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The three faces of factor intensities

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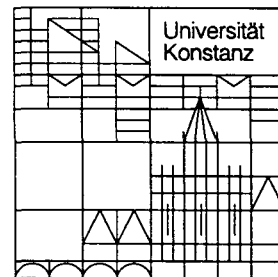
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**Sonderforschungsbereich 178
„Internationalisierung der Wirtschaft“**

Diskussionsbeiträge



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The Three Faces of Factor Intensities

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The Three Faces of Factor Intensities

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The concept of factor intensity has played a key role in the development of international trade theory. The factor proportions utilized in the production of commodities differ from activity to activity. Some commodities employ a higher ratio of capital to labor than do others, and the basic Heckscher-Ohlin Theorem explaining the pattern of international trade links a nation's factor endowment proportions of capital to labor to the capital/labor factor intensities of its export activities. This theorem has been exhaustively analyzed to reveal that exceptions may occur when technologies exhibit factor-intensity reversals, when demand conditions are highly asymmetric between countries, or when the number of factors and commodities exceeds the frequently-assumed value two. Our remarks in this paper proceed along different lines. We argue that in explaining the link between factor intensities associated with a nation's exports, imports or non-traded activities and that nation's factor endowment base, at least three rather separate roles for factor intensities can be identified. Once this is done, paradoxical statements such as, "Exports from labor-abundant countries are capital intensive", can be shown to have some validity. Furthermore, in explaining this position recourse is had to various characteristics of technology and trade which have been in the forefront of recent developments in trade theory, e.g., quality differences in an intra-industry setting, increasing returns to scale activities, uncertainty in production, and the role of services in trade.

I. The Traditional Inter-industry Face

The traditional role for factor-intensity comparisons relates techniques used in two separate industries. Thus suppose capital, both of the physical and human variety, and labor

are the only two productive factors, and that only two commodities (both tradeable) can be produced. In a two-country world the Heckscher-Ohlin Theorem states that the more capital abundant country exports the more capital-intensive commodity. Retain the two-factor assumption, but now expand the countries and commodities. In such a multi-commodity model, industries can be ranked according to their capital/labor ratios. If all industries face world markets, production can be narrowed to either one or two products, and the capital/labor proportions employed there will closely match the ratio in which these two factors are found in the country's endowment bundle. In such a multi-commodity framework it is a bit misleading to argue that capital-abundant countries export capital-intensive goods. Instead, it is more accurate to state that international trade allows a great concentration of productive activity, and with reference to the inter-industry capital/labor ranking, a country exports commodities (or a commodity) whose input requirements resemble those found in the overall endowment bundle, net of resources required for a nation's nontraded activities.

This multi-commodity setting provides a useful framework within which to emphasize a point about Heckscher-Ohlin trade theory. The theory provides no predictions linking a country's factor endowment base to the relationship between factor proportions utilized in its exportable sector and its import-competing sector. Thus consider the small-country case in which commodity prices are given in world markets. Figure 1 illustrates the case of four commodities, and displays the Hicksian unit value isoquant for these commodities - a convex hull made up of curved sections in which only one traded good is produced, and linear segments along which two goods are produced. Commodity 4 is the most capital-intensive,

and capital/labor ratios decrease with the numbers. Now consider two possible factor-proportions rankings for a country, shown by rays *A* and *B*. In either case the country produces capital-intensive commodities (3 and 4) compared with traded commodities not produced. But in case *A*, the more capital-intensive commodity 4 is imported since production is sufficiently small. That is, although the country is a capital-abundant country, a comparison of intensities adopted by the traded commodities *actually produced* reveals that it exports the labor-intensive commodity (3, compared with 4). (This trading pattern is reversed if the endowment proportions are shown by ray *B*.) The correct proposition is that a nation's *production* of tradeables corresponds closely in the required factor proportions with the nation's factor endowment base, compared with other commodities *not* produced, and therefore imported. This leaves room for a highly capital abundant country to export a commodity that is more labor-intensive than the other commodity locally produced as an import-competing commodity.

II. The Intra-industry Face

The importance of intra-industry trade is one of the points of departure for the "new trade theory". The first models of this phenomenon assumed that within each industry there existed a set of monopolistically competitive firms, each producing a type of industrial product which differed from that of all other firms in that industry in the minds of consumers. To simplify matters, production functions were posited to be identical for all firms in the industry, thus ruling out the significance of factor input proportions within the industry.¹ Tastes were either of the love-of-variety type or ideal-preference type, with strict

symmetry so that all varieties produced would have equal market shares and prices. That is, these models illustrated *horizontal* differentiation. Eventually models of *vertical* differentiation were developed.² In this latter case it was possible to rank products within an industry by quality, and individuals with higher incomes would be attracted by commodities of higher quality.

Within an industry suppose that higher-quality varieties require more capital-intensive techniques. As well, to encourage some activity in this sector to take place, suppose that the type of capital utilized in this industry is specific to the sector, but not to the variety produced.³ As in the case of inter-industry trade, a country's factor proportions will tend to select the varieties produced for world markets, but other varieties may be produced for the home market as non-tradeable items. If this is a labor-abundant country with relatively low income levels, the variety of commodities in this sector which gets exported may reflect the higher level of incomes abroad and therefore be produced by more capital-intensive techniques than utilized by non-tradeables destined for lower income groups at home. Thus the industry as a whole might be labor-intensive relative to other industrial groups, and the labor-abundant country's comparative advantage may well lie with this industry, but the *intra-industry* ranking by factor intensities would identify exports with the more capital-intensive sectors.

Furthermore, consider the realistic feature of production whereby there is uncertainty regarding the quality of final output even within any industry sub-group. That is, the use of more capital-intensive techniques may be required to fashion a product which, on average, will be of higher quality, but for any sub-group there will be a variation in the

quality of the output. *Quality control* refers to procedures whereby the variance in output (for any sub-group) is reduced. Such procedures usually require extra doses of physical capital or, perhaps more importantly, skilled labor. Thus even agricultural products, such as tea or fruit, range in quality (for any given original set of inputs), and more effort must be made to assure that a given output has lower variance for any desired mean. The techniques required to attain greater control over quality may well involved intensive use of capital or skilled labor, although exceptions can certainly be found where sorting and grading is primarily an unskilled labor-intensive activity. If labor-abundant countries wish to export to higher-income countries, the latter may insist on greater controls on variance in quality. Once again, within an industry the labor-abundant country may export commodities produced by more capital-intensive techniques than those utilized in non-tradeable varieties.

Finally, the famous proposition associated with the names of Alchian and Allen has relevance to this issue of the factor proportions found in a country's export bundle.⁴ Consider the outputs of any two sub-groups in an industry. Transport costs, assumed to be the same for either of the sub-groups, serves to raise the price of both in the importing country as opposed to the producing country. But the *relative* price of the higher-quality product is lower in the importing country, and thus substitution effects in demand encourage imports of the higher-quality products. (As Borcharding and Silberberg point out, a similar result follows even if the consumer travels instead of the product. This is of relevance to a country's tourist trade. For example, American tourists in London, attracted by the opportunity to see good theater, often select the better, higher-priced, seats. Once costs of

transport are added in, these seats are relatively not that much more expensive than seats in the upper balconies.) Thus even a labor-abundant country may find that within industrial categories exportables are produced with higher capital/labor ratios than are other sub-groups, which are the non-tradeables.

It is possible to consider a matrix of the commodities produced within a country. Columns are associated with different industries. Suppose, on average, these are ranked in number from lower to higher capital intensities. Rows reflect sub-groups within industries, with higher-numbered rows representing higher quality, lower variance items, produced by greater (physical and human) capital-intensive techniques. A labor-abundant country will, following the Heckscher-Ohlin Theorem, find its exportables in the group of industries with lower column numbers. But the intra-industry capital intensity ranking will be high. Viewing the matrix as a whole, the country's exports will be found in the lower left-hand corner -- labor intensive in the inter-industry ranking, and capital-intensive in the intra-industry ranking.

III. The Service Face

The preceding remarks address the issue of how factor proportions differ in the *production* of goods destined for export markets from those destined to be consumed locally. Exporting requires more than production, however. As argued by Jones and Kierzkowski (1990), the role of *services* becomes increasingly important in an age in which advances in technology have drastically lowered the costs of transport, communication, and co-ordination of production blocs in disparate locations. Before a country can succeed in exporting a

commodity, a network of service and distribution outlets must be established in the importing country, and these activities are often characterized both by increasing returns to scale and by human or physical capital-intensive techniques. To the extent that some costs are fixed per unit output (e.g. transport costs), while others are sunk (e.g. costs of establishing distribution nodes, knowledge of legal technicalities in the importing country), the Alchian and Allen argument again supports exports of higher-quality lines in an industry.

As our example of trade from a highly unskilled labor abundant country reveals, these three faces of factor intensities do not always point in the same direction. Thus the labor abundant country will tend to export commodities which are labor-intensive compared with other industrial groups (the inter-industry ranking), while also exporting commodities which are capital-intensive in an intra-industry ranking. A highly capital-abundant country would, along traditional Heckscher-Ohlin lines, tend to find its exportables among its capital-intensive industries. The Alchian and Allen argument would tend to support exportables from the intra-industry capital intensive items as well. However, if trade is in part directed to countries with significantly lower income levels, it may be the case that exports to these areas come from a middle range of intra-industry capital intensities. Finally, most service activities associated with establishing export markets abroad may require human and physical capital intensive techniques, regardless of income levels in the importing country.

IV. A Simplified Model

Some of these ideas can be portrayed in a simplified, competitive, model of a small open economy. We begin by assuming all commodities are tradeables, with prices given on world markets. Following that illustration is a discussion of how the presence of non-tradeables alters the nature of equilibrium as well as allowing more explicitly for the role of asymmetries in demand between relatively poor, labor-abundant countries and relatively high-income capital-abundant countries.

The basic underlying feature of the model is the existence of two kinds of capital. One kind, labelled K , is homogeneous (perhaps physical capital or generally well-trained and flexible human capital). The other is sector-specific (again, physical and/or human in form); thus H_i denotes the quantity of such capital available to the i th sector. Unskilled labor, L , is also mobile between sectors, but an assumption of separability in the technology is imposed so that in sector i a product M_i (the output of a process utilizing only unskilled labor, L_i , and mobile capital, K_i) is combined with sector-specific H_i to produce a number of *varieties*. These are distinguished by quality, with those varieties requiring a greater (H_i/M_i) ratio valued more highly by the world market. To introduce further notation, variety j in sector i has a price P_i^j (set by world market conditions), which exceeds P_i^n if and only if the ratio of input-output coefficients, (a_{Hi}^j / a_{Mi}^j) , is larger than (a_{Hi}^n / a_{Mi}^n) . We assume these ratios are increasing in j .

Figures 2 and 3 depict, respectively, the inter-sectoral allocation of resources among five sectors and the intra-sectoral variety choice made in sector 3. These diagrams are inter-related, and illustrated in them both is an example of an equilibrium in which prices of all

three varieties in each of five sectors is determined on world markets. The isoquants in Figure 2 are *unit-value* isoquants for the intermediate goods, M_i , used in sectors one through five. The isoquant for sector i reflects a "net" price given by the final world price, P_i^j , of the "best" variety (j) in sector i , less $a_{Hi}^j r_i$, where r_i is the (endogenously determined) highest rent which can be earned by sector-specific capital, H_i , in sector i . The Hicksian composite *convex hull* of these unit isoquants in Figure 2 is made up of curved sections (in which only one sector is actively producing) and linear segments (along which two sectors have positive outputs). As shown by the ray from the origin whose slope is the endowment proportion, K/L , in equilibrium only sectors two and three are in operation. Any local demand for any varieties found in sectors one, four or five must be satisfied by imports.

Figure 3 illustrates the intra-sectoral equilibrium in the third sector. (A similar kind of diagram, with perhaps a different configuration of varieties, could be drawn for sector two). The horizontal axis measures the quantity of intermediate good M_3 which is produced with K and L and used only in the third sector in combination with sector-specific H_3 , shown on the vertical axis. In drawing Figure 3 we assume equilibrium values for wages and rents to intersectorally mobile capital (w and r), which have determined techniques a_{L3} and a_{K3} to produce M_3 . The factor-price ratio, w/r , is indicated by the slope of the linear segment of the Hicksian composite unit-value isoquant in Figure 2 at point A , where it intersects the K/L ray from the origin. The cost of producing a unit of M_3 is $\{wa_{L3} + ra_{K3}\}$, reflected in the price, P_{M3} , whose inverse anchors the price line in Figure 3 showing combinations of sector-specific H_3 and M_3 which would cost \$1. Given the possibility of producing any of the three varieties available in sector 3 (the isoquants in Figure 3 are *unit-value* isoquants), the

return to H_3 is maximized by producing only the second variety. This choice for the best use of sector-specific capital parallels the selection for a small open economy in a Ricardian setting of that commodity whose production will maximize the wage rate given world commodity prices.

Figure 2 is similar to Figure 1 in showing that if a small open economy's technology is independent of world prices, trade entails a specialization to only one or two commodities. Such severe inter-sectoral specialization is less appropriate in the context of the present model, however, since rents on sector-specific capital can adjust to make production of some commodity in a sector more attractive. For example the unit-value isoquant for sector four in Figure 2 would shift in if less of the world price for the "best" variety in sector four had to be devoted to rental payments to H_4 . Thus the unit-value isoquants in sectors two, three and four could all be tangent to the same line, whose slope would indicate the equilibrium wage/rent ratio. If the unit-value isoquants for sectors one and five lay everywhere above such a line, it must be the case that sector-specific H_1 and H_5 could earn no rents. No variety in either sector would prove competitive even if payments are only required to be made to mobile L and K .

Some commodities may not be tradeable on world markets because of high real or artificial transport costs or because there is little world demand for these varieties. Local demand may raise price sufficiently in the home market that these commodities are produced as well. Figures 2 and 3 would have to be adjusted to make room for non-tradeables. Indeed, in some sectors strong local demand for certain varieties may drive out production of the tradeable good also utilizing the type of capital specific to that sector.

Thus in Figure 3 imagine a relatively-high priced non-tradeable variety four (in the third sector) which drives up the return, r_3 , above the level that allows competitive production of tradeable good 2 in the third sector.

Suppose in sector i there co-exists production of tradeable commodity j and a few non-tradeables. It is possible that commodity j is an import-competing product, but given that any varieties consumed but not produced (in this or any other sector) must be imported, it seems more reasonable to let tradeable commodity, j , be an export good. Is there any reason to expect the factor proportions, (a_{Hi}^j / a_{Mi}^j) , to differ from the comparable capital/ M ratios utilized in non-tradeables? Given our assumption that varieties differ in quality, much depends on asymmetries in *demand* between countries, especially as regards income levels. Thus if a country is labor-abundant with relatively low income levels compared with capital-rich countries, it may not produce varieties that are very capital-intensive. But an intra-sectoral comparison of factor intensities of varieties *actually produced* - between an exported variety and a non-traded variety - would suggest that the exportable is more capital-intensive. This is the second face of factor intensities, whereby in an intra-sectoral sense labor-abundant countries may export capital-intensive varieties in comparison to non-tradeable varieties satisfying local demand requirements. If quality control matters to higher-income nations abroad and if this requires extra doses of H_i , all the more reason to expect capital-intensive exports.

The Alchian and Allen result discussed in Section II refers to the possibility that transport costs involved in potential exports of higher and lower quality items may be roughly identical. Consider two such items with prices given in world markets, and ask what

the *relative* price of the higher quality item must be in the home market if such goods could be exported. Subtracting a constant cost of transport from the given world prices yields both goods lower-priced at home, but the relative price of the superior variety higher at home than abroad. Even if tastes were similar, substitution effects in demand and production would bias exports in favor of the higher-quality, more capital-intensive variety.

Finally, in this example as well as in others, a further role for factor intensities derives from the fact that *exporting* a commodity requires service activities as well as a production activity, and these activities may require fixed and/or set-up costs as well as relatively heavy use of human capital.

V. Illustrative Example

Although "tea" in general is a labor-intensive exportable product, India tends to export relatively "better quality" tea. There are three kinds of tea produced, CTC (Crush, Turn & Curl), Orthodox and Green. "Orthodox" is typically a high quality variety geared towards the export market. CTC is a low-quality variety destined for the domestic market. A careful plucking of tea leaves and the employment of a handful of very specialized "tea-tasters" determine the high quality blend. "Orthodox" is human-capital intensive. The price quoted in the local and international market reveals the quality difference. Note that the foreign price is f.o.b. (it excludes transport and other costs and roughly reflects quality differences).

Unit Price of Tea in Rupees per Kg.

<u>Year</u>	<u>Unit Export Price</u>	<u>Indian Auction Price</u>
1990	53.01	43.23
1991	55.91	40.30
1992	56.89	38.88
1993	64.93	48.93

The role of *experts tasting tea* is very important for generating the export blend. They are paid very highly and are quite few. Source: *Indian-Tea-Board*.

VI. Concluding Remarks

The concepts of factor intensities and factor endowments provide the center-piece for the Heckscher-Ohlin Theory of international trade. In this paper we have suggested that factor intensities have more than one "face" and care must be taken in the comparisons chosen. For example, the literature following the Leontief paradox in 1953 stressed the relationship between capital/labor ratios adopted in a nation's export sector and those utilized in its import-competing industries. The proposition that the capital-abundant country exports the commodity which is relatively capital intensive in this sense finds its best support in the classic two-country, two-commodity version of the theory. In the multi-country, multi-commodity case, we have illustrated that a capital-abundant country's export can easily be more labor-intensive than its import-competing sector. The more basic proposition is that a country's active production is centered on those sectors which require

capital/labor ratios somewhat similar to its endowment proportions.

There may be a number of varieties which can be produced within each sector. We have assumed that these varieties are vertically differentiated, with higher quality items produced by more capital-intensive techniques and appealing to consumers with higher income levels. The intra-sectoral comparison of factor-intensities which we have stressed is that between varieties exported and those consumed at home. If per-capita incomes are directly related to capital/labor endowment ratios, a relatively labor-abundant country may be exporting goods from a relatively labor-intensive sector but within that sector exporting higher quality varieties than are represented in its own (perhaps non-traded) consumption bundle. Thus the traditional intersectoral factor-intensity basis for trade relies primarily on supply-side differences between countries in their endowments, whereas the intra-sectoral pattern of trade and consumption reflects demand-side differences. For labor abundant countries exports may be found among the more labor-intensive sectors, but be given by the more capital-intensive varieties within those sectors. The importance of quality control for high-income consumers and the Alchian and Allen argument concerning transport costs also confirm that intra-sectoral pattern of trade.

The third "face" of factor intensities emerges from the fact that exporting is an activity that requires service inputs as well as production. If these inputs, the co-ordination activities and the acquisition of knowledge about foreign markets, are human or physical capital-intensive, the case for labor-abundant countries to require a high capital/labor ratio in its exporting activities is made even stronger. Our few empirical illustrations are consistent with this view.

Appendix

In this appendix we provide a more detailed, algebraic account of the simplified model described in Section IV. There we illustrated a possible equilibrium in which all goods are tradeable, only two sectors (2 and 3 in Figure 2) have active production levels, with only one variety actually produced in each sector. Figures 2 and 3 illustrated that other varieties in these sectors or in other sectors could become active if prices or factor endowments were sufficiently altered. Having made that point, we restrict ourselves here to a discussion of how small changes in the parameters of the model (traded commodity prices and all factor endowments) affect returns to inputs and output levels.

To simplify the notation, we assume that only sectors 1 and 2 are active, with sector 1, being labor-intensive. And, in each sector, we assume it is only variety 1 that is produced, with P_1 and P_2 denoting the given prices of variety 1 in sector 1 and variety 1 in sector 2. The parameters of the model are these two prices (P_1, P_2), and factor endowments: mobile labor and capital (L, K) and sector-specific capital (H_1, H_2). Labor and mobile capital produce intermediate goods in each sector (M_1 and M_2), and these are each combined with sector-specific capital to produce two final outputs: variety 1 in sector 1, denoted X_1 , and variety 1 in sector 2, denoted X_2 . To be determined are the output levels of intermediate goods, (M_1, M_2), of final goods, (X_1, X_2), the prices of intermediate goods, (P_1^M, P_2^M), the returns to mobile factors (w, r), and the rents to sector-specific capital (r_1, r_2). Following standard procedure (e.g. Jones, 1965) we focus on equations of change in *relative* terms ($\hat{X} = \frac{dX}{X}$). Although eight equations of change are required to solve for the specified variables of change, no more than a pair of equations at a time needs to be analyzed. As

in Section IV, a_{ij} denotes the amount of input i ($i = L, K, M$ or H) per unit output of good j ($j = M_1, M_2, X_1, X_2$). The use of intermediates, M_1 and M_2 , allows the production of a given variety in any sector to depend on inputs of labor, mobile capital, and sector-specific capital, with separable production technology.

We start with the pair of competitive profit conditions for the two intermediates:

$$a_{L1}\omega + a_{K1}r + P_1^M \quad (1)$$

$$a_{L2}\omega + a_{K2}r = P_2^M \quad (2)$$

Differentiating, letting θ_{ij} denote the distributive share of input i in output, j :

$$\theta_{L1}\hat{\omega} + \theta_{K1}\hat{r} = \hat{P}_1^M \quad (3)$$

$$\theta_{L2}\hat{\omega} + \theta_{K2}\hat{r} = \hat{P}_2^M \quad (4)$$

Subtraction reveals that:

$$(\hat{\omega} - \hat{r}) = \frac{1}{|\theta|} (\hat{P}_1^M - \hat{P}_2^M), \quad (5)$$

where the determinant, $|\theta|$, equal to $(\theta_{L1} - \theta_{L2})$, is positive by our assumption that higher numbered sectors are more capital-intensive. Thus any increase in the relative price of the intermediate good used in the first sector to that in the second raises the wage/rent ratio for mobile factors. Of course changes in prices of intermediates are endogenous to the model.

A key pair of relations is the requirement that labor and mobile capital be fully employed in producing the intermediates, M_1 and M_2 , used in each sector to produce final

goods. Thus:

$$a_{L1}M_1 + a_{L2}M_2 = L \quad (6)$$

$$a_{K1}M_1 + a_{K2}M_2 = K \quad (7)$$

Differentiation, letting λ_{ij} denote the fraction of factor i employed in sector j , yields,

$$\lambda_{L1}\hat{M}_1 + \lambda_{L2}\hat{M}_2 = \hat{L} - \{\lambda_{L1}\hat{a}_{L1} + \lambda_{L2}\hat{a}_{L2}\} \quad (8)$$

$$\lambda_{K1}\hat{M}_1 + \lambda_{K2}\hat{M}_2 = \hat{K} - \{\lambda_{K1}\hat{a}_{K1} + \lambda_{K2}\hat{a}_{K2}\} \quad (9)$$

The changes in input-output coefficients are derived in standard fashion. For example, in the first sector, $[\theta_{L1}\hat{a}_{L1} + \theta_{L2}\hat{a}_{L2}]$ equals zero by the cost-minimization condition. As well, by definition of the elasticity of substitution between mobile labor and capital in producing M_1 , σ_1^M , $\{-\hat{a}_{L1} + \hat{a}_{K1}\} \equiv \sigma_1^M (\hat{w} - \hat{r})$. This pair of relationships suffices to yield solutions for \hat{a}_{L1} and \hat{a}_{K1} :

$$\hat{a}_{L1} = -\theta_{K1}\sigma_1^M (\hat{w} - \hat{r}) \quad (10)$$

$$\hat{a}_{K1} = \theta_{L1}\sigma_1^M (\hat{w} - \hat{r}) \quad (11)$$

Substituting this pair of terms (and the analogous pair for sector 2) into the preceding pair of equations yields (12) and (13):

$$\lambda_{L1}\hat{M}_1 + \lambda_{L2}\hat{M}_2 = \hat{L} + \delta_L (\hat{w} - \hat{r}) \quad (12)$$

$$\lambda_{K1}\hat{M}_1 + \lambda_{K2}\hat{M}_2 = \hat{K} - \delta_K (\hat{w} - \hat{r}) \quad (13)$$

Where:

$$\delta_L = \lambda_{L1} \theta_{K1} \sigma_1^M + \lambda_{L2} \theta_{K2} \sigma_2^M$$

$$\delta_K = \lambda_{K1} \theta_{L1} \sigma_1^M + \lambda_{K2} \theta_{L2} \sigma_2^M$$

Finally, the solutions for \hat{M}_1 and \hat{M}_2 shown separately can be written as:

$$\hat{M}_1 = e_1^M (\hat{P}_1^M - \hat{P}_2^M) + \frac{[\lambda_{K2} \hat{L} - \lambda_{L2} \hat{K}]}{|\lambda|} \quad (14)$$

$$\hat{M}_2 = -e_2^M (\hat{P}_1^M - \hat{P}_2^M) - \frac{[\lambda_{K1} \hat{L} - \lambda_{L1} \hat{K}]}{|\lambda|} \quad (15)$$

where the determinant, $|\lambda|$, equals $(\lambda_{L1} - \lambda_{K1})$ and has the same sign as $|\theta|$ (positive) and e_i^M is the elasticity of supply of intermediate good i with respect to M_i 's relative price if endowments are fixed. Thus, for example,

$$e_1^M = \frac{[\lambda_{K2} \delta_L + \lambda_{L2} \delta_K]}{|\lambda| |\theta|} \quad (16)$$

We turn our attention, now, to techniques of production for X_1 (and, by analogy, for X_2), the first variety in sector 1. The elasticity of demand for input M_1 , for given amounts of sector-specific capital, H_1 , can be denoted by γ_1 , and is defined by:⁵

$$\hat{H}_1 - \hat{M}_1 = \gamma_1 (\hat{P}_1^M - \hat{P}_1) \quad (17)$$

Substitution of this, and the comparable definition of γ_2 , into the solutions for \hat{M}_1 and \hat{M}_2 yields the following pair of relationships:

$$(e_1^M + \gamma_1) \hat{P}_1^M - e_1^M \hat{P}_2^M = - \frac{(\lambda_{K2} \hat{L} - \lambda_{L2} \hat{K})}{|\lambda|} + \hat{H}_1 + \gamma_1 \hat{P}_1 \quad (18)$$

$$- e_2^M \hat{P}_1^M + (e_2^M + \gamma_2) \hat{P}_2^M = \frac{(\lambda_{K1} \hat{L} - \lambda_{L1} \hat{K})}{|\lambda|} + \hat{H}_2 + \gamma_2 \hat{P}_2 \quad (19)$$

This pair can be used to solve for the endogenously-determined set of price changes, \hat{P}_1^M and \hat{P}_2^M , with respect to changes in any of the endowments or the commodity prices for final varieties given on world markets. The full solutions are shown below:

$$\hat{P}_1^M = \frac{1}{\Delta} \{A_1^L \hat{L} + A_1^K \hat{K} + (e_2^M + \gamma_2) \hat{H}_1 + e_1^M \hat{H}_2 + \gamma_1 (e_2^M + \gamma_2) \hat{P}_1 + \gamma_2 e_1^M \hat{P}_2\} \quad (20)$$

$$\hat{P}_2^M = \frac{1}{\Delta} \{A_2^L \hat{L} + A_2^K \hat{K} + e_2^M \hat{H}_1 + (e_1^M + \gamma_1) \hat{H}_2 + \gamma_1 e_2^M \hat{P}_1 + \gamma_2 (e_1^M + \gamma_1) \hat{P}_2\} \quad (21)$$

where, $\Delta = (\gamma_1 \gamma_2 + \gamma_1 e_2^M + \gamma_2 e_1^M) > 0$

$$A_1^L = \frac{1}{|\lambda|} [\lambda_{K1} e_1^M - \lambda_{K2} (e_2^M + \gamma_2)]; \quad A_1^K = \frac{1}{|\lambda|} [\lambda_{L2} (e_2^M + \gamma_2) - \lambda_{L1} e_1^M]$$

$$A_2^L = \frac{1}{|\lambda|} [\lambda_{K1} (e_1^M + \gamma_1) - \lambda_{K2} e_2^M]; \quad A_2^K = \frac{1}{|\lambda|} [\lambda_{L2} e_2^M - \lambda_{L1} (e_1^M + \gamma_1)]$$

With these formal solutions in hand, it is relatively simple to analyze the effect of endowment and price changes.

I. Changes in the Endowment of Specific Capitals

There are four exogenously given factor endowments in this model (L, K, H_1, H_2) and only two final goods produced (the first variety in each of the two sectors), so it comes as no surprise to find that endowment changes at given world prices exert an independent

influence on input prices. From the solutions for \hat{P}_1^M and \hat{P}_2^M it is clear that an increase in the endowment of either sector-specific capital serves to raise the prices of both intermediate goods. If H_1 alone goes up, \hat{P}_1^M exceeds \hat{P}_2^M , implying that intermediate output M_1 rises at the expense of M_2 . With M_2 falling and H_2 constant, rental returns to sector-specific capital in sector 2, r_2 , must be driven down. With P_1^M rising, the return r_1 is driven down as well, indicating that the ratio H_1/M_1 must rise. That is, production of M_1 increases, but not, relatively, as much as H_1 .

Although an increase in endowment H_1 clearly must lower its rental, r_1 , the return to sector-specific capital in sector 2 not only falls as well, it may fall more than r_1 . In general the competitive profit equations of change for final goods indicate:

$$\theta_{M1}\hat{P}_1^M + \theta_{H1}\hat{r}_1 = \hat{P}_1 \quad (22)$$

$$\theta_{M2}\hat{P}_2^M + \theta_{H2}\hat{r}_2 = \hat{P}_2 \quad (23)$$

If final goods prices are constant and H_1 rises, both P_1^M and P_2^M rise (with $\hat{P}_1^M > \hat{P}_2^M$). Substitution reveals that \hat{r}_2 may be less than \hat{r}_1 (both are negative); a sufficient condition guaranteeing the opposite (that $\hat{r}_1 < \hat{r}_2$) is that variety 1 in sector 2 be capital intensive in its use of H_2 relative to variety 1 in sector 1 (i.e. $\theta_{H2} > \theta_{H1}$).

If H_1 alone rises, final output (of variety 1) in sector 1 rises and in sector 2 falls since M_1 also increases and M_2 falls (with H_2 constant). In a diagram such as Figure 2, the unit-value isoquant for M_1 would shift inwards by more than the unit-value isoquant for M_2 and the wage/rental ratio, w/r , must rise. It is an open question whether the return to mobile capital, r , must fall, but \hat{r} is less than \hat{P}_2^M and \hat{w} exceeds \hat{P}_1^M . In a diagram such as Figure

3 (adjusted so that variety 1 is the favored good in the first sector), the horizontal intercept of the unit expenditure line shifts leftwards as P_1^M rises, and the vertical intercept rises as sector-specific rentals fall.

II. Changes in Endowments of Mobile Capital or Labor

The solutions for the effects of endowment changes in L or K on the prices of M_1 and M_2 seem more ambiguous. Consider, first, a situation in which both labor and mobile capital increase by the same relative amount. With sector-specific capital fixed, outputs of both M_1 and M_2 would increase if P_1^M and P_2^M were unchanged. But these output movements drive up sector-specific rentals and push down both P_1^M and P_2^M . They need not fall by the same relative amount, however. As is clear from the solution, the ranking of \hat{P}_1^M with \hat{P}_2^M depends on the size of γ_1 and γ_2 . If $\gamma_1 > \gamma_2$, it is a signal that more M_1 is required relative to M_2 and P_1^M/P_2^M will rise to encourage asymmetry in production.

If just the labor force expands, the solutions for \hat{P}_1^M and \hat{P}_2^M separately reveal an ambiguity. However, consider their changed ratio, $(\hat{P}_1^M - \hat{P}_2^M)$:

$$(\hat{P}_1^M - \hat{P}_2^M) = - \frac{1}{\Delta} \left\{ \frac{\lambda_{K1}\gamma_1 + \lambda_{K2}\gamma_2}{|\lambda|} \right\} \hat{L} \quad (24)$$

Recall that intersectorally M_1 is labor-intensive. At an unchanged P_1^M/P_2^M ratio, the increase in L means that the output of M_1 would rise and M_2 fall, which, by raising r_1 and lowering r_2 , would cause a fall in P_1^M/P_2^M .

III. Changes in Final Traded Goods' Prices

For given endowments, an increase in the price of either final commodity raises both P_1^M and P_2^M . More generally phrased, the following ranking holds if $\hat{P}_1 > \hat{P}_2$:

$$\hat{r}_1 > \hat{P}_1 > \hat{P}_1^M > \hat{P}_2^M > \hat{P}_2 > \hat{r}_2 \quad (25)$$

The outliers are the rents on sector-specific capital. The change in the intermediate good price ratio, P_1^M/P_2^M , is:

$$(\hat{P}_1^M - \hat{P}_2^M) = \frac{\gamma_1 \gamma_2}{\Delta} (\hat{P}_1 - \hat{P}_2), \quad (26)$$

a fraction of $(\hat{P}_1 - \hat{P}_2)$. The change in final goods' price ratio raises M_1 and lowers M_2 and has a profound effect on sector-specific rentals. Thus M_1 and M_2 act like the mobile factor in the specific factors model, with returns trapped between final commodity price changes.

Footnotes

1. For an exposition see Helpman and Krugman (1985).
2. See especially Falvey and Kierzkowski (1987).
3. For example, see Jones and Marjit (1992).
4. See Alchian and Allen (1964) as well as Borchering and Silverberg (1978).
5. If σ_1 denotes the elasticity of substitution between H_1 and M_1 in producing X_1 , it is easy to show that γ_1 equals σ_1/θ_{H1} .

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Figure 1

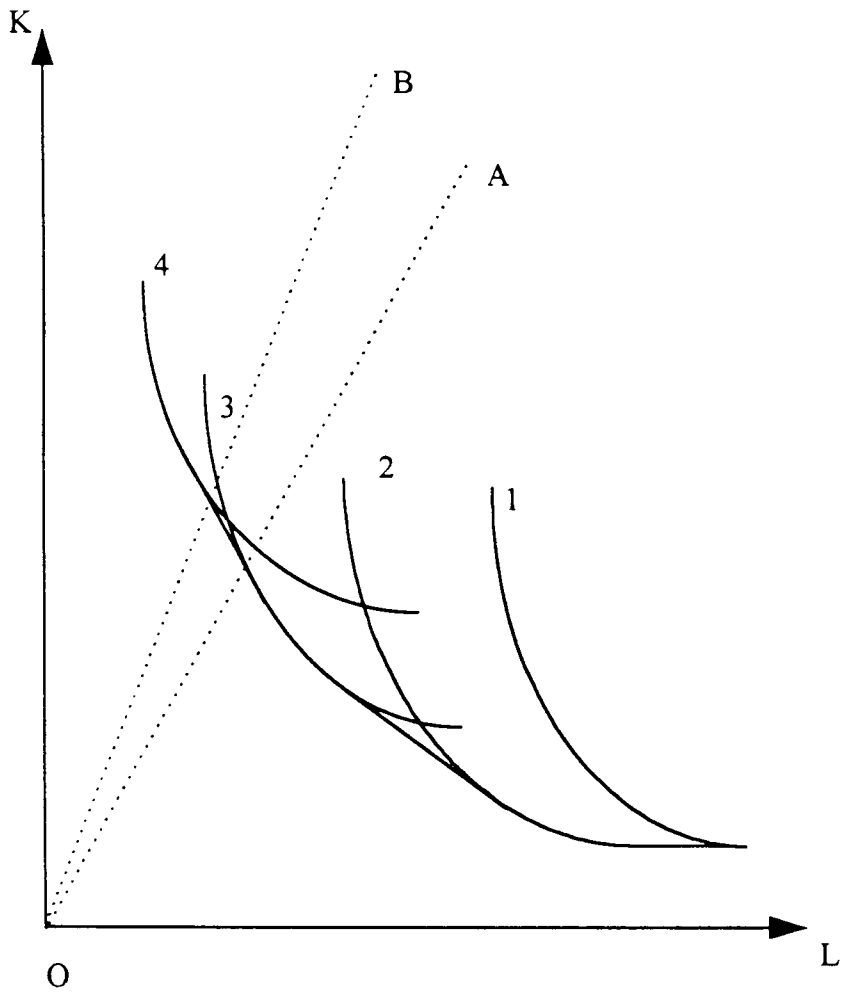


Figure 2

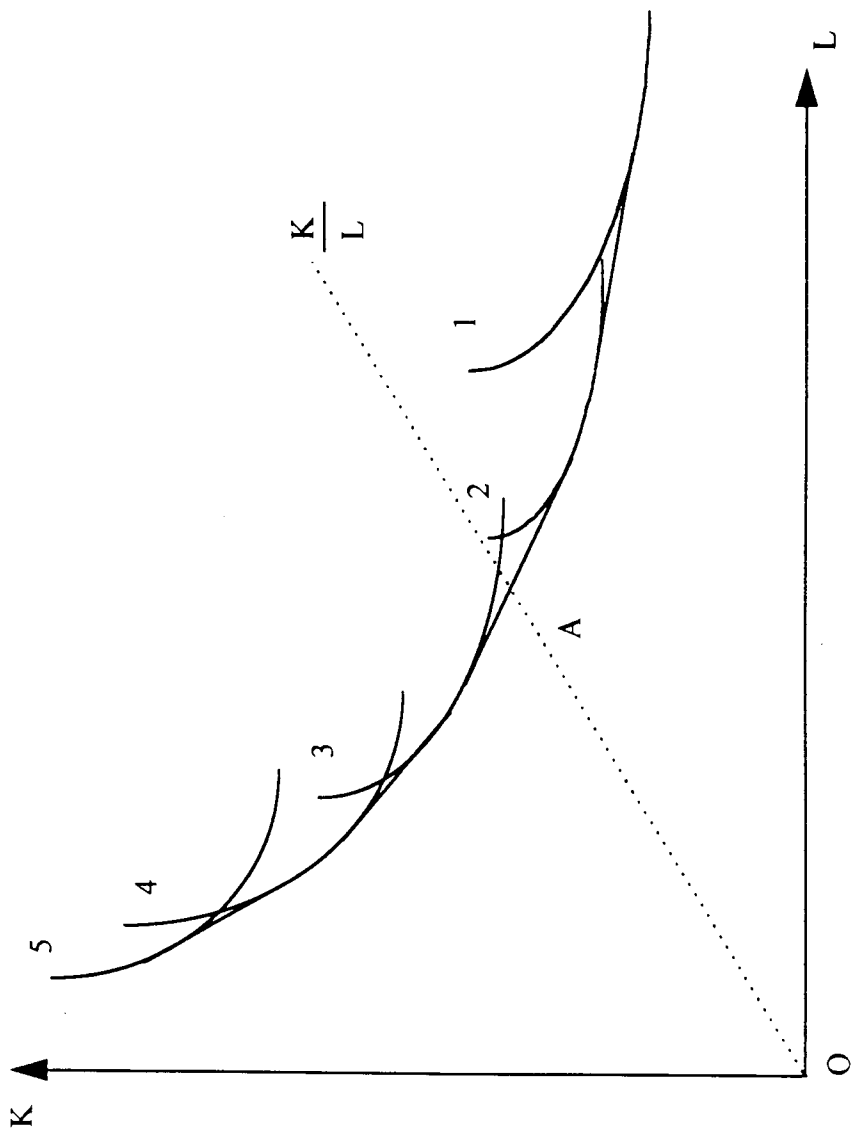


Figure 3

