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AGRICULTURAL DEVELOPMENT SYSTEMS. EGYPT PROJECT

UNIVERSITY OF CALIFORNIA, DAVIS

COMPLEMENTARITY OF TRADE AND LABOR MIGRATION

by

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WORKING PAPER

USAID/EGYPT

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Complementarity of Trade and Labor Migration

In theory, free trade in commodity markets can reduce incentives for international labor migration. The basis for this is the derivation in static analysis of a seemingly unambiguous result: factor mobility and trade are substitutes. This basic result of the Heckscher-Ohlin-Samuelson (H-O-S) model is that, under very restrictive assumptions, free trade will cause wages paid to labor, say, in Egypt and Saudi Arabia, to converge towards equilization, even though labor migration between the two countries is prohibited.

Recently the substitutability of trade and labor migration has been challenged on both theoretical and empirical grounds. Here we examine conditions under which removal of a small import tariff may encourage mobility of some factor, say labor. This phenomenon is defined as the complementarity of trade and factor mobility. Then mobility of at least one factor becomes a necessary condition for factor price convergence. (Here it is assumed that there exists substitutability between factors in production.)

Moreover in this paper we find that although trade and mobility in one factor may be complements, yet trade and mobility in another factor may be substitutes. Freer trade may increase incentives for labor migration yet at the same time diminish incentives for capital mobility, for example. Here incentives for labor migration are said to increase when the gap between wages paid to labor widens between two countries.

Hence a basic policy prescription from International Trade theory is called into question. Policies which are designed to remove barriers to trade and capital mobility may prove ineffective in either narrowing the wage gap or in encouraging foreign capital investment (that is, capital mobility).

The final question is whether or not temporary labor migration isn't a good thing, in which case we shouldn't have to worry about free trade encouraging labor migration. In static analysis it is commonplace to assume that marginal productivity of each factor is positive and that full employment prevails. Under these conditions the effects of labor migration upon the labor-sending country are unambiguous. Gross Domestic Product declines, wages increase, and labor-intensive production diminishes. If the relatively labor-abundant country[1] enjoys comparative advantage in the labor-intensive industry, which we might expect, then it is the industry of comparative advantage which contracts as a result of the wage increases.

If there exists at least some substitutability between factors in production, then labor migration will cause returns to each factor to converge towards equilization; thus labor emigration discourages foreign capital investment, for example, by narrowing the gap between returns paid to capital in the two countries.

Finally, the policy implications for the labor-sending country of the phenomenon of complementarity of trade and labor migration are illuminated.

Underpinnings of Comparative Advantage

The basic question underlying all analyses of the substitutability of trade and factor mobility is this: from what causes does comparative advantage arise? The argument implicit in this essay is that comparative advantage may arise not merely from differences in relative abundance of factors; it also arises from differing marginal productivities. In most cases, comparative advantage arises from a combination of these two causes.[2]

In the production setting, it is the interaction between relative factor endowments and technologies exhibiting differing factor productivities or variable returns to scale which can cause an indeterminate effect of freer trade upon wages. But this interrelationship has historically been neglected by hypothesis. The following section summarizes the development of the theory to its present condition, emphasizing the trend which has existed to date towards consideration only of comparative advantage arising from differences in relative factor endowments.

Ricardo (1911) developed the theory of comparative advantage based upon differences in factor productivities between countries. Thus, in Ricardo's model, technologies differ between countries in the sense that marginal returns from augmenting the factor of production differ between countries. Yet this analytical basis for the consideration of comparative advantage was to remain nearly neglected for most of the Twentieth Century.

Ohlin (1933), Stolper-Samuelson (1941) and Heckscher (1949) attempted to develop a theory of comparative advantage based solely upon relative factor endowments by hypothesizing conditions under which comparative advantage arising from technological differences in factor productivities does not exist.

The Heckscher-Ohlin-Samuelson approach (in its simplest form) hypothesizes the following: a) two countries, two outputs, two inputs; b) identical technologies in both countries; c) one output is intensive in the first factor; the other is intensive in the second; d) the factor intensity in each industry is independent of scale or relative factor returns; e) neither output is an input to the production of the other; f) both outputs are produced by each country both before and after trade; g) initial factor

endowments in each country differ in proportion but are not too disparate between countries; h) factors are homogeneous, mobile within each country, immobile between countries; i) full employment and perfect competition prevail; hence values of marginal product equal wages; j) opening trade changes the price ratio of the two commodities in each country; and k) all industries exhibit constant returns to scale.

Under these very restrictive assumptions, wages to the same factor can be guaranteed to converge as a result of trade. Since technologies are identical and factors homogeneous, the most efficient outcome is for wages to the same factors to equalize in the two countries. Thus, wage convergence of all factors in the direction of their respective world values of marginal productivity unambiguously increases world efficiency.

Mundell (1957) demonstrated that if the Heckscher-Ohlin-Samuelson assumptions hold then free factor mobility will cause all trade to cease if an export tariff of infinitesimal size is imposed. On a more general level, this means that if factor mobility and trade are substitutes, in the sense that each causes wages to converge, then factor mobility will effectively diminish the comparative advantage enjoyed by each country and trade will decrease.

Objections have been raised to the H-O-S model because its predictions are violated frequently in the real world. Trade and capital mobility, or trade and labor migration, may increase together. Are these divergences just temporary aberrations or is there a structural basis for the complementarity of trade and factor mobility unaccounted for by the H-O-S model?

Complementarity of Trade and Factor Mobility

Substitutability of trade and factor mobility does not always comport with the real world because the assumptions of the H-O-S model do not always hold. Effectively eliminated from consideration are differences in technology between countries or differing returns to scale between industries which might cause factor marginal productivities to differ between countries.

Schmitz and Helmberger (1970) found that sufficient differences between countries in technology, or equivalently, in the marginal productivity of a given factor, may give rise to the complementarity of trade and factor mobility. Concerned with the analysis of trade in primary commodities between LDCs and developed countries, they argued that increased capital mobility may actually increase the volume of trade. They apparently did not consider the possibility that increases in trade may affect incentives for capital mobility, or for labor migration.

Purvis (1972) demonstrated that even when all industries exhibit constant returns to scale, free trade is not sufficient to guarantee world efficiency if differences in technology between countries exist. In this case factor mobility becomes a necessary condition for world efficiency. Purvis defined factor mobility arbitrarily to mean capital mobility.

More generally, we can say that if marginal productivities of the same factor differ between countries then freer trade may cause wages paid to the same factor to become more disparate between countries, thus encouraging factor mobility. Underlying this analysis is the implicit assumption that comparative advantage may arise due to differences between countries in marginal productivities of factors. For world efficiency, measured as convergence of all factor wages to their respective world values of marginal

productivity, factor mobility is necessary. Whether this means mobility of capital or of labor is immaterial to the result.

Economists are prone to make the generalization that between "similar" countries one should expect substitutability of factor mobility and trade; between "dissimilar" countries, complementarity. This extremely loose rendition of the Purvis result does not stand close scrutiny, however. Even if tastes and technologies are identical and all of the other H-O-S assumptions hold, if it is assumed that returns to scale differ between industries, then wages to the same factor may diverge as a result of freer trade. Note that this result will require relaxation of the assumption of constant returns to scale. The following section summarizes the literature concerning variable returns to scale; then justifications for the relaxation of the assumption of constant returns to scale are presented. (See the Mathematical Appendix for a formal development of variable returns to scale.)

Variable Returns to Scale

The incorporation of the concept of variable returns to scale into the H-O-S trade model--as opposed to constant returns to scale--may give rise to the existence of complementarity of trade and factor mobility. (Another cause might be differing technologies between countries.) Variable returns to scale models assume identical technologies in both countries, but may allow for differing returns to scale between industries.

Based on the work of Jones (1968), Panagariya (1980) has shown that external economies or diseconomies of scale may reverse the Stolper-Samuelson theorem. This theorem states that under the H-O-S conditions (above), we can be assured that a change from autarky to free trade will cause the wage paid

to the relatively abundant factor to increase and the wage paid the relatively scarce factor to decrease. Thus all wages converge towards equalization, reducing incentives for mobility of any factor between countries.

What a reversal of Stolper-Samuelson means is that freer trade may cause the wage paid to the "scarce" factor to increase.[3] This result depends upon relaxation of the assumption of constant returns to scale, and the amount of the increase will be scale dependent. Thus, even if capital is in relative scarcity, the price of capital may increase as a result of trade, both relatively and absolutely. Similarly, the wage paid to labor may increase in the relatively labor-scarce country, thus encouraging labor migration.

Markusen and Melvin (1981) have developed further results, having assumed increasing returns to scale in one industry but constant returns in the other. Their conclusions include the following observation, relevant to this discussion:

> "Factor price differences . . . under free trade exceed the factor price differences which one would obtain if one or both countries had a small tariff."

That is, if the gap between wages paid to the same factor in different countries had been smaller before the introduction of a small import tariff then the movement towards freer trade will increase incentives for factor mobility. This is the definition of complementarity of trade and factor mobility employed in this paper.

In fact, the assumption of increasing returns to scale is overly strong for the derivation of this rather simple result. Even if technologies are identical in the two countries, if both industries face decreasing returns to scale, then removal of a small import tariff in the labor-abundant country may

increase incentives for labor emigration if the industries face differing returns to scale. This occurs in the numerical example included in the Mathematical Appendix, where the gap between wages paid to labor in the two countries widens when a small import tariff is removed.

In general, overly strong assumptions should be avoided because they may produce counter arguments on side issues irrelevant to the main discourse. This, unfortunately, is the case with the increasing returns to scale assumption. One usually expects complete specialization by each country in the production of one good or the other when increasing returns exist. This is because the production possibilities set is no longer convex. But Jones, Panagariya, Markusen, and Melvin have ended up imposing incomplete specialization. This approach is burdensome and unnecessary here.

As mentioned above, comparative advantage can be thought of as having been derived from (at least) two sources: varying relative factor abundance between the two countries and differing factor marginal productivities.

Given two industries which employ the same factors but exhibit differing returns to scale, it is trivial to demonstrate that the world marginal productivities of the two factors would differ even if both factors were completely and costlessly mobile and world endowments of the two factors equal. Given identical technologies in both countries and decreasing returns to scale in both industries, the country which stands to gain the most from trade is the one endowed relatively abundantly in the factor employed relatively intensively in the industry with greater returns to scale. This turns out to be the factor which exhibits the greatest marginal productivity at world equilibrium, given equal world endowments of both factors.

As defined above, it is the real wage difference between countries which provides the incentive for labor migration, not comparisons of (domestic)

relative factor prices. Given decreasing returns to scale, it can be shown that relative returns to the abundant factor, say labor, increase, yet it may be the case that the wage gap nevertheless widens between countries. This is because returns to labor may also increase in the capital-abundant (foreign) country. (See the numerical example in the Mathematical Appendix.)

At this point an examination of the plausibility of the assumption of constant returns to scale and the arguments which have been put forward in its favor is in order. This requires a digression on the subject of the replicability argument.

Replicability Argument

First, it should be noted that replicability is an argument, not a theorem. Second, that practically all trade theory implicitly depends upon it since constant returns to scale are almost always assumed to prevail.

The notion of replicability is that given the availability of homogeneous factors there will exist industry-wide firm replicability even if firms individually face decreasing returns to scale. Thus, in the absence of barriers to entry (which might be entailed, for example, by the fixity of some factors such as water or land in agriculture), the industry itself will face either constant or increasing returns to scale, since the optimal-sized firm can always be replicated. (If there are no barriers to entry and the industry faces decreasing returns to scale we are left with a mathematical oddity.)[4]

For the purposes of the H-O-S model, the set of possible technologies can be narrowed still further. Suppose we assume increasing returns to scale. If there exist barriers to entry only one firm can prevail; with no barriers presumably oligopoly will eventually result. But these results, which may

seem highly probable upon even the most cursory examination of international trade markets, have been precluded by the hypothesis that all firms are price-takers; the assumption that perfect competition prevails. Thus the only remaining possibility, it is often argued, is constant returns to scale.

Our result has remained simply an argument due to the practical difficulty of its being tested. Interwoven in the replicability argument are three maintained hypotheses which are themselves difficult to justify empirically: homogeneous factors, perfect competition, and no barriers to entry. (Implicitly, discrete jumps in industry cost curves also are ruled out.)

At this juncture it is useful to list some of the advantages of adopting the hypothesis of constant returns to scale. The assumption is desirable because it renders the problem mathematically tractable. First order conditions for the minimization of cost can be manipulated algebraically so that wage ratios do not depend upon output levels. Similarly, factor employment ratios do not depend upon output levels. The assumption of constant returns to scale allows generalization of results and thus leads to the construction of theorems. Without this assumption, even in the two-dimensional case, the solution to each example depends upon the parameters assumed in the example. Thus the number of possible permutations is infinite, the solution to each of which is likely to be highly nonlinear and troublesome. Professors Stolper and Samuelson noted as much in 1941.[5] Today, with the advent of computer simulation techniques, many of these permutations can be solved quite inexpensively; in fact this is what Panagariya has done, for a few numerical examples.

Allocation of Economic Rent

The least compelling argument in favor of the assumption of constant returns to scale is the following: it will guarantee zero economic profits in keeping with the assumption of perfect competition. If, for example, it is assumed that the industry faces decreasing returns to scale, due perhaps to the fixity of some factor, say land, then if only labor and capital are considered factors there will remain a surplus "accounting" profit unallocated either as wage or capital return. If this return accrues to management or to land ownership then these factors should be included in the production functions. Since H-O-S models assume that perfect competition prevails, all factors must in the long run be paid only their respective opportunity costs, driving "economic" profit to zero. The assumption of constant returns to scale is sufficient, but not necessary, for "economic" profit to be driven to zero.

The first problem with this argument is that even the most cursory observation of International Trade suggests that the assumption of perfect competition is overly optimistic. Increasing returns to scale, collusion, monopoly and oligopoly power often seem to be the rule rather than the exception. But just as the solution to the problem of resource allocation by the multi-output firm (to which the H-O-S models are analogous) depends upon the assumption of perfect competition, so has the failure of any model to satisfactorily explain oligopolistic behavior precluded Internatonal Trade models which incorporate the very real empirical fact that monopoly power exists.[6]

The second problem with the adoption of the assumption of constant returns to scale in order to ensure zero economic profit is that it is not a

necessary condition either for zero profit or for perfect competition. The Jones-Panagariya model assumes perfectly competitive firms whose combined industrial output is characterizd by economies or diseconomies of scale, external to the firms but internal to the industry. Thus each firm enjoys, or at least makes decisions as if it enjoys, long run constant returns to scale; long run economic profit at the firm level is zero.

Thus we are considering the plausibility of the final maintained hypothesis on the list of those assumed by the replicability argument: that there exist no barriers to entry. A typical counter-example is the agriculture industry, or any industry which faces long run fixity in some factor. The fixity of land or of water in the long run restricts entry by an infinite number of farmers to the agriculture industry. The long-run industry supply curve slopes up, positive "accounting" profits exist, but zero "economic" profits exist; ". . . such a situation could well persist in the long run."[7]

Decreasing Returns to Scale

Typically, positive "accounting" profits in the case of decreasing returns to scale can be interpreted as returns to a factor which has been unaccounted for. (See the above example concerning unallocated returns to management or land ownership opportunity costs.) Jones and Panagariya on the other hand, have developed a model whereby each firm enjoys, or at least makes decisions as if it enjoys, constant returns to scale; diseconomies of scale are external to the firms, but internal to the industry.

One possible interpretation of how this case might arise is the following: "accounting" profits apparent at the industry level, derived from

external diseconomies, are, again, a function of some factor of production external to firms but internal to the industry, in the sense that it is unaccounted for by the firms in their cost calculations. Thus, although entry to the industry is restricted in the long run by fixity in some factor(s), accounting profits encourage entry by new firms, since individual firms do not perceive the factor fixity.

Examples are not difficult to formulate. Consider the Oklahoma Dust Bowl; recall the soil depletion by individual farmers each maximizing individual short-run profit, who failed to perceive soil quality as a resource to which must be allocated "accounting" profit.

Thus, "accounting" profits to the industry can be interpreted as a short run phenomenon preceding, or encouraging, expansion of the number of firms in the industry. In the long run "economic" profits are driven to zero; eventually, the exploitation of the unaccounted resource--in this example, topsoil depth and quality--is internalized by the firms in the industry as a long run cost. (Unfortunately, historically, such unaccounted costs often become apparent to the industry only in retrospect.)

Ungeneralizability of Stolper-Samuelson Beyond the Two-Dimensional Example

So the assumption of constant returns to scale may be relaxed except in the very long run which, when we are considering labor migration, could mean a generation or more. The astute reader will argue that if there is some factor unaccounted for in the model, such as land ownership or management ability, then inclusion of this factor within the model will leave us once again with constant returns to scale. But it is not the apparent existence of decreasing returns to scale which causes the Stolper-Samuelson Theorem to break down, it

is the implicit or explicit presence of a third factor! Stolper-Samuelson cannot be generalized beyond the two-dimensional case.

Using the model developed by Diewert and Woodland (1977) to generalize international trade theory to large numbers of factors and goods, it can be shown that Stolper-Samuelson is fundamentally dependent upon the two-dimensional assumption, and breaks down without it. Perhaps even more worrisome is the fact that no method has yet been developed to analyze the comparative statics of international trade models, like that constructed by Diewert and Woodland, without making the assumption that there exist no produced goods which are non-traded. This means that the assumption that there exist no intermediate goods used as inputs is not made for convenience; Stolper-Samuelson breaks down without it. (For a formal statement of these assertions, see the Mathematical Appendix.)

The Krauss-Neal Explanation of Complementarity

In fact there is some empirical evidence to support the contention that labor migration and trade may in certain circumstances be complementary. Neal (1980) finds correlation between increases in migration of labor and increases in trade within the EEC. Specifically, labor migrations from Italy, Greece, Spain, Portugal, Yugoslavia, Turkey, Morocco and Tunisia to Germany and France were studied. It was found that ". . . increased migration between countries is generally accompained by increased trade." Dr. Neal goes on to theorize that increases in labor migration caused increases in trade, in the direction of increased imports by the labor-sending country. He believes that remittances from "guestworkers" provided the cash necessary to purchase imported items and that exposure to high-wage societies changed the tastes of

the migrant laborers. References are made to Krauss (1976), who shows labor-sending country consumption gains when the labor-intensive good is nontradeable and labor migrates freely (see Figure 1). Consideration of this model, and of its plausibility, follows.

THE KRAUSS MODEL

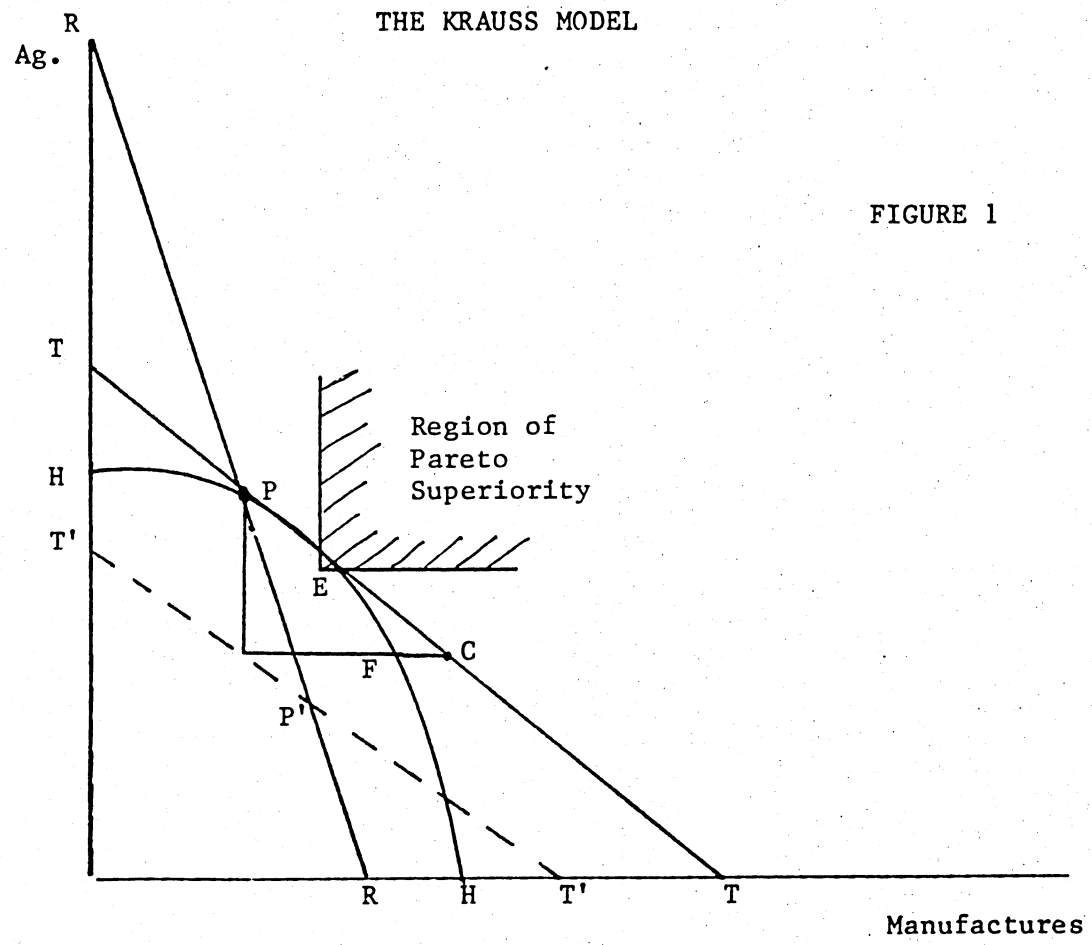

FIGURE 1

HH is the transformation curve. RR, the Rybczynski Line, shows the locus of outputs as the endowment of one factor varies at constant prices. TT are the terms of trade given free trade in both commodities. E is equilibrium under autarky. P is the production point if both goods are tradeable, neither factor is mobile. C is the consumption point given free trade. P' is the production point if only manufactures are tradeable and labor is allowed to migrate, given constant prices (e.g., TT parallel to T'T'). Line segment

P'C represents labor's income earned abroad. Note that gross Domestic Product falls from E to P' in the movement from autarky to labor exportation.

In this model, if remittances equal 100 percent of migrants' wages, then consumption point C is attainable through labor migration. But empirical studies indicate that remittance payments at best average 40 percent of the guestworker's paycheck, tapering off the longer the migrant continues to reside and work away from home.[8] Thus gains from labor migration are a hazy assertion at best. If remittances do not equal or exceed P'F then there exists no Hicks-Kaldor compensating allocation by which consumption gains can be alleged.

Note that labor migration unambiguously decreases GDP, increases imports and decreases production by the industry in which there exists comparative advantage. In this example consumption of imported manufactures increases whereas the agricultural sector suffers.

The results of the Krauss model are based upon assumptions which seem superscilious given the context in which we are speaking. All of the H-O-S assumptions are imposed including constant returns to scale in each industry and identical technologies between countries. Thus comparative advantage accruing from differing marginal productivities is excluded by hypothesis, a questionable assumption about trade between LDC's and developed countries. Then the labor-intensive good is assumed nontradeable, while labor is allowed freedom to migrate. This was manifestly not the case in the EEC, where freer commodity trade accompanied freer migration.

A more subtle, nagging doubt springs from the application of this model to the EEC. The assumption is made that increased imports in labor-sending countries were <u>caused</u> by labor remittances. Neglected is the fact that the

same period was characterized by reductions of import tariffs. Although remittances certainly may have contributed to increased imports, it seems likely that reduced tariffs may have induced increased purchases of imported items by the more affluent classes in labor-sending countries. Whether purchases attributable to remittances account for the majority of the increases in imports is a matter requiring further empirical research. It is hard to conceptualize the more affluent classes as labor migrants.

Complementarity of Trade and Labor Migration

The theoretical results of this paper are that the disparity in wages between countries may be shown to increase upon removal of a tariff, given decreasing returns to scale in production and differing returns to scale between industries. Thus incentives for labor migration may increase through a movement to freer trade. Clearly this is an equally plausible explanation for the correlation which Dr. Neal has observed; correlation obviously cannot imply causal direction.

Regardless of the interpretations as to cause and effect, the Neal study lends empirical evidence to the theoretical results herein. We find that freer commodity trade is <u>not</u> necessarily a substitute for labor migration if technologies differ between countries or if returns to scale differ between industries.

In the case of complementarity of trade and labor migration, we know that factor mobility becomes a necessary condition for factor price convergence towards equalization. Thus the policy prescription to encourage 'trade in place of migration'[9] may be impotent. Often it is argued that in this case barriers to both trade and capital mobility should be removed in order to accomplish factor price equalization.

But it turns out that the removal of a small import tariff may increase incentives for labor migration, yet simultaneously reduce incentives for capital mobility (again, the reader is referred to the numerical example in the Mathematical Appendix). Hence trade barriers may be inextricably linked with issues of factor mobility, and the policy prescription of free trade and capital mobility may prove incapable of achieving its end.

If we are willing to believe that the labor-sending country sustains an overall gain from labor migration, as the Krauss model would suggest, then this might not be such a bad thing. But it should be noted that, given substitutability of factors in production, labor migration will also diminish incentives for foreign capital investment (capital mobility). In the Krauss model, returns to capital equalize, hence incentives for foreign capital investment are nil. Gross Domestic Product unambiguously declines.

Further, the Krauss model assumes that the migration of labor is temporary. In response to short-run phenomena, therefore, the industry of comparative advantage suffers. Certainly a reallocation of internal resources will result from the emigration of the abundant factor. Thus the agricultural sector in Egypt can be expected to become more capital-intensive as a result of labor migration to Saudi Arabia, for example.[10]

But given the assumption that the migration of labor is temporary, this could very well mean longer durations of domestic unemployment if the "guestworker" program is terminated.

Let us say a priori that foreign capital investment is to be desired. If the conditions described above prevail, the recommendation should be to negotiate specific political agreements linking the temporary migration of labor and reduced import tariffs to foreign capital investment.

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Footnotes

[1]Relative labor-abundance is here defined to mean that in a two-dimensional model the relative price of labor to that of, say capital, is less in the labor-abundant country than in the labor-scarce country.

[2]Here it is assumed that tastes do not vary between countries. Certainly it is possible as Robinson (1947) has shown, that comparative advantage may arise due to differences in tastes.

[3]See footnote number 1. Here "freer" trade is taken to mean removal of a small import tariff in a small country. Thus, $\frac{P_1}{(P_2+\tau)} < \frac{P_1}{P_2}$ for $\tau \to 0^+$ where good 1 is exported, and good 2 is produced in a process making relatively intensive usage of the "scarce" factor.

[4]Increasing average costs and free entry are characterized by an infinite number of firms each producing an infinitesimal level of output, an absurdity. (See Varian; 1978, pp. 60-61.)

[5]See Stolper and Samuelson (1941), pp. 73. What is noted is that "diverse patterns of complementarity and competitiveness emerge as possibilities" when there are more than three factors of production in a country, a catalog of which ". . . is outside the scope of (the cited) paper."

[6]It should be mentioned that Krugman (1980) introduced a trade model employing economies of scale in production. In this model wages equalize as a result of trade, but there is some question as to how germane this finding is to our discussion of comparative advantage. Krugman assumes only one factor of production and that industries all have exactly the same production function. Thus comparative advantage accruing from differences in factor marginal productivities is again excluded by hypothesis.

[7]Varian, Ibid.

[8]Martin (1981) points out that "guestworkers" tend to settle and stay in the labor-receiving country; thus remittances tend to taper off the longer the stay.

[9]See ILO, Trade In Place of Migration, 1979.

[10]Empirical support for this conclusion is to be found in Richards and Martin (1981).

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Mathematical Appendix:

(1) Variable Returns to Scale

Panagariya (1980) develops Jones' (1968) variable returns to scale model under the assumption that the industry production function is homothetic:

$$C_i^h(W,y_i) = \frac{h_i(y)}{y_i} \cdot C_i^1(W,y_i),$$

given production function $y_i = h_i^{-1}(f_i(x^i))$ where f_i is concave and homogeneous of degree one in inputs x; h^{-1} is monotonic and concave.

For the numerical example which follows:

let $y_i = [a_1x_1^P + (1-a_1)x_2^P]^{1/P \frac{1}{1-\varepsilon}}$

$-\infty < P \leq 1 \Rightarrow$ CES production function

$-\infty < \varepsilon < 0 \Rightarrow$ decreasing returns to scale

$0 < \frac{1}{1-\varepsilon} < 1$

then

$$y^{P(1-\varepsilon)} = a_1x_1^P + (1-a_1)x_2^P.$$

Consider

$$h(P) = \frac{y^{e(1-\varepsilon)} - a_1x1^P - (1-a_1)x_2^P}{P}$$

as $P \to 0$. Thus the production function will be of the Cobb-Douglas gender.

By L'Hopital's Rule.

$$\lim h(P) = (1-\varepsilon)y^{P(i-\varepsilon)} \frac{\ln y - a_1\ln x_1 - (1-a_1)\ln x_2}{1}$$

$$= (1-\varepsilon)\ln y - a_1\ln x_1 - (1-a_1)\ln x_2$$

$$\Rightarrow y^{(1-\varepsilon)} = x_1^{a_1} x_2^{(1-a_1)}$$

$$y = x_1^{\frac{a_1}{(1-\varepsilon)}} \; x_2^{\left(\frac{1-a_1}{1-\varepsilon}\right)} \quad ; \text{ flexible.}$$

Note: $\frac{a_1}{1-\varepsilon} + \frac{1-a_1}{1-\varepsilon} < 1.$

(2) Numerical Example

Suppose country A and country B have identical production functions:

$$y^1 = (x_1^1)^{1/2} \; (x_2^1)^{1/4}$$

$$y^2 = (x_1^2)^{3/8} \; (x_2^2)^{1/2}$$

(where superscripts denote the industry, and subscripts denote the factor.) Suppose tastes are identical and prices are determined exogenously. Country A enjoys comparative advantage in production of y^2 and country B in production of y^1:

$$P^A = (2, 5/3) \qquad P^B = (3/2, 3)$$

Let factor endowments vary:

For A: $x_1 = 3, x_2 = 6$
For B: $x_1 = 6, x_2 = 3$

where x_1 = capital
x_2 = labor

Given autarky, first order conditions for country A are:

$$\frac{(x_2^1)^{1/4}}{(x_1^1)^{1/2}} = W_1 \qquad \frac{1(x_1^1)^{1/2}}{2(x_2^1)^{3/4}} = W_2$$

$$\frac{15(x_2^2)^{1/2}}{16(x_1^2)^{5/8}} = W_1 \qquad \frac{5(x_1^2)^{3/8}}{4(x_2^2)^{1/2}} = W_2$$

$\Rightarrow$ $x_1^1 \cong 0.36417$ $\qquad W_1^A \cong 1.222$

$x_2^1 \cong 0.2955534$ $\qquad W_2^A \cong 0.758$

$x_1^2 \cong 2.63583$

$x_2^2 \cong 5.7044466$

First order conditions for country B under autarky:

$$\frac{3(x_2^1)^{1/4}}{4(x_1^1)^{1/2}} = W_1 \qquad \frac{3(x_1^1)^{1/2}}{8(x_2^1)^{3/4}} = W_2$$

$$\frac{9(x_2^2)^{1/2}}{8(x_1^2)^{5/8}} = W_1 \qquad \frac{3(x_1^2)^{3/8}}{2(x_2^2)^{1/2}} = W_2$$

$\Rightarrow$ $x_1^1 \cong 0.340$ $\qquad W_1^B \cong 0.652$

$x_2^1 \cong 0.0660852$ $\qquad W_2^B \cong 1.677$

$x_1^2 \cong 5.660$

$x_2^2 \cong 2.9339148$

given trade, suppose P* = (7/4, 11/4), a simple average of autarchic prices.

Then first order conditions for both countries are:

$$\frac{7(x_2^1)^{1/4}}{8(x_1^1)^{1/2}} = W_1 \qquad \frac{7(x_1^1)^{1/2}}{16(x_2^1)^{3/4}} = W_2$$

$$\frac{33(x_2^2)^{1/2}}{32(x_1^2)^{5/8}} = W_1 \qquad \frac{11(x_1^2)^{3/8}}{8(x_2^2)^{1/2}} = W_2$$

$\Rightarrow$ for A:

$x_1^1 \cong 0.15845$ $\qquad W_1^A \cong 1.301$

$x_2^1 \cong 0.1228617$ $\qquad W_1^A \cong 0.839$

$x_1^2 \cong 2.84155$

$x_2^2 \cong 5.8771383$

=> for B:

$x_1^1 \cong 0.8107$ $\quad W_1^B \cong 0.620$

$x_2^1 \cong 0.1660325$ $\quad W_2^B \cong 1.514$

$x_1^2 \cong 5.1893$

$x_2^2 \cong 2.8339675$

Thus relative wage to the "scarce" factor has decreased in each country as a result of the movement from autarky to free trade:

$\frac{W_1^A}{W_2^A} \cong 1.612$ $\quad \frac{W_2^B}{W_1^B} \cong 2.572$ under autarky;

$\frac{W_1^A}{W_2^A} \cong 1.550$ $\quad \frac{W_2^B}{W_1^B} \cong 2.442$ given free trade,

as per the Stolper-Samuelson theorem.

Now, suppose country B, a small country, levies a small import tariff on good y_2 such that $P_*^B = (7/4, 23/8)$. Then,

f.o.c.B

$\frac{7(x_2^1)^{1/4}}{8(x_1^1)^{1/2}} = W_1$ $\quad \frac{7(x_1^1)^{1/2}}{16(x_2^1)^{3/4}} = W_2$

$\frac{69(x_2^2)^{1/2}}{64(x_1^2)^{5/8}} = W_1$ $\quad \frac{23(x_1^2)^{3/8}}{16(x_2^2)^{1/2}} = W_2$

=> $x_1^1 \cong 0.6952$ $\quad W_1^B \cong 0.642$

$x_2^1 \cong 0.1405247$ $\quad W_2^B \cong 1.589$

$x_1^2 \cong 5.3048$

$x_2^2 \cong 2.8594753$

Thus $\frac{W_1^B}{W_2^B} \cong 0.404$, representing a deterioration in labor's share (the abundant factor), as we would expect by the Stolper-Samuelson theorem.

Note, however, that absolute wages have not changed in accordance with relative wages:

$$\text{Sign} \begin{bmatrix} \frac{\partial W_1}{\partial P_2} \\ \\ \frac{\partial W_2}{\partial P_2} \end{bmatrix} = \begin{bmatrix} + \\ \\ + \end{bmatrix}$$

Furthermore, the gap between wages paid to labor in the two countries narrows, yet the gap between returns to capital widens:

$$\frac{W_1^B}{W_1^A} \cong 0.476 \qquad \frac{W_2^A}{W_2^B} \cong 0.554 \qquad \text{under free trade}$$

$$\frac{W_1^B}{W_1^A} \cong 0.493 \qquad \frac{W_2^A}{W_2^B} \cong 0.528 \qquad \text{given tariff on } y_2$$

(converges) (diverges)

Thus incentives for labor migration increase and incentives for foreign capital investment diminish when a tariff on the import of y_2 is removed.

(3) Ungeneralizability of Stolper-Samuelson beyond the Two-Dimensional Case: (The following is a simplified version of Diewert and Woodland (1977).)

Consider Figure 2. Given constant returns to scale, the expansion path of each industry in input space will be simply a ray passing through the origin, such as the ray OB' or OD'. Thus, the maximum output given any cost constraint will be exactly the output which would be obtained through maximization of a linear programming problem. Thus international trade models

DECREASING RETURNS TO SCALE.

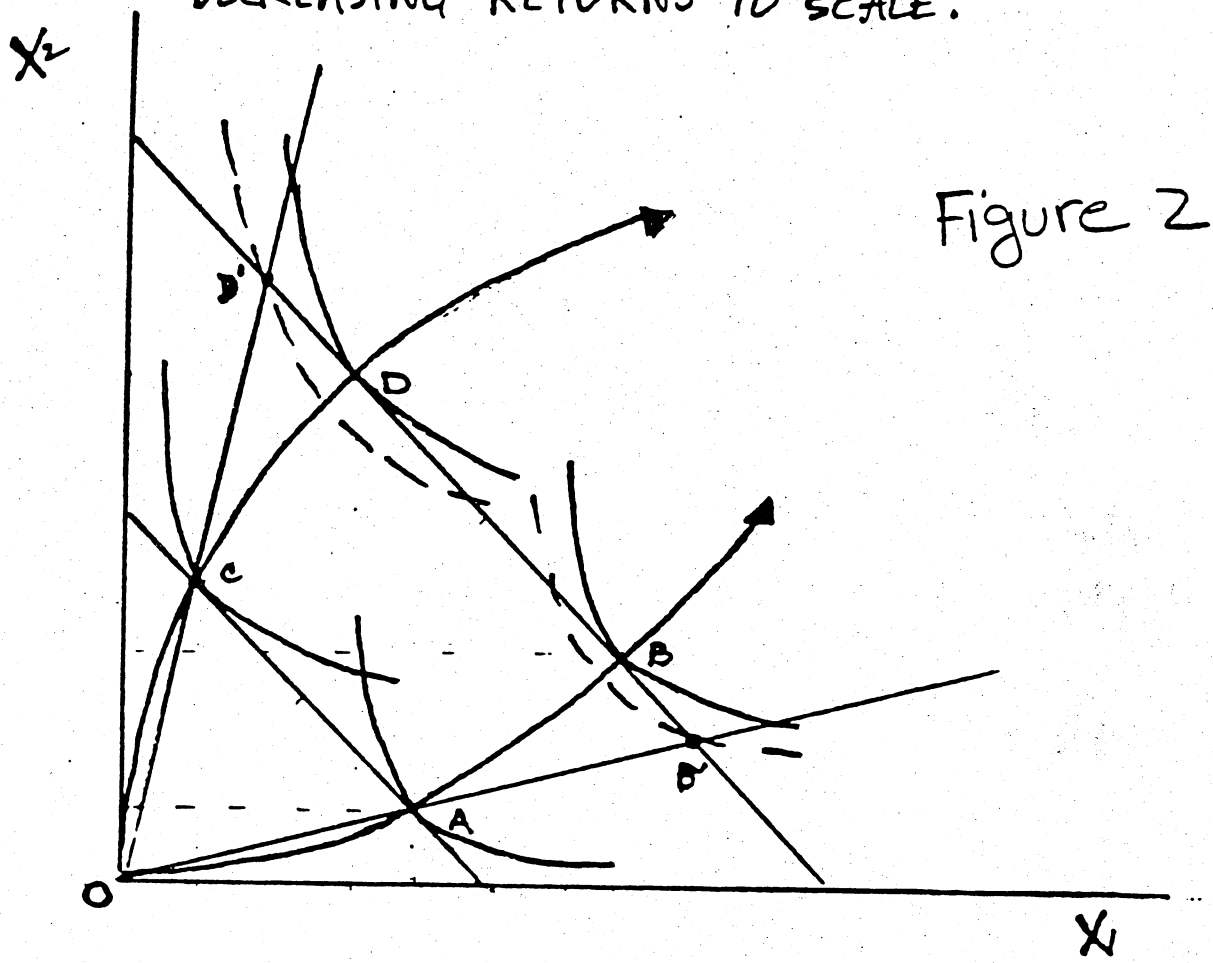

Figure 2

A → B represents a doubling of costs and output, industry y¹.
A → B′ represents a doubling of inputs, but does not accomplish a doubling of output.

C → D represents a doubling of costs and output, industry y².
C → D′ represents a doubling of inputs, but does not accomplish a doubling of output.

can be generalized using a technique analogous to linear programming, given constant returns to scale. This is the approach which is followed below.

Define:

$Y = (y_1,\ldots,y_K)'$ internationally traded commodities;

$p = (p_1,\ldots,p_K)'$ prices of those commodities;

$X = (x_1,\ldots,x_N)'$ nontraded commodities or "factors;"

$v = (v_1,\ldots,v_N)'$ vector of "factor" endowments;

$w = (w_1,\ldots,w_N)'$ wages to "factors;"

$z = (z_1,\ldots,z_N)'$ activity levels for each of M industries;

$A' = (a^1,\ldots,a^M)_{(NxM)}$ matrix of input coefficients;

$B' = (b^1,\ldots,b^M)_{(KxM)}$ matrix of input-output coefficients;

where $B'z = Y$ is defined as net output, $A'z = X$ is "factor" demand, and

$$a^m = \begin{bmatrix} a^{1m}(w) \\ \vdots \\ a^{Nm}(w) \end{bmatrix} \qquad b^m = \begin{bmatrix} b^{1m}(w) \\ \vdots \\ b^{Km}(w) \end{bmatrix} \qquad m = (1,\ldots,M) \text{ activities.}$$

Here the dependence of input coefficients and input-output coefficients is solely upon wages, due to constant returns to scale; and this argument is dropped for simplicity of notation. We can write the primal and dual problems, using notation analogous to linear programming:

Max $p'B'z$

s.t. $A'z \leqq v$, $z \geqq 0$

Min $w'v$

s.t. $Aw \geqq Bp$, $w \geqq 0$

We can write the Lagrangean expression for the dual problem and derive Kuhn-Tucker conditions:

$L = w'v + z'(Bp - Aw)$

$$v - A'z \geqq 0 \qquad w'(v - A'z) = 0 \qquad z \geqq 0$$

$$Bp - Aw \leqq 0 \qquad z'(Bp - Aw) = 0 \qquad w \geqq 0$$

Thus, if $w >> 0$ then $v - A'z = 0$, and if $z >> 0$, then $Bp - Aw = 0$ (or if $z_m > 0$ then $b^{m\prime}p - a^{m\prime}w = 0$). These results establish factor clearance and zero profitability, respectively.

By duality, if there exists a feasible vector Y, then there exists a solution $(\overline{Y},\overline{w})$ if and only if $p'\overline{Y} - \overline{w}'v$.

For the purposes of comparative statics, it is necessary at this point to impose M = K. Diewert and Woodland never acknowledge this explicitly, but they nevertheless have imposed this assumption, since they have derived a square (MxM) matrix through the differentiation operation $B \frac{\partial P}{\partial Z}$, which implies M = K for simple conformability. (See pp. 385, op. cit.) This assumption is equivalent to requiring that no goods are produced which are not internationally tradable, a rather stringent imposition.

Total differentiation of the binding constraints from above yields the following system:

$$\begin{bmatrix} \sum_{i=1}^{N} \frac{\partial v^i}{\partial w'} & \frac{\partial v}{\partial z'} \\ A\frac{\partial w}{\partial w'} & B\frac{\partial P}{\partial z'} \end{bmatrix} \begin{bmatrix} dw \\ dz \end{bmatrix} = \begin{bmatrix} \frac{\partial v}{\partial v'} & -\sum_{i=1}^{N} \frac{\partial v^i}{\partial P'} \\ B\frac{\partial P}{\partial v'} & B\frac{\partial P}{\partial P'} \end{bmatrix} \begin{bmatrix} dv \\ dP \end{bmatrix},$$

an application of Shephard's Lemma. Thus

$$\begin{bmatrix} S_{ww} & A' \\ A & 0 \end{bmatrix} \begin{bmatrix} dw \\ dz \end{bmatrix} = \begin{bmatrix} I & -S_{wp} \\ 0 & B \end{bmatrix} \begin{bmatrix} dv \\ dp \end{bmatrix}$$

where the zero matrices are due to constant returns to scale and/or the assumption of a small country; and S_{ww}, S_{wp} are matrices of factor-to-factor and factor-to-internationally traded commodity substitution terms, respectively.

Also note that, since $A \equiv A(w)$ is not dependent upon z, by the assumption of constant returns to scale, we can write $\frac{\partial v}{\partial z'} = A' \frac{\partial z}{\partial z'} = A'$.

If $B = I$ and $S_{wp} = 0$, we get:

$$\begin{bmatrix} S_{ww} & A' \\ A & 0 \end{bmatrix} \begin{bmatrix} dw \\ dz \end{bmatrix} = \begin{bmatrix} dv \\ dp \end{bmatrix}, \text{ where } \begin{bmatrix} S_{ww} & A' \\ A & 0 \end{bmatrix}^{-1} \text{ exists only if}$$

$N \geq M$, due to the troublesome zero matrix, since S_{ww} is a singluar matrix.*

By these assumptions we require that no outputs are employed as inputs and that the number of "factors" exceed or equal the number of commodities produced. If we further impose $M = N$, then we have:

$$\begin{bmatrix} dw \\ dz \end{bmatrix} = \begin{bmatrix} 0 & A^{-1} \\ (A')^{-1} & -(A')^{-1} S_{ww} A^{-1} \end{bmatrix} \begin{bmatrix} dv \\ dp \end{bmatrix} = \begin{bmatrix} \frac{\partial w}{\partial v'} & \frac{\partial w}{\partial p'} \\ \frac{\partial z}{\partial v'} & \frac{\partial z}{\partial p'} \end{bmatrix} \begin{bmatrix} dv \\ dp \end{bmatrix}$$

*S_{ww} is singular by Euler's Expansion, the fact that the cost functions are homogeneous of degree 1 in w, and assuming $w >> 0$. Thus $S_{ww} w = 0 \Rightarrow$ rank $(S_{ww}) < N$.

In the 2 factors, 2 sectors, 2 internationally traded goods case (e.g., if $N = M = K = 2$), if reversals of factor intensity in production are prohibited and factor i is employed relatively intensively in sector i, i = (1,2), then det $A > 0$, and

$$\text{sign } \frac{\partial w}{\partial p'} = \text{sign } \frac{\partial z}{\partial v'} = \begin{bmatrix} + & - \\ - & + \end{bmatrix}$$

(e.g., the Stolper-Samuelson and Rybczynski theorems, respectively.)

Furthermore, we have $S_{ww} =$

$$\begin{bmatrix} \frac{\partial^2 C^1}{\partial w_1 \partial w_1} + \frac{\partial^2 C^2}{\partial w_1 \partial w_1} & \frac{\partial^2 C^1}{\partial w_1 \partial w_2} + \frac{\partial^2 C^2}{\partial w_1 \partial w_2} \\ \frac{\partial^2 C^1}{\partial w_2 \partial w_1} + \frac{\partial^2 C^2}{\partial w_2 \partial w_1} & \frac{\partial^2 C^1}{\partial w_2 \partial w_2} + \frac{\partial^2 C^2}{\partial w_2 \partial w_2} \end{bmatrix}$$

By concavity of the cost functions, and assuming that there exists at least some substitutability between factors in production, we have:

$$\text{sign } S_{ww} = \begin{bmatrix} - & + \\ + & - \end{bmatrix} \quad \text{which implies sign } -(A')^{-1} S_{ww} A^{-1} = \begin{bmatrix} + & - \\ - & + \end{bmatrix}$$

(e.g., the Law of Supply). Finally, for small changes, we have $\frac{\partial w}{\partial v'} = 0$, (e.g., the Factor-Price Equalization Theorem).

On the other hand, if $N = M = K > 2$ then even if all of the other assumptions are imposed, we can say only that $\frac{\partial w}{\partial p'}$ and $\frac{\partial z}{\partial v'}$ are positive semi-definite matrices. Hence the absolute wage to the "abundant" factor may decrease as the result of a movement from autarky to free trade (as in the numerical example); that is we can say nothing about the sign of $\frac{\partial w_i}{\partial p_j}$, $i \neq j$.

Thus the Stolper-Samuelson and Rybczynski theorems do not necessarily hold except in the two-dimensional case, meaning that the implications derivable from them are not generalizable.