CAPITAL UTILIZATION IN THE HECKSCHER-OHLIN MODEL

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International variations in capital utilization as a result of operations are a significant but neglected characteristic of the world economy. In this paper we introduce endogenous capital utilization into the Heckscher-Ohlin model and we show that: if workers differ internationally in their willingness to work the abnormal hours associated with higher levels of capital utilization, the factor-price equalization theorem will no longer be valid, nor will technology and endowments be the sole determinants of comparative advantage. An interesting feature of this result is that workers' willingness to engage in shift-work, for example, affects, through firms' decisions, the availability of capital services, and thus the production possibility set of the economy. Moreover, this same phenomenon also creates a situation in which capital mobility is likely to enhance rather than substitute for trade. A brief comparison with alternative approaches to the introduction of capital utilization in trade models is also provided in the paper.

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In the last twenty years the literature on capital utilization has pointed out that the duration of operations within the day is an important economic variable.[1] Cost-minimizing firms, in deciding the duration of operations, balance the cheapening of captial services against the higher hourly wages demanded by workers for work during abnormal hours. Empirical research shows that there is substantial international variation in the hours of utilization of capital stock and in the associated hours of work on late shifts. The data indicate that a major portion, if not the bulk of international variation in hours of utilization of the capital stock, is attributable to differences in *planned* or anticipated hours of operation, rather than to cyclical variations in demand or to supply bottlenecks.[2]

The available data on shift premiums indicate substantial international variation (Betancourt, 1981). Moreover, the pattern of the shift-work data across industries and countries (Baily; Bautista; Betancourt, 1985; and Phan-Thuy) reveals that shift-work is extremely prevalent in some countries (for example, Yugoslavia and India) and is rather rare in others (for example, France and Japan), being resorted to, in the latter countries, primarily in continuous process operations (such as blast furnaces), or in industries characterized by extremely high capital intensity (such as chemicals). The most plausible explanation for the observed patterns of shift-work is that countries differ substantially in their workers' distaste for shift-work. One study calculated the shift differentials that would be consistent with the observed shift-work decisions and with the profit-maximizing theory of shift-work and came up with the following premiums

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[1] The basic references in the partial equilibrium theory of capital utilization are Marris, Georgescu-Roegen, Winston and McCoy, Betancourt and Clague (1981), and Baily. Surveys are provided by Winston (1974, 1982), Oi, Foss, and Betancourt and Clague (1981). The present paper draws particularly on the capital utilization model in Winston and McCoy.

[2] This statement is based on the observation that time series data within a country do not exhibit large *cyclical* variation in hours of operation of capital stock or in the proportion of workers engaged in shift-work. For data and discussion, see Betancourt and Clague (Page 163-170). To be sure, there is pronounced cyclical variation in overtime hours, but overtime hours are small relative to shift-working hours (no more than a third in U.S. manufacturing.)

for second-shift work; India, 3%; Israel, 12%; France, 30% and Japan, at least 45% (Betancourt, 1981).

Here we shall present a trade model incorporating endogenous capital utilization. Since our emphasis is on long run or planned utilization, variations in capital utilization will be accomplished through variations in shift-work. Firms' shift-work decisions will be based in part on the shift workers' preferences with regard to working during abnormal hours (such as evenings, nights and weekends).

The model here incorporates one kind of international variation in workers' tastes --those pertaining to working during abnormal hours. Other types of worker preferences, however, may also be relevant to comparative advantage and international trade-- workers' toleration of boring and repetitive tasks, and their willingness to undertake hazardous jobs or to work in polluted work environments. The particularly interesting feature of workers' willingness to engage in shift-work is that it affects, through firms' decisions, the availability of capital services and thereby affects the production possibility set of the economy. This feature calls for treating shift-work preferences separately from other worker preferences.

Quite recently efforts have been made to introduce endogenous capital utilization into trade models. There are three published papers of this nature, one by Svensson and two by the present authors (1984 and 1985). The papers by Svensson and by Betancourt *et. al.* make what we shall call the "separate-labor-markets assumption"; that is, from the point of view of the firm, there is no direct link between the normal-hours wage and the abnormal-hours wage. The 1985 paper by the present authors employs the "single-labor-market assumption"; that is, the two wages are linked via a shift-premium function.

The separate-labor-markets assumption dramatizes the differences in tastes among workers -- some are more willing to work during abnormal hours than others. From the point of view of trade theory, the introduction of these taste differences amounts to increasing the number of factors of production from two to three (Svensson; Betancourt, 1984), while the number of goods remains at two, with the well-known consequence that the commodity price equations are no longer sufficient to determine factor prices. For this reason, the Stolper-Samuelson, Rybczynski, and Factor-Price Equalization theorems break down.

The single-labor-market approach, adopted in Betancourt, *et. al* (1985) and in the present paper, assumes that workers within a country have the same tastes with respect to working during abnormal hours, but all workers find it distasteful and demand higher wages in compensation.[3] As will be explained in the paper, under this approach the introduction of endogenous capital utilization does not create another factor market to be cleared. Therefore the introduction of endogenous capital utilization under the single-labor-market approach does not alter the existing relationship between the number of goods markets and the number of factor markets.

Our previous paper (Betancourts *et. al.,* 1985), using the single-labor-market approach, introduced capital utilization into a two-sector model characterized by factor specificity. We show there that allowing capital utilization to be chosen endogenously enhances the richness of results that may be generated by the specific-factors model. In the present paper we introduce endogenous captial utilization into the standard 2x2 Heckscher-Ohlin model. Whereas in the earlier paper we assumed capital to be intersectorally immobile, here we allow it to move freely so as to equalize the rental rates across sectors. Indeed, in the spirit of Neary, the model in this paper may be viewed as the long-run version of the model in our previous paper.

The main findings of the paper may be summarized as follows: First, when endogenous capital utilization is introduced into the standard 2x2 Heckscher-Ohlin model under the assumption of identical worker preferences with regard to shift-work, the Stolper-Samuelson and Rybczynski

[3] It is consistent with the single-labor-market approach to allow preferences with respect to work during abnormal hours to differ across countries. Such an assumption is quite analogous to the standard international trade textbook assumption of identical commodity tastes within a country and different tastes across countries.

theorems remain valid. Second, if value-factor-intensity reversals are ruled out, the Factor-Price Equalization Theorem continues to hold if shift preferences are identical internationally, but not if these preferences differ internationally. In the latter case in fact, factor prices will diverge internationally in a manner predictable by the factor intensities of commodities. Third, when shift preferences differ internationally, the country with the greater aversion to shift-work will normally have a lower rate of capital utilization, but this outcome can be reversed under certain circumstances. Fourth, since international differences in shift preferences are themselves a source of comparative advantage, the capital-labor version of the Heckscher-Ohlin theorem is no longer valid. Finally, when comparative advantage is due solely to international differences in shift preferences, capital mobility is likely to expand trade rather than to substitute for it.

The paper is organized in the following way. In Section I, we outline the general equilibrium model incorporating endogenous utilization. In Section II we review the partial equilibrium theory of capital utilization. Section III considers comparative statics for the small open economy and Section IV presents a two-country framework in which international differences in shift-working preferences can be analyzed. Conclusions are contained in Section V.

I. THE MODEL

Consider an economy producing two goods, 1 and 2, using two primary factors, labor and capital. Let X_i, L_i, and K_i, respectively, represent the flow of output, labor services, and the stock of capital in industry i (i = 1,2) during the period of analysis. Define the units of capital services so that the capital stock K_i, when used for U_i shifts, generates U_iK_i amount of capital services per day. If the capital stock is operated the entire normal-time shift, we set $U_i + 1$ and capital services equal capital stock.

In order to bring out the role of capital utilization most clearly, we assume that only one sector, sector 1, operates the capital stock beyond the normal-time shift.[4] In other words, we set $U_2 \equiv 1$ and $U_1 \equiv U > 1$, where the precise value of U is determined endogenously. We proceed by first considering the problem of the shift-working sector, sector 1.

We assume a putty-clay technology implying that the capital-services-to-labor-services ratio can be varied *between* any two periods of analysis but not *within* any one period. That is, if U (> 1) shifts are operated --one during the normal hours and U - 1 during the abnormal hours-- the number of workers operating on the capital stock at an instant must remain unchanged across the shifts. Once the machines have been built, the same capital-services-to-labor-services ratio must be maintained during the normal and abnormal hours of operation. The putty-clay technology also implies the existence of positive *ex-ante* substitutability between factors so that substitution between labor and capital is possible between two periods in response to a change in factor prices.

In our experience economists tend to seize upon any restriction of substitutability as a serious limitation on the analysis, but as a practical matter, the degree of substitution in the flows of capital and labor services occurring between day and night is surely very small. A given set of machines has a particular normal crew size and this crew size will not usually change from the day shift to the night shift. In any case, surely the assumption of zero *ex-post* substitution is much more realistic than the assumption that the *ex-ante* and *ex-post* elasticities of substitution are the *same,* which is the only other analytically tractable alternative used, for example, by Svensson. Finally, we note that our assumption of zero *ex-post* substitution in factor service flows does not rule out short-run variations in utilization with a given capital stock, which is one of the senses of ex-post substitution in Winston (1974).

Given this description of the technology, we can write the flow of output of good 1 in any one period as

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[4] All of our results can be shown to be valid when both sectors operate the capital stock beyond the normal-time shift.

$$(1) \qquad X_1 = F_1(K_1, L_1/U) = F_1 [(U-1)K_1, (U-1)L_1/U] = F_1(UK_1, L_1)$$

where F_1 determines the form of the production function, which is linear homogeneous in labor and capital services.

Work during abnormal hours must be compensated by a higher wage. Denoting the normal-time wage by w per unit of time and the abnormal-time wage by w_a, we write

$$w_a = [1 + \beta (U, \delta)] w$$

where $\beta(U, \delta)$ is the premium for working during abnormal hours. The premium increases continuously with U. The parameter δ reflects a change in the shift-premium function. An increase in δ reflects an increased unwillingness to work during abnormal hours. Hence, we have: $\beta_U > 0$, $\beta_\delta > 0$, and $\beta_{U\delta} > 0$.

Remembering that industry 1 employs L_1/U workers during the normal hours and $(U-1)L_1/U$ workers during the abnormal hours, we can write the average wage in industry 1 as[5]

$$(2) \qquad w_1 = (1/L_1) [wL_1/U + w_a(U-1)L_1/U] = [1 + (U-1) \beta (U, \delta)/U] w = [1 + a(U, \delta)] w$$

where $a(U, \delta)$ has been used to denote the average wage differential $(U-1) \beta (U, \delta)/U$.

Let us denote the price of commodity i by p_i and the rental rate on capital by r. Given the normal-shift wage w in equation (2), the total cost of producing output X_1 will be given by $rK_1 + [1 + \alpha (U, \delta)] wL_1$.

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[5] As is well known from the literature on public finance and trade theory, the possibility of different wages in the two sectors also exists in the presence of partial factor taxation or a unionized wage. The presence of a shift-premium is conceptually different, however, from the presence of factor taxes or the unionized wage. For while the latter constitutes distortions in the economy from a social welfare point of view, the former does not.

Therefore cost minimization by firms in sector 1 leads to the following Lagrangean expression

(3) $\text{Min } Z = rK_1 + [1 + \alpha(U, \delta)]\ wL_1 + \quad [X_1 - F(UK_1, L_1)]$

where is the Lagrange multiplier and the assumption of perfect competition by firms in industry 1 leads to $\lambda = p_1$. Thus the first-order conditions implied by (3) can be written as

(4) $p_1(\partial F_1/\partial L_1) = [1 + \alpha(U, \delta)]\ w$

(5) $p_1(\partial F_1/\partial K_1) = p_1\ [\partial F_1/\partial(UK_1)]\ U = r$

(6) $p_1(\partial F_1/\partial U) = p_1\ [\partial F_1/\delta\ (UK_1)]\ K_1 = \alpha_U wL_1$

Equations (4) and (5) are the usual conditions for the optimal employment of labor and capital, respectively. Equation (6) gives the condition for the optimal utilization of capital. If we were to view capital utilization as a third factor of production, we must equate the value of marginal product of capital utilization to its marginal cost (= $wL_1\partial\alpha/\partial U$). The latter is incurred in the form of the additional wage paid to the workers exposed to working abnormal hours. Shortly we shall give a more detailed explanation of the firm's optimal rate of utilization.

Turning now to sector 2, we have

(7) $X_2 = F_2\ (K_2,\ L_2)$

Cost minimization by firms in this sector yields

(8) $p_2\ (\partial F_2/\partial L_2) = w$

(9) $p_2\ (\partial F_2/\partial K_2) = r$

Finally, full employment of resources requires

(10) $K_1 + K_2 = K$

(11) $L_1 + L_2 = L$

where K and L, respectively, denote the fixed endowments of capital and labor.

Our model is now completely specified. Equations (1) and (4-11) constitute a system of 9 equations in 9 endogenous variables, namely, X_1,

X_2, L_1, L_2, K_1, K_2, U, w, and r. As usual, we can set $p_2 = 1$ and $p = p_1/p_2 = p_1$ and obtain the effects of the exogenous changes in each of p, K and L on the endogenous variables by differentiating totally the nine equations and solving the resulting system of equations. At present, we note that given the homogeneity of the production functions and the cost minimizing conditions (4-6), (8) and (9), we can write

(12) $$rK_1 + [1 + \alpha(U, \delta)]\ wL_1 = p_1X_1$$

(13) $$rK_2 + wL_2 = p_2X_2$$

It must be remembered that (12) and (13) have been derived from the cost minimizing conditions and as such do not constitute additional independent equations of the model.

II. THE ECONOMICS OF CAPITAL UTILIZATION

In this section we review the partial equilibrium theory of optimal capital utilization. To understand the firm's choice of U, let us rearrange slightly equation (6)

$$p_1\ [\partial F_1/\partial\ (UK_1)]\ (K_1/L_1) = \alpha_U w$$

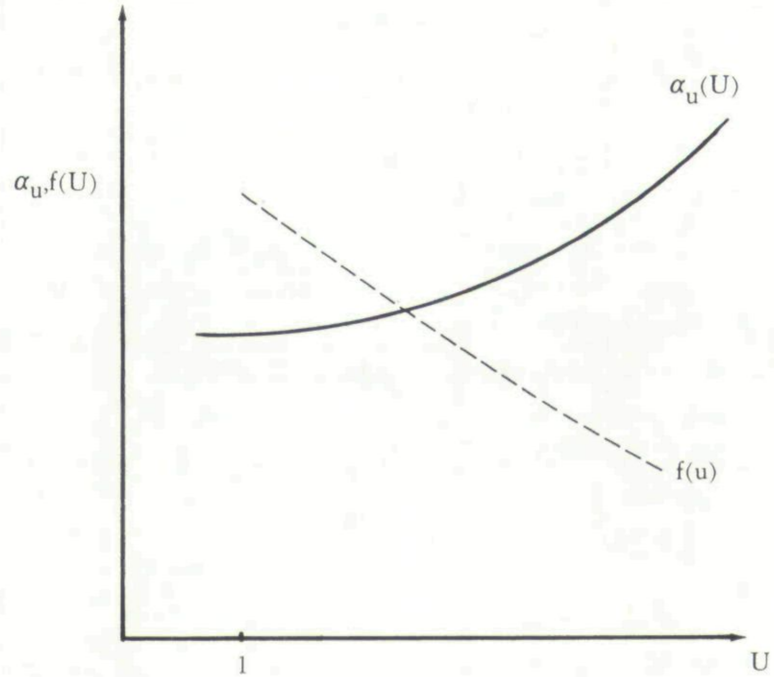
Here the left-hand side is the marginal value product of utilization per worker, while the right-hand side is the marginal cost of utilization per worker. Writing $k_1 = K_1/L_1$ and substituting from (5) we have

(6′) $$f(U) = (1/U)\ (r/w)k_1(U) = \alpha_U(U)$$

where for convenience we shall think of the left-hand side, f(U), as representing the marginal value product of utilization and α_U as representing marginal cost.

The choice of optimal U is depicted in Figure I (below). We shall show that f(U) is likely to be downward sloping (the condition for this shape is indicated in footnote 6 below); α_U can be either upward or downward sloping. An interior solution requires that α_U either be upward sloping or, if downward sloping, be less steep than f(U). To elucidate further the choice of optimal U, we shall discuss both of these functions.

FIGURE I



Turning first to α_U, let us recall

$\alpha(U, \delta) \equiv (U\text{-}1)$ ⅛¹b$(U, \delta)/U$

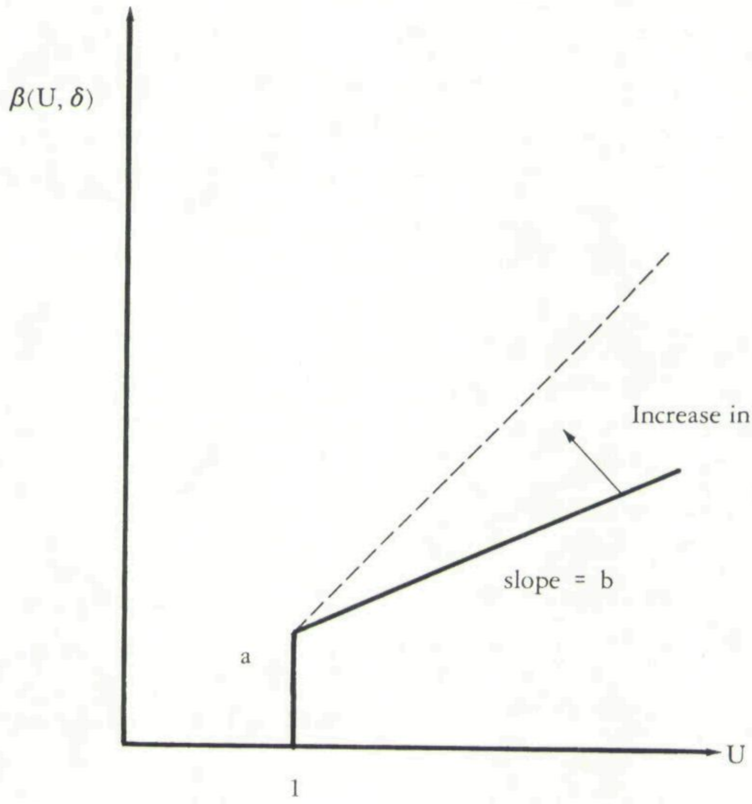
β is the shift-premium function. It tells how much more the shift-workers earn than the day workers. is the wage differential function. It tells how much more the workers in industry 1 earn than the workers in industry 2.

For clarity of exposition, it is useful to consider a special case of the shift-premium function, namely,

$\beta(U, \delta) \equiv a + b\,\delta(U\text{-}1)$

where a and b are positive constants and δ is the parameter representing a change in the shift-premium function. We set δ equal to 1 initially and then we consider an increase in δ. The increase in δ causes the β function to rotate upwards as shown in Figure II (below).

FIGURE II



Leaving aside the change in δ for the moment, let us consider the wage differential function. We have in general

$$\alpha U = (U-1) \quad _{U}/U + \beta/U^2 > 0$$

$$\alpha UU = (U-1)\beta \ _{UU}/U + 2\beta_U/U^2 - 2\beta/U^3 \gtrless 0$$

In our special case we have

$$\alpha_{UU} = (2/U)\ (-a/U^2 + b\delta)$$

Thus in our special case the α_U function may slope downwards before turning upwards, or it may be upward sloping throughout.

The condition for an interior solution is that the α_U function cut the f(U) function from below in Figure I (page 10), or in mathematical terms

(14) $$f'(U)/f(U) < \alpha_{UU}/\alpha_U$$

Differentiating f(U) we obtain

(15) $$f'(U) = (-1/U^2)\ (r/w)k_1 + (1/U)\ (r/w)\ (dk_1/dU)$$

The first term, which is negative, reflects the declining marginal value product of capital services as utilization increases with constant k_1 (where k_1 is the ratio of capital stock employment). The second term depends for its sign on dk_1/dU.

To understand dk_1/dU it is useful to write down the definition of the factor-service elasticity of substitution.

$$\sigma_1 = (\hat{S}_1 - \hat{L}_1)\ (\hat{w}_1 - \hat{r}^*)$$

where $S_1 = UK_1$ is the flow of capital services, w_1 is the average wage in sector 1 as defined by (3), $r^* = r/U$ is the price of capital services in sector 1, and the circumflex (^) denotes a proportionate change. Manipulation of this definition yields

$$\hat{k}_1 = \hat{K}_1 - \hat{L}_1 = \hat{U}(\sigma_1/\theta_{1L}-1)$$

where $\theta_{1L} = w_1L_1(1+\alpha)/p_1X_1$ is the share of labor in total costs. This equation may be written

(16) $$dk_1/dU = (1/U)k_1(\sigma\ \ _1/\theta_{1L}0-1)$$

It can be seen from this equation that an increase in U has two offsetting effects on k_1. First, suppose that σ_1 is zero. Then the increase in U enables the factory to operate with a smaller capital stock. This effect explains the -1 term. But now let σ_1 exceed zero. The increase in U cheapens capital services and makes labor services more expensive and thereby induces substitution of capital services for labor services. This substitution explains the σ_1/θ_{1L} term. Now, if $\sigma_1 = \theta_{1L}$, these two effects cancel out and dk_1/dU equals zero.

Returning to the condition for an interior solution, we substitute (16) into (15) to obtain[6]

$$(17) \qquad f'(U)/f(U) = (1/U)(-2 + \sigma_1/\theta_{1L})$$

and in (14) we have

$$(18) \qquad -2 + \sigma_1/\theta_{1L} < U\alpha_{UU}/\alpha_U = R$$

where R is the elasticity of the α_U curve. (18) is the second-order condition for the interior choice of U to be a cost-minimizing one.

Finally in this section, let us consider a change in workers' preferences reflecting an increased distaste for shift-work. We continue to assume that w and r are held constant for the individual firm but we allow the price of the sector's output to rise to reflect the higher cost of production. (Otherwise the firm would go out of business.)

We represent the change in tastes by changing δ (starting from $\delta = 1$). A rise in δ represents increased distaste for shift-work. We can derive the following

$$(19) \qquad \hat{U}[(2+R) - \sigma_1/\theta_{1L}] = Ad\delta + (\hat{w} - \hat{r})(\sigma_1 - 1)$$

where $A = \sigma_1\alpha\delta/(1+\alpha) - \alpha_{U\delta}/\alpha_U$. The second-order condition (18) ensures that the term in square brackets in (19) is positive. Since the firm has no control over w and r, let us set $\hat{w} - \hat{r} = 0$. Then the effect of the taste

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[6] We see that the f(u) function is downward sloping as long as $\sigma_1 < 2\theta_{1L}$.

shift on optimal utilization depends on the term A.

The effects of the taste shift on optimal utilization may be explained in terms of the curves in Figure I (page 10). The change in δ has two effects: it shifts up the α_U curve (the $-\alpha_{U\delta}/\alpha_U$ term in A) and it shifts out the f(U) curve via the increase in k_1, which comes about because the average wage is higher.

We may regard the normal outcomes as the one in which A is negative, that is, in which the shift in tastes reduces the optimal level of U. The paradoxical case of a positive A cannot be ruled out. Whether the paradox arises or not depends in part on the precise nature of the change in tastes, in particular on whether the $\beta(U, \delta)$ function shifts vertically upward or whether it rotates upward as illustrated in Figure II (page 11). The outcome also depends on how large σ_1 is, for the source of the paradox is that k_1 rises sharply when w_1 goes up. In this paper we shall devote our attention to the nonparadoxical case where A is negative. We show in the longer version that in the special case of our $\beta(U, \delta)$ function, if $\sigma_1 \leq 1$, then A must be negative.

Returning now to the $(\hat{w}-\hat{r})$ term in (19), let us contemplate the effect of a change in the factor prices facing the firm, say $\hat{w}-\hat{r} > 0$. We see that the effect of this change on U depends on σ_1. If $\sigma_1 < 1$, then a rise in w/r reduces utilization, but if $\sigma_1 = 1$, the rise in w/r has no effect on utilization. This result is well known in the partial equilibrium literature of utilization (Betancourt 1981; Winston 1974). The explanation for the result is that utilization depends on both r/w and K_1/L_1. When $\sigma_1 = 1$, a change in r/w has an offsetting effect on K_1/L_1 which leaves utilization unaffected.

III. A SMALL OPEN ECONOMY

In this section we convert our general equilibrium model to differential form under the assumption that commodity prices are fixed. In the manner familiar to trade theorists, let us differentiate (1), (7), (10), (11), (12) and (13) to obtain

$$\text{(20)} \qquad \hat{X}_1 = \theta_{1K}\hat{K}_1 + \theta_{1K}\hat{U} + \theta_{1L}\hat{L}_1$$

(21) $\hat{X}_2 = \theta_{2K}\hat{K}_2 + \theta_{2L}\hat{L}_2$

(22) $\lambda_{1K}\hat{K}_1 + \lambda_{2K}\hat{K}_2 = \hat{K}$

(23) $\lambda_{1L}\hat{L}_1 + \lambda_{2L}\hat{L}_2 = \hat{L}$

(24) $\theta_{1K}\hat{r} + \theta_{1L}\hat{w} = \hat{p}_1 - \theta_{1L}\alpha_\delta d\delta/(1+\alpha)$

(25) $\theta_{2K}\hat{r} + \theta_{2L}\hat{w} = \hat{p}_2$

The θ_{ij} (i=i,2; j=K,L) represent the income shares while the λ_{ij} denote the allocational shares of factors in the relevant sectors. Specifically, $\theta_{iK} = rK_i/p_iX_i$, $\theta_{iL} = (1+\alpha)wL_1/p_1X_1$, $\theta_{2L} = wL_2/p_2X_2$, $\lambda_{iK} = K_i/K$ and $\lambda_{iL} = L_i/L$. Note that in deriving (24) and (25), use has been made of (20), (21) and (6′). We also have the definitions of the elasticities of substitution and the equation for $\hat{U}$ that was derived in the previous section (equation 19).

(26) $\sigma_1 = (\hat{U} + \hat{K}_1 - \hat{L}_1)/[\hat{w} - \hat{r} + \hat{U}\sigma_1/\theta_{1L} + \alpha_\delta d\delta/(1 + \alpha)]$

(27) $\sigma_2 = (\hat{K}_2 - \hat{L}_2)/(\hat{w} - \hat{r})$

(19) $U[(2+R) - \sigma_1/\theta_{1L}] = Ad\delta + (\hat{w}-\hat{r})(\sigma_1 -1)$

where $A = \sigma_1\alpha_\delta/(1+\alpha) - \alpha_{u\delta}/\alpha_U$, normally assumed negative. (19-27) are nine equations in nine unknowns: $\hat{X}_1$, $\hat{X}_2$, $\hat{K}_1$, $\hat{K}_2$, $\hat{L}_1$, $\hat{L}_2$, $\hat{w}$, $\hat{r}$, and $\hat{U}$.

Let us start by noting the modifications introducted into the standard two-sector Heckscher-Ohlin model by endogenous capital utilization. First, the output of sector 1 depends on the rate of utilization (in equation 20). Second, the cost of production of commodity 1 is affected by a change in preferences with respect to shift-work (in equation 24). Third, the elasticity of substitution is defined in terms of factor-service elasticities (in equation 26), and finally, of course there is an equation for utilization itself (equation 19).

For future reference, let us define $\lambda = \lambda_{1K} - \lambda_{1L} = \lambda_{2L} - \lambda_{2K}$ and $\theta = \theta_{1K} - \theta_{2K} = \theta_{2L} - \theta_{1L}$. Here λ and θ, respectively, are the usual measures of relative captial intensity in the two industries in physical and value terms. Note that given the fact that the average wage is higher in sector 1 than in sector 2, it is possible for the physical and value factor intensities to differ. It is shown in the longer version, however, that at least in the small country context this possibility is ruled out by stability conditions, which is analogous to Neary's (1978) finding for the standard model.

It is of some interest to note that despite the important modifications noted above, the Stolper-Samuelson and Rybczynski theorems continue to be valid in our model. The reason for this result is that given our wage-differential function (2), the evenness property of the Heckscher-Ohlin model is preserved. That is, there are two factor markets to clear and exactly two outputs that can adjust. Consequently, factor prices depend entirely on commodity prices as reflected in equations (24) and (25). [We hold tastes constant here and hence set $d\delta = 0$ in (24).] If commodity prices change, factor prices must change in the fashion predicted by the Stolper-Samuelson theorem to ensure zero profits in both industries. Similarly, if factor endowments change at constant world prices, the two outputs must be adjusted in Rybczynski fashion to maintain full employment. Note that when factor endowments alone change, since factor prices do not change, the optimal rate of capital utilization remains unchanged as well (equation 19). Formally, the Rybczynski theorem then follows from equations (20-23).

It is useful now to perform the algebra associated with the Stolper-Samuelson theorem and at the same time to consider a change in the shift-premium parameter δ. The effects on factor prices can be found by solving (24) and (25) to yield[7]

$$(28) \qquad \hat{r} - \hat{p}_i = -(\theta_{2L}\theta_{1L}/\theta)\ \alpha_\delta d\delta/(1+\alpha) + (\theta_{iL}/\theta)\hat{p}$$

$$(29) \qquad \hat{w} - \hat{p}_i = (\theta_{2K}\theta_{1L}/\theta)\alpha_\delta d\delta/(1+\alpha) - (\theta_{iK}/\theta)\hat{p}$$

$$(30) \qquad \hat{w} - \hat{r} = (\theta_{iL}/\theta)\alpha_\delta d\delta/(1+\alpha) - \hat{p}/\theta$$

[7] The effects of $d\delta$ are formally the same as in the factor-markets distortion literature. (Batra, pages 254-255).

where $\hat{p} = \hat{p}_1 - \hat{p}_2$. The Stolper-Samuelson results follow from the terms involving $\hat{p}$. A rise in p raises the real return to capital and reduces that to labor, if sector 1 is capital intensive ($\theta > 0$). Turning now to the d terms, we see that a rise in δ (reflecting increased distaste for shift-work) has the same effects on w and r as a decline in p. This result occurs because the rise in δ raises the average cost of producing commodity 1 (at given w and r). To bring the cost down in sector 1, while keeping it constant in sector 2, the return on the factor in which sector 1 is intensive must fall, and the return on the other factor must rise.

Next we consider the effects of $\hat{p}$ on utilization. Substituting from (30) into (19) and setting $d\delta = 0$ yields

$$\hat{U} \quad [(2 + R) - \sigma_1/\theta_{1L}] = \hat{p}(\sigma_1 - 1)/\theta$$

where the term in square brackets is positive by the second-order condition. We see from this equation that the effect of $\hat{p}$ on U depends on θ and σ_1. Specifically, if sector 1 is capital intensive, a rise in p ($=p_1/p_2$) raises or lowers U as $\sigma_1 \lessgtr 1$. The explanation for this result lies in the Stolper-Samuelson theorem (as represented by equation 30) and in the effect of w/r on U (as discussed above in connection with (equation 19).

IV. A TWO-COUNTRY MODEL

In this section, let us suppose there are two countries A and B with identical production functions but different endowments of capital and labor. Initially we suppose that A and B have identical shift-premium functions. As long as the factor endowments lie within the cone of diversification and there are no value factor intensity reversals, in the absence of transport costs there will be equalization of w and r, identical levels of U and identical shift premiums in the two countries.

Now let δ be higher in country B than in country A, reflecting an assumption that workers in B find shift-work more distasteful than workers in A. We can use (28-30) to describe the relationships between the two countries. First note that (30) can be written as

$$(31) \qquad \theta(\hat{r} - \hat{w}) + \theta_{1L}\alpha_\delta d\delta/(1 + \alpha) = \hat{p}$$

We now interpret (31) as reflecting the differences between the two countries. With commodity prices equalized internationally, we have $\hat{p} = 0$. Clearly r/w now diverges between the two countries. Specifically, if $\theta > 0$, we have $(r/w)_B < (r/w)_A$. The Stolper-Samuelson equations (28) and (29) also imply in this case that $r_B < r_A$ and $w_B > w_A$.

Thus, divergence in the wage-differential functions causes divergence in factor prices in the Heckscher-Ohlin model. But the direction of the divergence in factor prices depends on the factor intensities of the commodities. In the example above, in which $\theta > 0$, normal-time wages (w) are higher in the country (B) with the greater aversion to shift-work.

The level of utilization will also differ between the two countries. Let us repeat (19) here for convenience.

$$(19) \qquad \hat{U}\,[(2 + R) - \sigma_1/\theta_{1L}] = Ad\delta + (\sigma_1 - 1)\,(\hat{w} - \hat{r})$$

Recall from the discussion of the partial equilibrium analysis (Section II) that the term A is normally taken as negative. In the present context, this term indicates that country B would have a lower level of utilization than country A. But the other term, $(\sigma_1-1)\,(\hat{w}-\hat{r})$, must also be taken into consideration.

From (31), setting $\hat{p} = 0$, we have

$$(32) \qquad (\sigma_1-1)\,(\hat{w}-\hat{r}) = (\sigma_1-1)\theta_{1L}\alpha_\delta d\delta/\theta\,(1 + \alpha)$$

The sign of this term depends on $(\sigma_1-1)/\theta$. For example, if $\sigma_1 < 1$ and $\theta > 0$, this term will be negative. In this case, the divergence in shift-premium functions causes r/w to be lower in country B than in country A, and this divergence tends to favor lower utilization in country B. Thus, this term reinforces the effect of term A and we may conclude that country B will have a smaller rate of utilization than country A.

Suppose, on the other hand that, $\sigma_1 < 1$ and $\theta < 0$. In this case, $(\sigma_1-1)/\theta$ is positive. Here the divergence in shift premium functions causes r/w to be higher in country B than in country A and this divergence tends to favor higher utilization in country B. It is even possible for the term in (32) to dominate the $Ad\delta$ term in (19) so that utilization would be higher in the country with the greater aversion to shift-work, although this paradoxical case must be considered unusual.

It is also apparent that this model's comparative advantage does not depend on capital and labor endowments alone. Thus, the traditional statement of the Heckscher-Ohlin theorem on comparative advantage is on longer valid, except in the case of identical shift-premium functions across countries. In the general case, comparative advantage may be based no international differences in workers' tastes, as well as on differences in capital and labor endowments. The determinants of comparative advantage are discussed in the longer version of this paper, which also discusses the case of international capital mobility. It has been pointed out above that international differences in shift-work preferences cause capital rentals to differ across countries, thereby setting up incentives for capital movements. It can be shown that, under plausible conditions, capital movements complement rather than substitute for trade; this result resonates with the findings of Markusen that capital movements complement trade when trade is based on something other than factor proportions.

V. CONCLUSIONS

International differences in the willingness of workers to engage in shift-work are an important feature of reality. This paper has explored some of the consequences of introducing international differences in shift-work preferences into the Heckscher-Ohlin model. Our model retains the even character of the standard Heckscher-Ohlin model, and hence, the Stolper-Samuelson and Rybczynski theorems continue to hold. These theorems prove useful in analyzing the effects of differences in shift-work preferences. While the Factor-Price Equalization theorem no longer holds in the presence of international differences in shift-work preferences, the direction of divergence in factor prices depends on factor intensities in Stolper-Samuelson-like fashion. Comparative advantage is now affected by shift-work preferences as well as factor endowments, and when comparative advantage is derived entirely from shift-work preferences, it is likely that capital mobility will expand rather than substitute for trade.

The paper also presents a general equilibrium analysis of capital utilization. As a result of the general equilibrium effects of differences in shift-work preferences, in the Heckscher-Ohlin model the country with the greater aversion to shift-work is likely to (but need not) have a lower rate of capital utilization.

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