Purvis, Douglas D.

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TECHNOLOGY, TRADE AND FACTOR MOBILTY

DOUGLAS D.PURVIS
Queen's University and University of Chicago

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

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TECHNOLOGY, TRADE, AND FACTOR MOBILITY

BY

DOUGLAS D. PURVIS

University of Chicago
and
Queen's University

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The well-known factor price equalization theorem is often invoked to provide trade theorists with justification for the conventional--and often convenient--assumption of complete international immobility of factors of production. If conditions of the theorem are satisfied, and free trade does in fact give rise to the equalization of factor returns, then it is inconsequential in which country production takes place--factors may be relocated without disturbing (or increasing) the productive efficiency of the equilibrium. Mundell's original analysis (7) then brings us full circle to the "commodity price equalization theorem": If the conditions of the factor price equalization theorem are met, but a tariff on trade is imposed, then factor mobility can replace trade in establishing productive efficiency. Further, one factor completely internationally mobile is sufficient to restore the identical equilibrium as existed in the free trade, no factors mobile case. Free trade and factor mobility are perfect substitutes![1]

Recent work by Jones (4) and Kemp (6) have analyzed further the implications of introducing factor mobility--and in particular capital mobility--into the analysis of international trade. However, these have concentrated on generating optimum tariff and tax (on capital services) formulae for the individual country trying to maximize its own welfare. The present paper is more in the tradition of the Mundell analysis in that we are more concerned with world efficiency in production--that is, in maximizing potential world welfare.

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[1] This must be qualified to the extent that international payments for factor services are subject to the impediments to trade that led initially to the factor movement. See also the demand issue raised by Olivera (9) that arises when labor is the mobile factor.

However, the conditions under which the perfect substitute relationship between free trade and factor mobility holds are indeed quite stringent.[1] Even if we accept the two-good, two-factor, constant returns to scale framework of the factor price equalization theorem, the remaining assumptions of that theorem are subject to considerable criticism. Contemporary opinion seems to hold that the assertion of identical technologies as between countries is too restrictive, and not representative of the "real world."[2] Further, recent work by Johnson (3), and Stiglitz (10), in the context of growth, Melvin (7) in considering increasing returns to scale in production, and Jones (5) in the context of relaxing the identical technologies assumption, has argued that complete specialization in production by one country is not an unusual or unexpected case.

This note is an attempt to set out a simple model of production and trade in which the original analysis of Mundell can be viewed, but in which the implications of complete specialization in production and relaxing the identical technologies assumption can easily be viewed.

In Section I we retain the identical technology assumption in order to explicitly treat the complete specialization case. Not surprisingly, we find that if free trade gives rise to one country being completely specialized in production, then factor mobility is superior to free trade. In Section II, we relax the identical technology assumption, and find that free trade and factor mobility may not be substitutes, but may in fact be complements in the sense that the introduction of factor mobility into a free trade situation may increase the level of trade in the final position.

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[1] See Mundell (8) for an explicit statement of the conditions.

[2] For an excellent discussion of this issue, see Amano (1). See also the two papers by Jones (4), (5).

Assume two countries, A and B, producing two final goods, X and Y under conditions of constant returns to scale, using two homogeneous factors of production, capital and labor. The production of X is assumed to be relatively labor intensive at all possible factor price ratios.[1] Country A is assumed to be abundant in its physical endowment of capital relative to B, i.e. $(K/L)_a > (K/L)_b$.

I. Specialization and the Gains from Factor Mobility

Retaining the identical technology assumption, and assuming no perverse demand behavior, we note that Country A is relatively abundant in its endowment of capital in terms of pre-trade factor prices, that is, in autarcky $(w/r)_a > (w/r)_b$, so that the introduction of trade would lead A to export Y and import X. The world production possibility set can be constructed by inverting B's autarky production set and sliding it along that of A, as is done in Figure 1. Alternatively, this procedure can be viewed as summing the output vectors of each country at all possible common price ratios. With no factor mobility, the world production possibility set is M'HJN', where OM' equals 0_aX_a plus 0_bX_b and ON' equals 0_aY_a plus 0_bY_b. In the region HJ both countries produce both goods--there is incomplete specialization--and factor prices will be equalized if demand conditions give rise to an equilibrium in this region. In this region, impediments to trade stimulate factor movements, and the analysis presented by Mundell follows directly. Then, if we abstract from the difficulties of tastes changing due to new environments as factors move (see Olivera (9)), it follows that in this region factor-mobility and

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[1] Throughout, capital refers to real, or physical capital. We are abstracting from the possibility of a factor intensity reversal in either country.

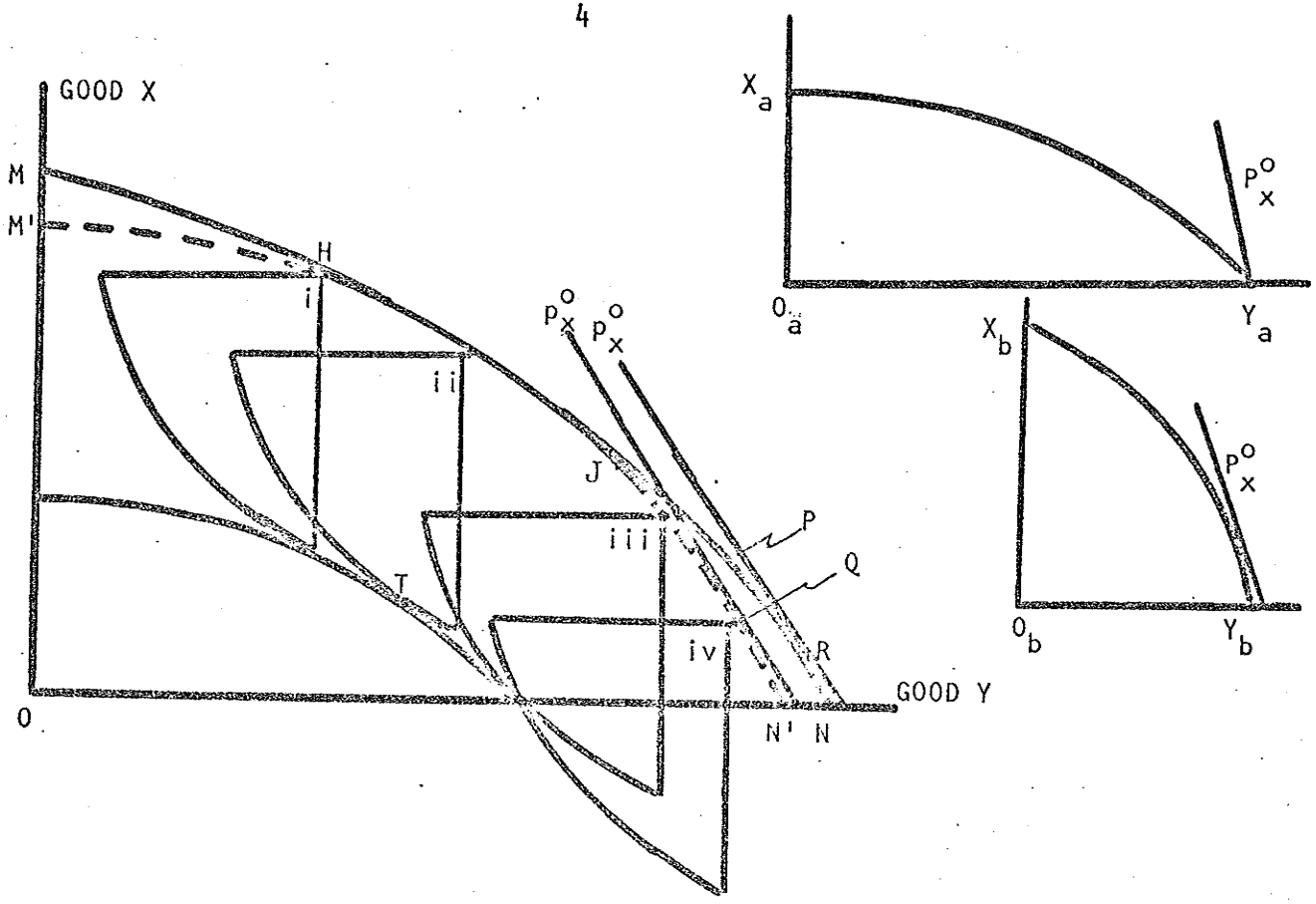

FIGURE 1

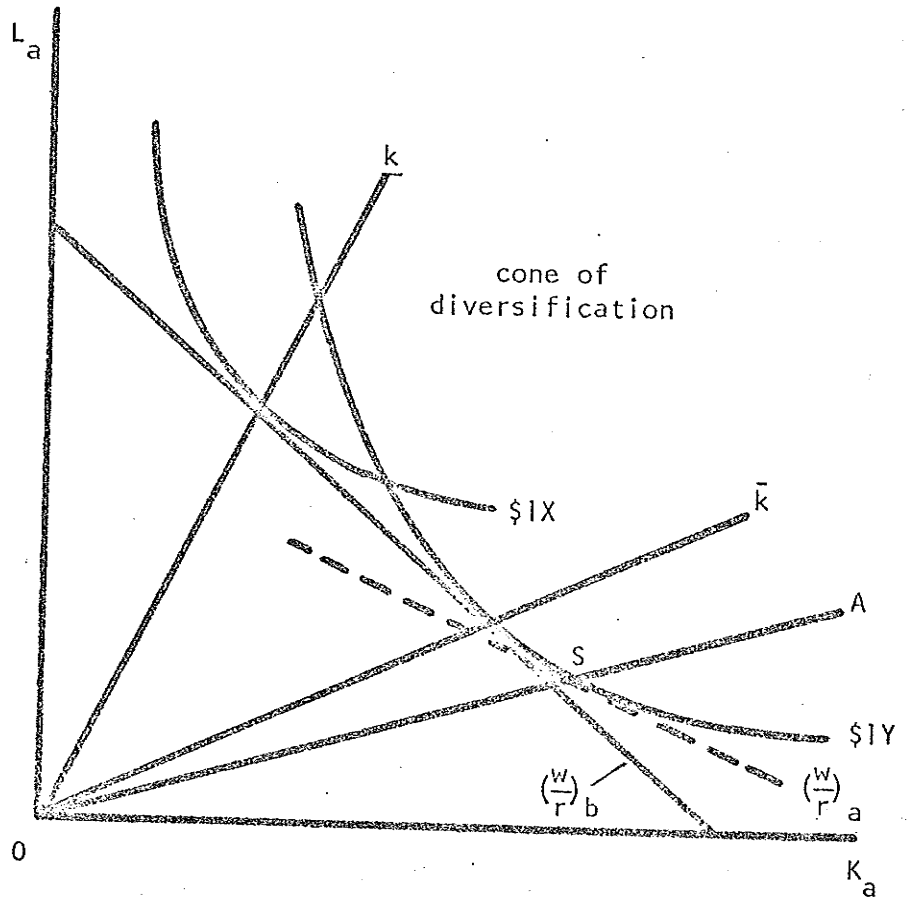

FIGURE 2

free-trade are perfect substitutes. Then in this region, it doesn't matter in which country production takes place--a movement in the capital stock at constant prices will not alter world production as long as both countries continue to produce both goods.

However, the regions M'H and JN' are regions of inefficiency--along M'H country B specializes in the production of X, and along JN' country A specializes in the production of Y. If either, or both, factors become mobile, they will move until marginal products are equalized. This, in turn, will cause the world production set to expand to MHJN in Figure 1. All points on MHJN are efficient in the sense that a free trade equilibrium anywhere on MHJN will result in the equalization of factor rewards.

Without loss of generality we can consider the case where A specializes in the production of Y, such as at Q in Figure 1. Q is the free trade, factors immobile equilibrium when demand conditions are such that the equilibrium price ratio is p_X^o. At Q, the marginal product of capital in A is less than that in B, and the marginal product of labor in A is higher than in B; then, there is incentive for capital to move from A to B, and for labor to move from B to A. Regardless of which factor moves, if prices are held constant at p_X^o, the Rybczynski theorem tells us that a new equilibrium will be established at R, with absolutely less X produced than at Q.[1] If neither good is inferior in world consumption, then noting that world income has risen the new equilibrium will be at, say, P, where more of each good is consumed, and where the relative price of X, p_X, has risen.

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[1] In the final equilibrium, A will continue to specialize, at the margin, in the production of Y, while the Rybczynski theorem tells us that with either a capital inflow or a labor outflow, B will produce absolutely less X. Hence, world output of X falls at constant prices.

Following Mundell, we consider only the capital mobile case. We assume that the owners of capital do not relocate with a capital flow, and that payments for the services of capital are freely transported to the owner in the country of origin.

The pre-outflow situation in Country A is at S in Figure 2, which is just the familiar unit value isoquant diagram. Capital will flow out until the endowment ray OA is contiguous with $O\bar{k}$ at which time A will be producing efficiently, although still specializing in production of Y. (Note that as p_x rises, $O\bar{k}$ swings down, and less capital flows out than in the prices constant case.)

The gains from the factor relocation can be viewed in two stages--those accruing at constant prices, and then those due to the terms of trade effect. At constant prices--the movement from Q to R--country B is unaffected. Hence all the gains from the efficiency effect accrue to country A. Moreover, the capital-labor ratio in A has fallen, so A labor loses. Therefore all the gains from the efficient reallocation of resources accrue to A capital, and A capital gains further at the expense of A labor.

The terms of trade effect refers to the movement from R to P, the increase in p_x serving to increase the return to labor in both countries--this is the familiar Stolper-Samuelson relationship. The increase in p_x represents an improvement in B's terms of trade, since by construction B must export X, and hence potential welfare in B unambiguously increases. Potential welfare in A may rise or fall--production is now efficient but the terms of trade have deteriorated.[1] Capital owned by A must gain and labor in A must lose; precisely the opposite of the distribution of gains to factors in B.

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[1] If labor were the mobile factor, it would not be possible to identify a country before and after the factor flow, and such statements about potential welfare from a country's viewpoint would not be meaningful.

II. Technology Differences between Countries

Now, consider relaxing the identical technologies assumption, but for simplicity continue to assume that the production of X is relatively labor intensive at all possible factor price ratios in both countries. Further, following Inada and Kemp (2), assume that there is some common commodity price ratio, p_X^* say, consistent with incomplete specialization for which the return to capital is equalized.[1] The world transformation curve with no factor mobility can be derived as in Figure 1, and the free trade situation can be analyzed as before, noting that in general--i.e., unless free trade gives rise to p_X^*--factor prices will not be equalized. In order to concentrate on technology differences, we initially assume that preferences are identical and homothetic, and hence we can construct world indifference curves. This is not as restrictive as it first appears; we are concerned with world productive efficiency, and hence with potential world welfare.

As Jones [5] argues, the introduction of technology differences leads to Ricardian modifications to the standard Heckscher-Ohlin theory of comparative advantage. Now it is possible for the labor abundant country B to import the labor intensive commodity X if country A had a technological advantage in producing X. That is, it is possible in autarky for labor to be relatively cheap in B while the labor intensive good is relatively expensive.

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[1] This assumption in effect makes the analysis more general inasmuch as it allows us to treat cases of both complete and incomplete specialization. If no such p_X^* existed, the comments concerning the linear segment of JJ' in Figure 3 would not be applicable. Since we are concerned primarily with demonstrating that a case can be constructed where factor mobility increases rather than eliminates trade, we do not undertake a rigorous specification of the technology differences. The interested reader is referred to the excellent discussion by Jones (5), pp. 78-81. Jones (5) cites an unpublished paper by John Chipman which he credits with the original analysis of the linear segment. [The assumption of no factor intensity reversal as between countries is made for simplicity, but is in no way crucial to the analysis.]

Consider now the no-factors-mobile world transformation curve FF' in Figure 3, and let W be the point on FF' which corresponds to p_x^*, and G and G' correspond to initiation of specialization in one country.[1] At W world production is efficient in the sense that no more of either good can be obtained without giving up some of the other good, even if a capital relocation is induced.

To see this, consider an exogenous transfer of capital from country A to B, holding p_x constant at p_x^*. Production in A will contract along a Rybczynski-line such that more X and less Y will be produced, and conversely for the expansion in B's production. Factor returns will be unchanged along the R-lines, and hence the return to capital will still be equalized. That factor rewards are unchanged means, of course, that world income in terms of either good is unchanged.

However, the R-lines will not, in general, be parallel.[2] We consider the case where the R-line in A is steeper than that in B--see Figure 4--and the above experiment leads to an increase in world output of X and a fall in Y. Production goes to H in Figure 3, and to H_a and H_b in Figure 4 where the new transformation curves are omitted for simplicity. Since income has not changed, demand conditions are unchanged, and the above experiment increases the excess supply of X and decreases that of Y.[3]

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[1] Note that now one country may specialize at both G and G'.

[2] In the n^{th} country, we have:

$$dX^n = \frac{-a^n_{LY}}{\Delta_n}\,dK;\quad dY^n = \frac{a^n_{LX}}{\Delta_n}\,dK;\quad \text{and}\quad (dX/dY)_n = -\frac{a^n_{LY}}{a^n_{LX}} < 0$$

where $\Delta_n = a^n_{LX}a^n_{KY} - a^n_{KX}a^n_{LY} > 0$ and where a^n_{ij} is the input-output coefficient which, in general, varies with n. Hence all four values above will, in general, differ between A and B.

[3] By Walras' Law, the sum of the excess supplies is zero. If the initial position W was one of equilibrium, then the experiment generates an excess supply of X and an excess demand for Y.

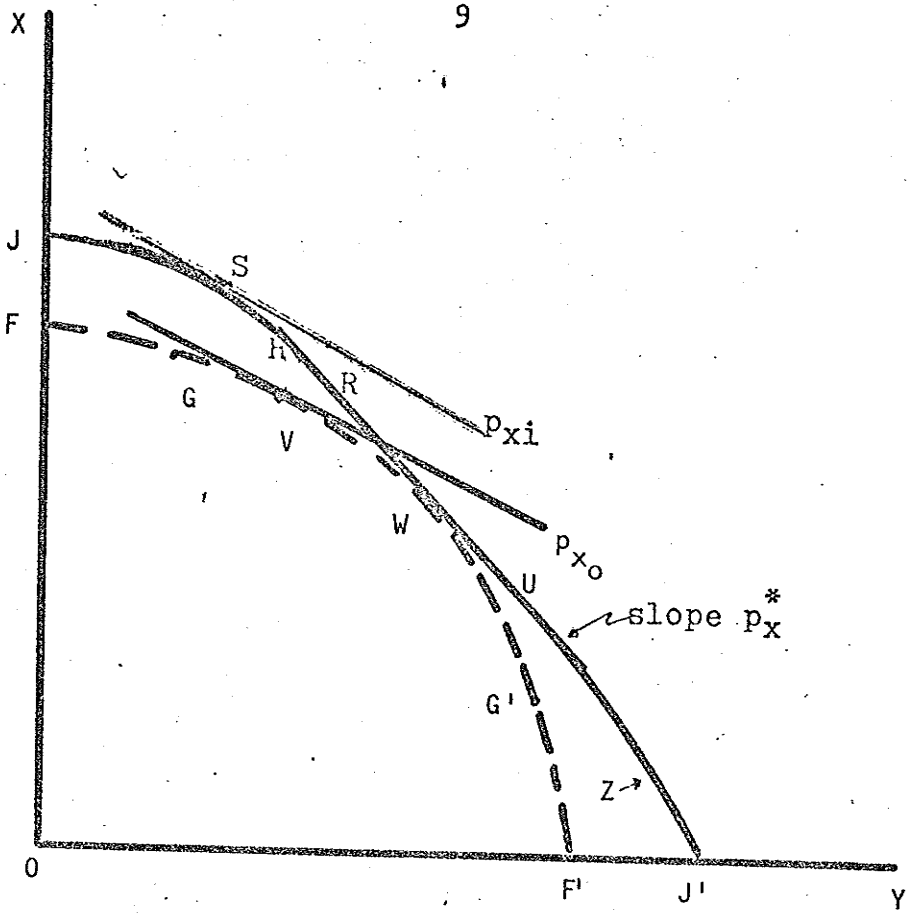

FIGURE 3

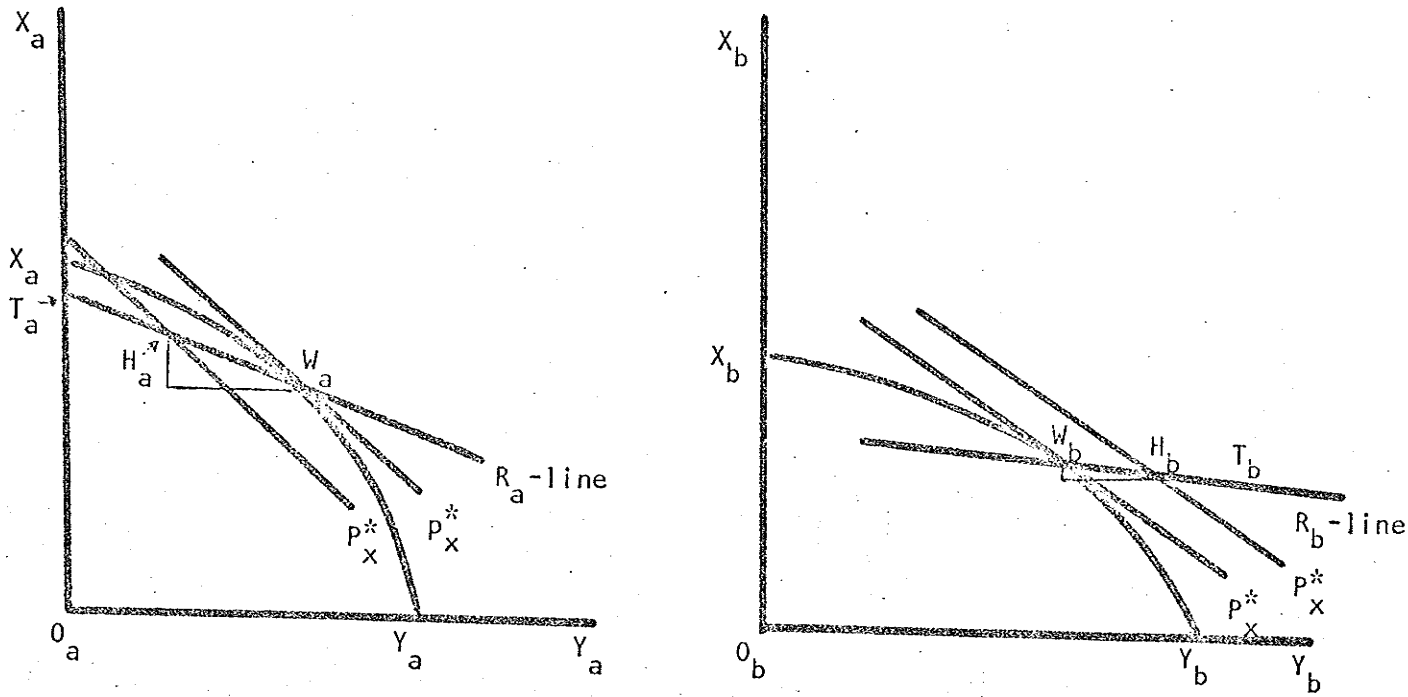

FIGURE 4

By considering similar experiments but of varying magnitude and direction of shift in the capital stock, we can trace out the capital-mobile production possibility set JJ' in Figure 3. Given p_x^*, as long as the capital movements are not sufficient to bring about complete specialization in either country, outputs of X and Y will change in a fixed ratio. Hence JJ' will be characterized by a linear segment representing a continuum of output combinations consistent with p_x^* for various allocations of the world capital stock. The fact that world income is unchanged is sufficient to establish that the slope of the linear segment is p_x^*![1]

If enough capital moves from A to B to cause A to be specialized in the production of X (positions T_a and T_b in Figure 4), any further shift will necessitate a rise in p_x for production equilibrium. Similarly, if enough capital moves from B to A, one country will be driven to specialize in Y, and further shifts would necessitate a fall in p_x. Hence the curved sections of JJ' correspond to cases of one country specialized in production.[2] Equilibrium, of course, will be determined by the tangency of a world indifference curve with JJ'.

Trade and Factor Mobility as Complements

Now, dropping the assumption of identical tastes as between countries, consider the case where free trade gives rise to production at V on FF', with p_{xo} greater than p_x^*. Assume that at V, the marginal product of capital in A

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[1] I am indebted to Michael Mussa for discussion on this point. Note that the horizontal shifts in the price curves tangent to the production possibility sets must be equal and offsetting. As in Section I, the outer locus (JJ') is the envelope of all loci FF' for all possible allocations of the world capital stock. The existence of many price ratios such as p_x^* implies many linear segments, the limit being a continuous curve as in Figure 1.

[2] It is this which makes specialization such an important case when technologies differ--any equilibrium price ratio other than p_x^* leads to one country specializing completely.

(MP_{ka}) is less than in B--then there is incentive for a capital flow from A to B, which, in the present case, would increase output of X; thereby creating an excess supply of X at p_{xo}. Equilibrium occurs when the return to capital is equalized, and is achieved by the fall in p_x caused by the excess supply of X. This gives rise to a new equilibrium at either R, say, with p_x equal to p_x^* if that price is achieved before A specializes, or at S with $p_{xi} > p_x^*$ if A achieves complete specialization. (If at V, $MP_{ka} > MP_{kb}$, equilibrium would be at either U or Z, again depending on whether complete specialization is achieved.)

In Figure 5 we illustrate this case, where $MP_{ka} < MP_{kb}$, again omitting the second transformation curves for simplicity. Initially, A produces at V_a and consumes at C_a, while B is at V_b and C_b, with $p_x = p_{xo}$. After the new equilibrium is achieved at R, A is at R_a and C_a', and B is at R_b and C_b', with MN in interest payments made from B to A. Trade is balanced before and after the capital flow, but the volume of trade is larger after the capital flow. Trade and factor mobility are complements! If A had achieved specialization, and equilibrium were at S with p_{xi}, production would be at S_a and S_b, and the complementarity would still be possible.

It is essential to note that this complementarity is not a necessary result of differing technologies, only a possible one. A necessary condition for complementarity is that the initial capital outflow generates an excess demand for imports and an excess supply of exportables at constant terms of trade.

In the present case, the capital abundant country A is initially exporting the labor intensive good X, so A must have a strong technological advantage in the production of X. At constant p_x, the capital outflow leaves income unchanged so demands in A are unchanged. By by the Rybczynski theorem,

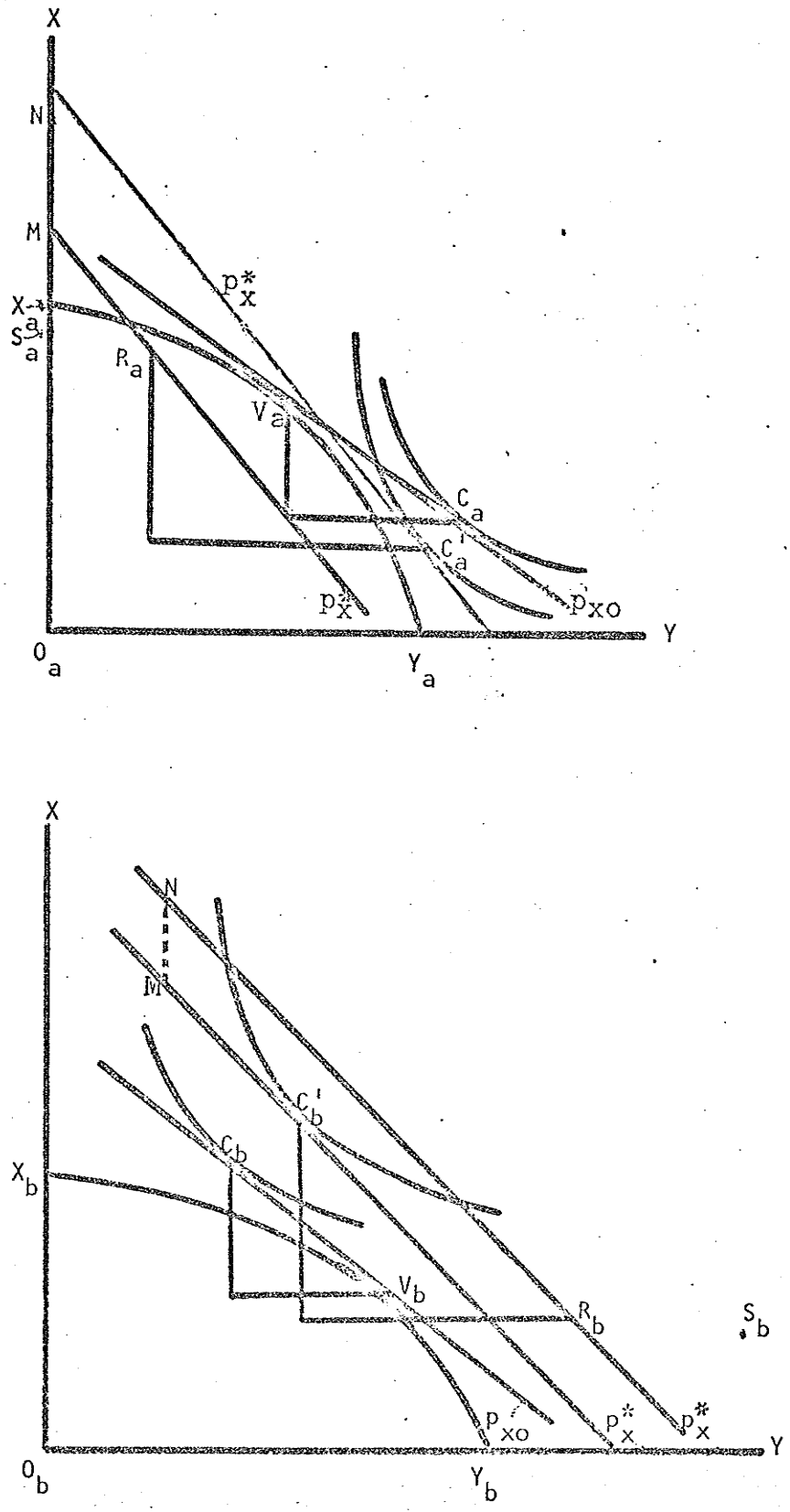
X
N
M
X_a
S_a
R_a
V_a
p_x^*
C_a
C_a'
p_{xo}
Y
0_a
Y_a
X
N
M
C_b'
C_b
X_b
V_b
R_b
S_b
p_{xo}'
p_x^*
p_x^*
Y
0_b
Y_b

FIGURE 5

output of X rises and Y falls, thus creating an excess supply of X (exportable) and an excess demand for Y (import). In country B, meanwhile, at constant p_{xo}, there has been an excess demand for X and an excess supply of Y; but by our assumption on the relative slopes of the respective R-lines, the net effect is an excess supply of X and an excess demand for Y, thereby causing the fall in p_x.

The reader should be able to verify that if A were initially exporting Y, or if B were the capital abundant country at free trade ($MP_{ka} > MP_{kb}$ at V) implying a capital inflow to A, then the capital flow would reduce the equilibrium volume of trade. Of course, if B were the capital abundant country and A were importing X, then we would again have complementarity. And of course, the above analysis is all based on the assumption that the A R-line is steeper than the B. If that were reversed, then for complementarity A would need to be the capital abundant country if she were exporting the capital intensive good, etc.

Finally, we could analyze the gains from factor mobility in much the same fashion as in Section I. However, the Stolper-Samuelson relationship would no longer be sufficient because the owned-factor transformation locus (that deriving from the initial factor endowment) would not be constant as factor services relocated. That this is so is, of course, due to the fact that production functions differ, so factor returns depend not only on capital-labor ratios, but in the location of the production activity.

It is also worth noting that the recent analysis presented by James Melvin (7) suggests that the presence of increasing returns to scale in production also creates the possibility of complementarity between factor mobility and free trade in the sense used in this paper.

III. Concluding Remarks

The foregoing analysis indicates that the relaxation of the identical technology assumption has far reaching implications for the conventional theory of trade and factor mobility. Also, we have stressed the importance of explicit consideration of cases of complete specialization in production. In terms of potential welfare, or the world production/consumption possibility curve, free trade is seen as generally not sufficient for attaining the maximum position. Further, we demonstrated that cases may arise where free trade and factor mobility are complementary.

This latter result is more than just an intellectual curiosity. Less developed countries in particular are often observed exporting or renting natural resources and raw materials. It seems plausible that these countries are able to carry on an increased volume of trade in finished goods because of this.

REFERENCES

(1) Amano, A., "Determinants of Comparative Costs: A Theoretical Approach," Oxford Economic Papers, November, 1964, pp. 389-400.

(2) Inada, Ken-Ichi, and Kemp, Murray, "International Capital Movements and the Theory of International Trade," The Quarterly Journal of Economics, August, 1969, pp. 524-528.

(3) Johnson, Harry G., "The Theory of Trade and Growth: A Diagrammatic Analysis," forthcoming in a volume in honor of C. P. Kindleberger.

(4) Jones, Ronald W., "International Capital Movements and the Theory of Tariffs and Trade," Quarterly Journal of Economics, February, 1967, pp. 1-38.

(5) _____, "The Role of Technology in the Theory of International Trade," in The Technology Factor in International Trade, edited by Raymond Vernon, National Bureau of Economic Research, 1970, pp. 73-92.

(6) Kemp, Murray, "The Gain from International Trade and Investment: A Neo-Heckscher-Ohlin Approach," American Economic Review, September, 1966, pp. 788-809.

(7) Melvin, J, R., "Increasing Returns to Scale as a Determinant of Trade," The Canadian Journal of Economics, August, 1969, pp. 389-402.

(8) Mundell, R. A., "International Trade and Factor Mobility," American Economic Review, June, 1957, reprinted in his International Economics, MacMillan, 1968.

(9) Olivera, J. H. G., "Is Free Trade a Substitute for Factor Mobility?," Economic Journal, March, 1967.

(10) Stiglitz, J. E., "Factor Price Equalization in a Dynamic Economy," Journal of Political Economy, March, 1970.