1 + f dn_2 + g dm \tag{27}$$

since the value of each firm's production is proportional to its fixed costs. We can find the welfare effect of this change by totally differentiating the price index, s_i, giving

$$d\left(s_1^{1-\epsilon}\right) = \bar{p}^{1-\epsilon}\left[dn_1 + t^{1-\epsilon}dn_2 + dm\right], \qquad d\left(s_2^{1-\epsilon}\right) = \bar{p}^{1-\epsilon}\left[t^{1-\epsilon}dn_1 + dn_2 + dm\right]. \tag{28}$$

Suppose that multinationals displace equal numbers of country 1 and country 2 firms, $dn_1 = dn_2$. Using this and (27) in (28) gives,

$$\frac{d\left(s_1^{1-\epsilon}\right)}{dm} = \frac{d\left(s_2^{1-\epsilon}\right)}{dm} = \bar{p}^{1-\epsilon}\left[1 - \left(1 + t^{1-\epsilon}\right)\frac{g}{2f}\right] > 0. \tag{29}$$

If multinationals displace country 2 firms only, i.e. $dn_2 < 0$, and $dn_1 = 0$, then

$$\frac{d\left(s_1^{1-\epsilon}\right)}{dm} = \bar{p}^{1-\epsilon}\left[1 - t^{1-\epsilon}\frac{g}{f}\right] > 0, \qquad \frac{d\left(s_2^{1-\epsilon}\right)}{dm} = \bar{p}^{1-\epsilon}\left[1 - \frac{g}{f}\right] < 0. \tag{30}$$

Equation (29) describes what happens in the centre of the endowment box where the economies are identical. Multinationals displace equal numbers of each countries' national firms and this reduces the price indices s_i, (raises $s_i^{1-\epsilon}$), hence raising real income. The gain in real income is the net effect of two opposing forces -- saving transport costs and losing varieties (since multinationals are larger than national firms). Notice that the term in square brackets is exactly the necessary condition for multinationals to exist in equilibrium (21). The fact that the condition for multinationals to raise welfare is the same as the condition for equilibrium to support multinationals is a reflection of the constrained efficiency of equilibrium.

Equation (30) describes what will happen if country 2 is large and/or well endowed with capital. Without multinationals n_2 is large relative to n_1, so multinationals displace n_2 more than they displace n_1. The directions of the inequalities in (30) hold if multinationals are active in equilibrium, and we see that country 1 will experience a welfare gain and country 2 a welfare loss. The reason is that the loss of varieties effects both countries equally, but the gain of transport cost saving accrues disproportionately to country 1, the country that in the absence of multinationals imports most of its x-industry consumption.

7. Factor prices and factor mobility. We have so far assumed that neither capital nor labor are internationally mobile -- multinationals draw on local factor markets for all their inputs. What happens if these factors can move in response to international factor price differences? How does the the presence of multinationals influence international factor price differences and consequent incentives for factor mobility?

With free trade there is no incentive for factor mobility within the FPE set. Assuming for the moment that multinationals do not exist, the presence of transport costs has two effects. As we have already seen (section 3) it reduces the size of the FPE set. It also creates international differences in the value of the x-sector price index, s_i, and hence in the value of the unit expenditure function. Although factor prices in terms of the numeraire are equalised within the FPE set, real incomes are not, because of these price index differentials.

The implications of this are illustrated in figure 7.1. The dashed line O_1bcO_2 in figure

7.1 gives the FPE set constructed exactly as in section 3 and figure 3.2. Above this line country 1 is poorly endowed with capital relative to labour, so $r_1 > r_2$ and $w_1 < w_2$, and conversely below the line. Adjusting for differences in price indices, s_i, real factor incomes are $R_i = r_i/e(1,s_i)$ and $W = w_i/e(1,s_i)$, and the lines $R_1 = R_2$ and $W_1 = W_2$ plot the endowment points along which real returns to each factor are equalised. The intuition behind the positions of these lines is straightforward. Consider point *d*. At *d* factor prices are equalised in terms of the numeraire, but economy 1 has more x-sector production than economy 2 (it has a larger market and a more capital intensive endowment). We consequently have $s_1 < s_2$, so country 1 has a higher real return to both factors. This means that *d* must lie below the iso-real-w line, and above the iso-real-r line.

Given these real factor price differences, the directions of factor mobility are illustrated by the arrows on the figure.[9] Labor mobility moves the endowment vertically to the iso-real-w line, $W_1 = W_2$, and capital mobility moves the endowment horizontally to segments O_1B or O_2C of the iso-real-r line. However, the line segment *BC* is unstable with respect to capital mobility. The reason is that a move to the right of this segment causes a large increase in x-sector production in country 1 (a Rybczynski effect, as country 1 gains more of the factor intensive in the x-sector), this reducing s_1 and thereby raising the real income of factors in country 1. This price index effect means that mobility of the factor intensive in the x-sector

[9] We assume that consumption occurs in the host country, so it is appropriate to deflate by the host expenditure function.

may cause divergence of the structure of the two economies.[10]

The comparison of labor and capital mobility indicates that divergence is associated with mobility of capital, the factor used intensively in the imperfectly competitive sector. What if both capital and labor are mobile? Real factor price equalisation occurs at point E, but this is unstable -- a small perturbation around this point leads to divergence. Full factor mobility therefore leads to one of the origins, with all activity agglomerated in one of the locations.

How is this picture changed if there are multinationals? Whereas figure 7.1 was constructed assuming $m = 0$, figure 7.2 permits multinationals to occur. (Both figures have the same trade costs, t = 1.2, and 7.2 has g/f = 1.25, as in figure 4.3). The effect of multinationals is to expand the set of endowments within which there is real factor price equalisation, from point *E* to line segment *FG*. *FG* has two properties. First, it lies in the region within which all x-sector production is undertaken by multinationals (cf figure 4.3); this means that no transport costs are incurred, so that the price indices, s_i, are the same in both countries. Second, *FG* lies on the main diagonal of the box; symmetry between the economies means that factor prices in terms of the numeraire are equalised. (Notice however that *FG* is restricted to this line, and does not cover the 2-dimensional subspace within which all x-sector production is undertaken by multinationals; as we have already seen there is no trade in this region, so production is determined by demand and factor prices must adjust to employ factors).

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[10] This is the same mechanism that creates agglomeration in the economic geography model of Krugman (1991).

The existence of multinationals therefore expands the real factor price equalisation set from a point to a line segment. Directions of factor mobility are once again illustrated by arrows, and, if both factors are mobile, the stable equilibria are the origins, O_1 and O_2, and the interior of the line segment *FG*. Whether the system ends up with agglomeration at one of the origins or goes to the line segment *FG* depends on initial values of the endowment. The presence of multinationals reduces -- but does not eliminate -- agglomeration. Intuitively, x-sector production is concentrated in the larger country if multinationals are excluded, and this country then hasa higher real price of capital unless it is also very capital abundant. Permitting capital to move thus causes further divergence of country size. Allowing multinationals to enter leads to the establishment of plants in the smaller country, thus increasing the demand and price for capital in that country, reducing factor price differences and the tendency towards agglomeration.

8. Concluding comments. All the ingredients used in this paper are very familiar; a 2x2x2 Heckscher-Ohlin structure; monopolistic competition; iceberg transport costs; and multinationals which trade off higher fixed costs against improved market access. Combining them all in a single model runs the risk of becoming intractable -- and it is certainly the case that we would not have first discovered the shapes of different regimes without the use of numerical methods. However, it turns out to be possible to provide analytical characterizations of key relationships in the model, including the FPE set and regions of parameter and endowment space within which different production regimes occur.

The main results from the analysis are, first, the importance of both relative and absolute factor endowments in determining whether or not multinationals operate. This suggests that convergence in income levels between major trading blocks -- Europe, the US and Japan -- may be one cause of the growth of multinationals.

Second, we established the consequences of multinationals, both for volumes of trade and for world and national welfare. The model suggests that convergence of country size may not be associated with growing volumes of intra-industry trade as suggested in previous literature; some (or possibly all) of this trade may be displaced by multinational production. The world as a whole benefits from the presence of multinationals, and these gains accrue disproportionately to countries whose factor endowment is such that, in the absence of multinationals, they would have few national firms. There may be welfare loss for a country which, in the absence of multinationals, has a large share of the world industry.

Third, we showed how mobility of the factor used intensively in the imperfectly competitive can be destabilizing, and create divergence of economic structure. However, the presence of multinationals seems to be a stabilising force, reducing the region of endowment space from which factor mobility would induce agglomeration.

Appendix;

Simulations: All simulations use the following functional forms:

$$c(w_i,r_i) = w_i^{2/3} r_i^{1/3}, \quad b(w_i,r_i) = w_i^{1/3} r_i^{2/3}, \quad e(1,s_i) = s_i^{1/2}. \tag{31}$$

World endowments are set at K = L = 1. The elasticity of demand for a single variety of differentiated product, $\epsilon = 5$. National firms have fixed input requirement f = 0.25. Values of t and g/f are reported in the text.

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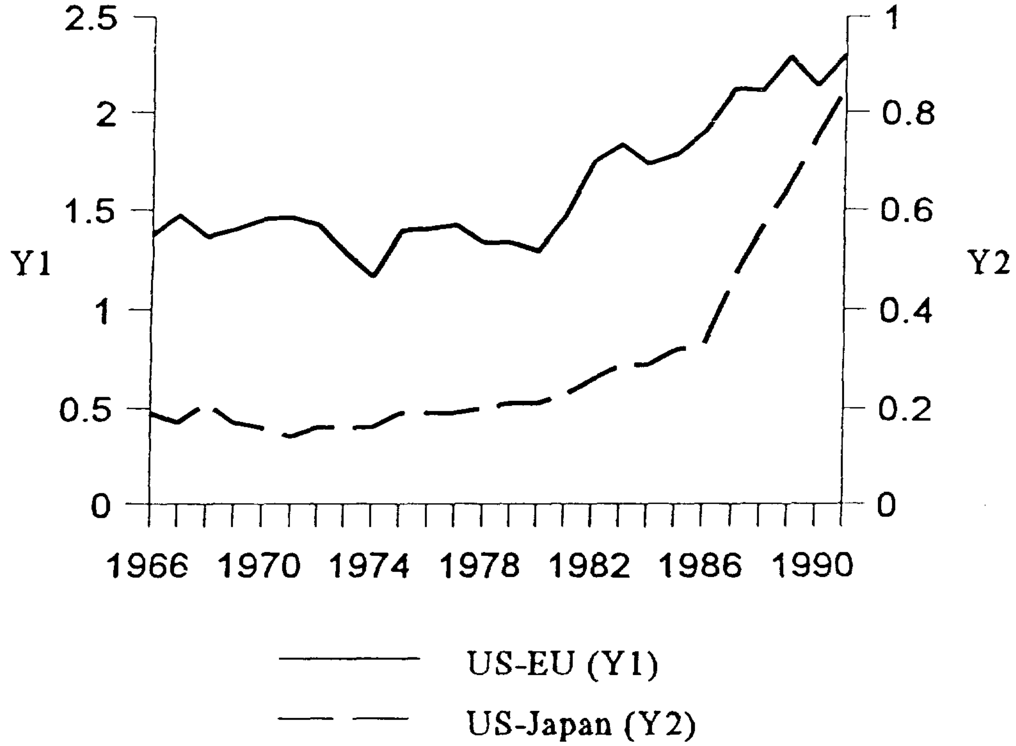
Figure 1.1

FDI / trade flows



Numerator: Sum of bilateral investment stocks (eg US in EU plus EU in US).
Denominator: Sum of bilateral export flows.

Sources: Trade data, UN Yearbook of International Trade Statistics.
Investment data, US Survey of Current Business.

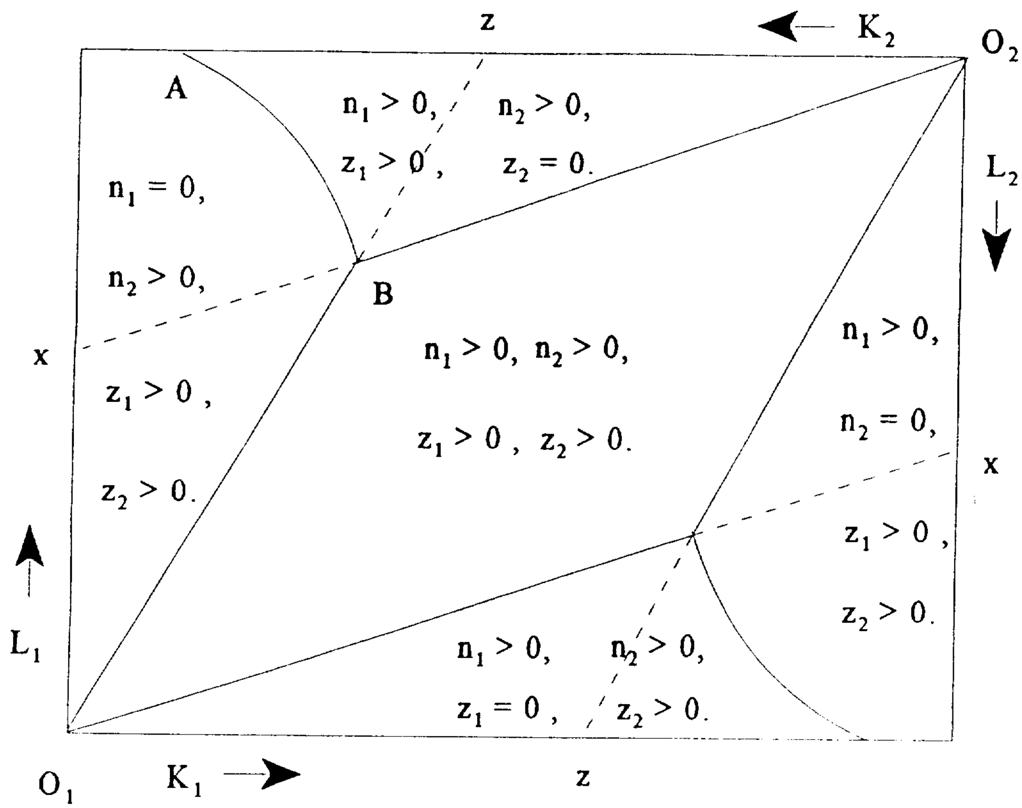


Figure 3.1: $t = 1.0$

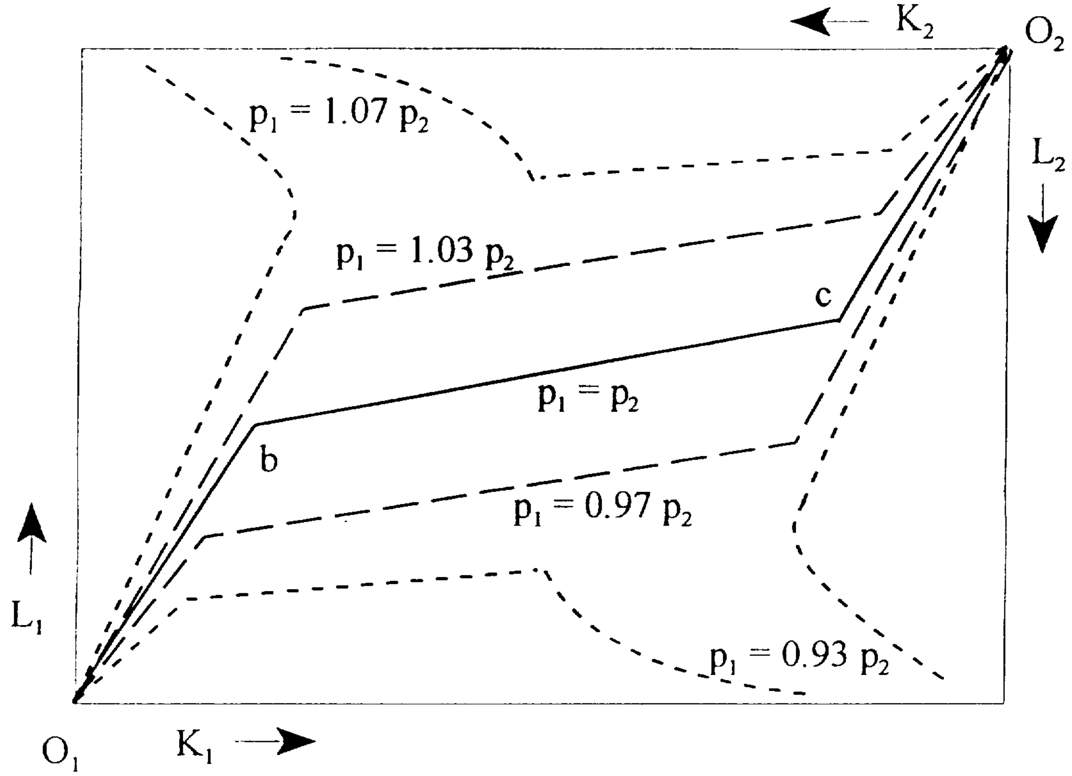


Figure 3.2: t = 1.2

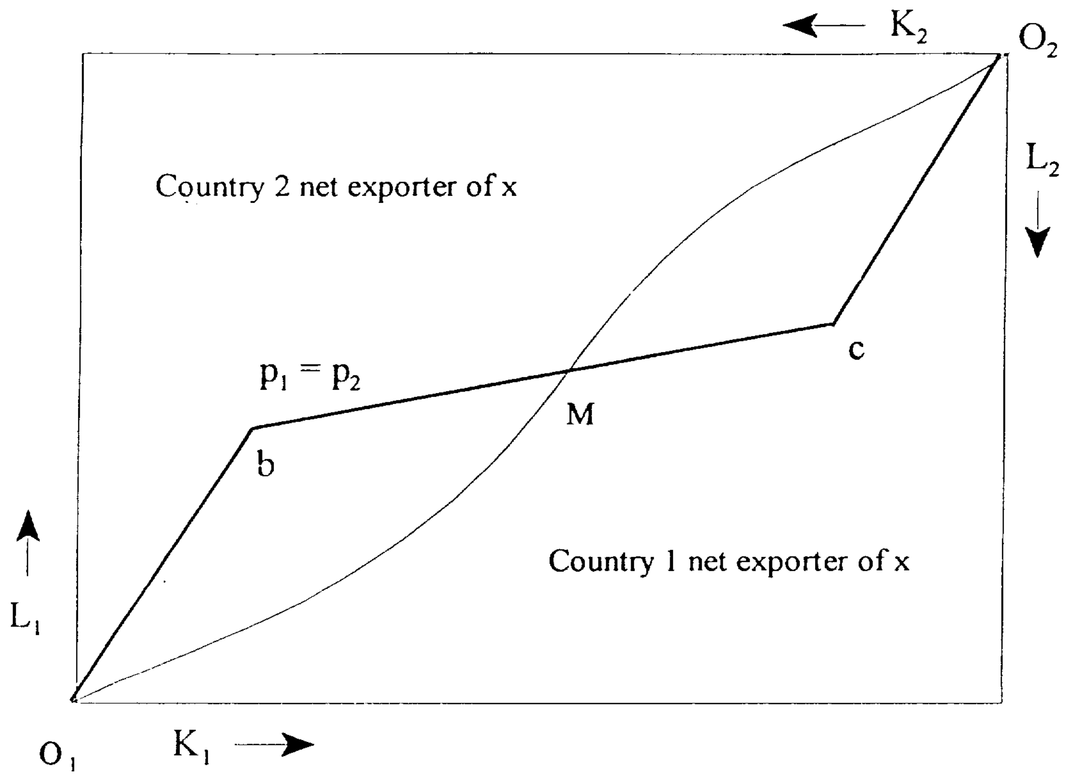


Figure 3.3: $t = 1.2$

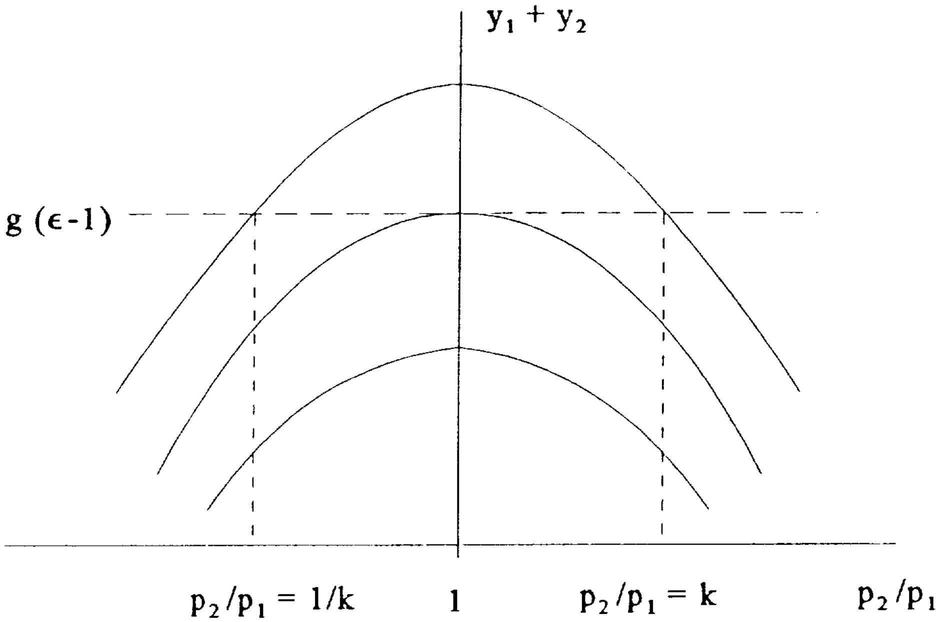
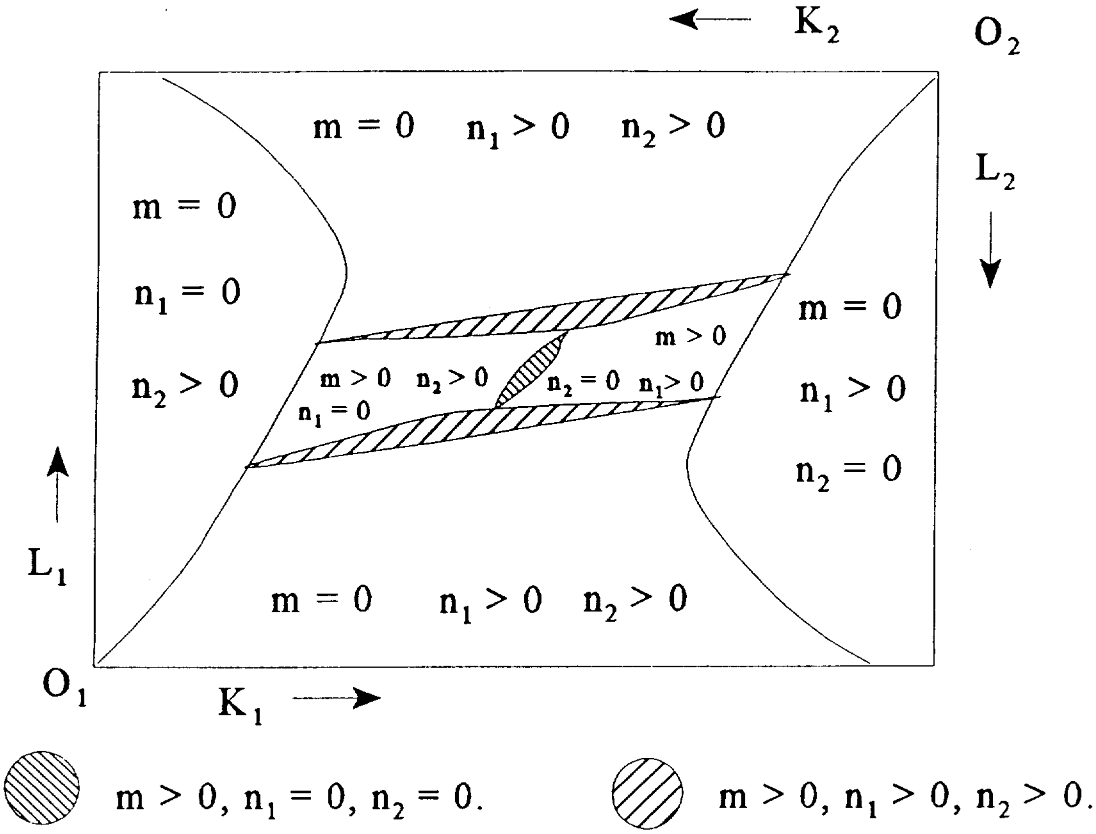
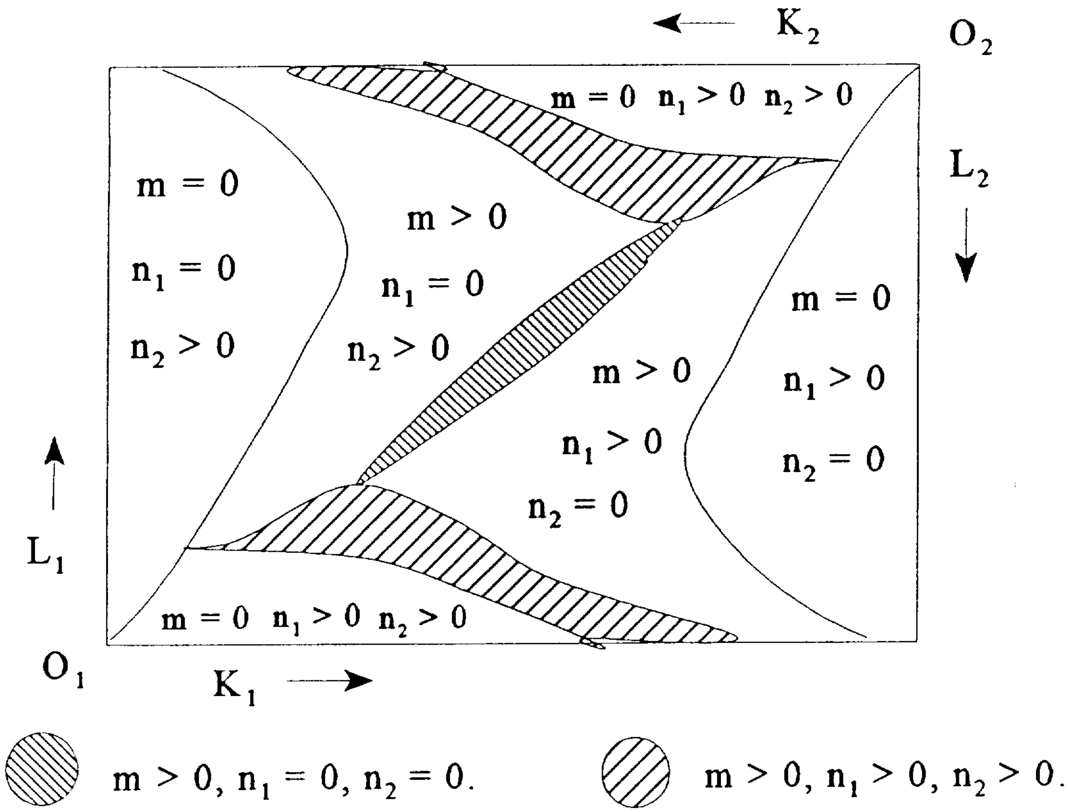


Figure 4.1



K2
O2
m = 0 n1 > 0 n2 > 0
L2
m = 0
n1 = 0
n2 > 0
m = 0
m > 0
m > 0 n2 > 0
n2 = 0 n1 > 0
n1 = 0
n1 > 0
n2 = 0
L1
m = 0 n1 > 0 n2 > 0
O1
K1
m > 0, n1 = 0, n2 = 0.
m > 0, n1 > 0, n2 > 0.

Figure 4.2:


K2
O2
m = 0 n1 > 0 n2 > 0
L2
m = 0
n1 = 0
n2 > 0
m > 0
n1 = 0
n2 > 0
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n2 = 0
m > 0
n1 > 0
n2 = 0
L1
m = 0 n1 > 0 n2 > 0
O1
K1
m > 0, n1 = 0, n2 = 0.
m > 0, n1 > 0, n2 > 0.

Figure 4.3:

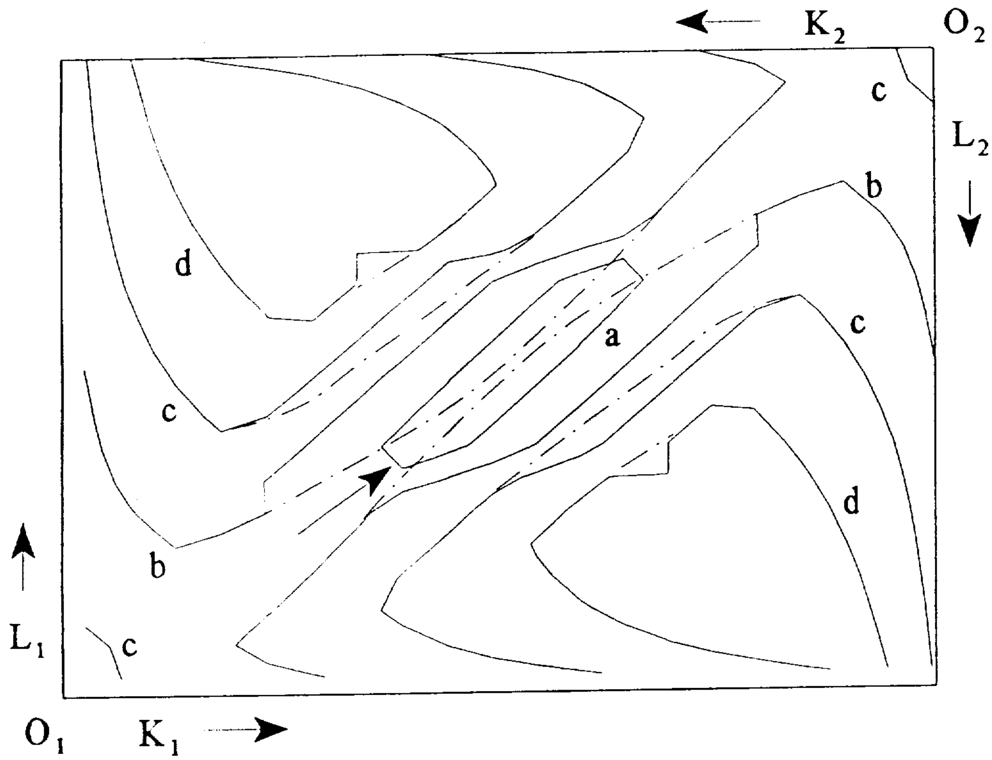

Figure 5.1: Iso-trade contours

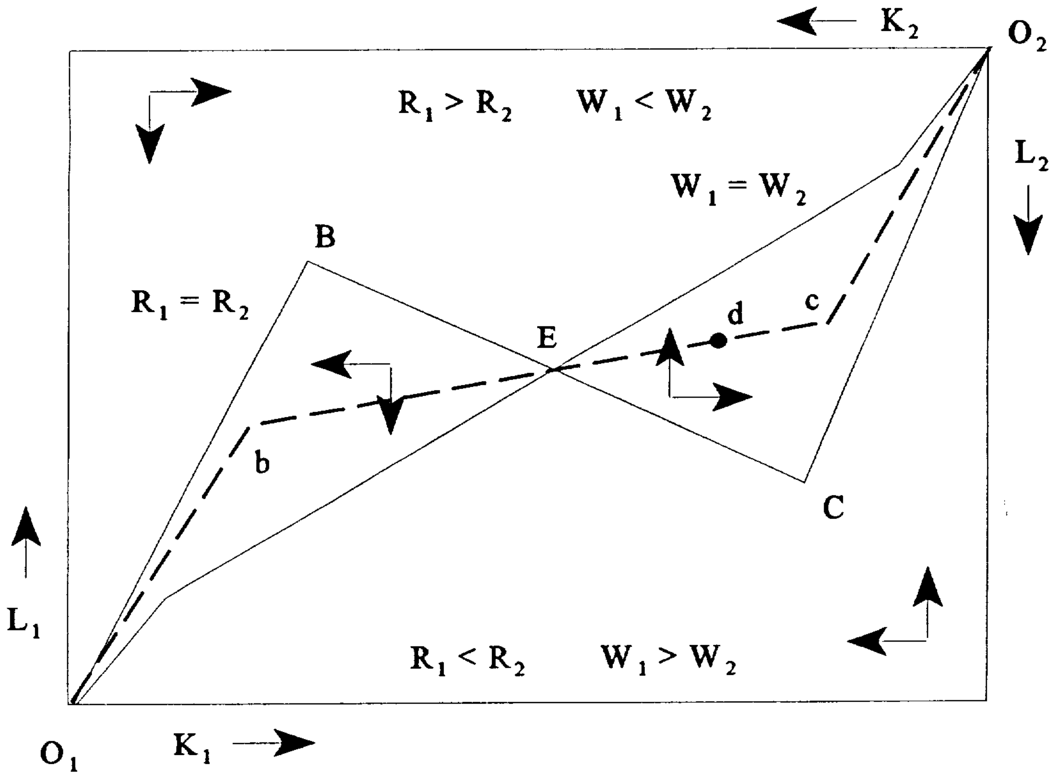

Figure 7.1

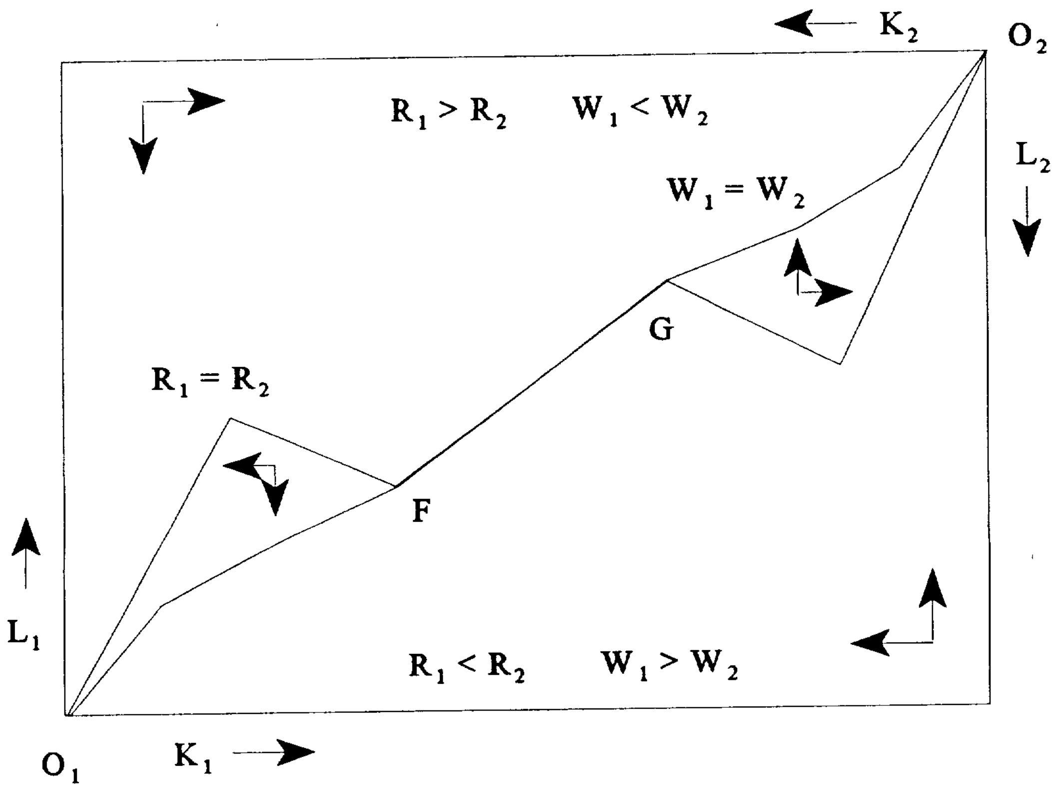

Figure 7.2