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Technical Change in a Model with Fair Wages and Unemployment

by

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CENTRE OF PLANNING AND ECONOMIC RESEARCH

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ABSTRACT

The purpose of this paper is to reconsider the results of the standard neoclassical theory of international trade regarding the effects of technical change. We adopt a fair wage hypothesis, by postulating a work effort function, which depends on the relative returns to labour and capital, and the level of unemployment. Our analysis shows that the results of the standard analysis, initiated by Findlay and Grubert, may change significantly, and that technical change may significantly affect involuntary unemployment, which is endogenously determined by the system, in contrast with most of the studies based on the standard model.

1. INTRODUCTION

One of the major issues that international trade theorists have dealt with is that of technical change. Since the publication of the work of Findlay and Grubert (1959) several authors have examined the effects that the several types of technical change may have on income distribution, output composition, and factor allocation.[1] The main vehicle for most of the analyses has been the simple two-sector general equilibrium model, particularly the approach popularized by the classic paper of Jones (1965).

Little is known, however, about the model and its properties when the assumption of perfect competition and market clearance is relaxed. With regard to the assumption of full employment, in particular, several authors have attempted to deal with this issue in various ways. Most of these studies, however, allow for unemployment which is due to exogenous factors, such as a generalized minimum wage (Brecher 1974), a specific-sector minimum wage (Harris-Todaro 1970), or other exogenously set distortions. Recent developments in the field of macroeconomics provide a microeconomic rationale for involuntary unemployment, as a result of the optimizing behaviour of agents. One such theory that has attracted the interest of many economists, is that of the efficiency wage theory of unemployment. Central to the efficiency wage hypothesis is the idea that firms may set wages above market-clearing levels whenever labour productivity depends positively on the real wage paid by firms.[2]

Very recently, Agell and Lundborg (1991, 1992) have introduced these ideas into the simple two-sector general equilibrium model, in order to examine the effects of tax and subsidy policies on unemployment and factor rewards, and the validity of the Heckscher-Ohlin model. More specifically, Agell and Lundborg adopt the fair wage/gift exchange approach of Akerlof, and specify workers' effort norm as a function of relative income and unemployment. By relative income we mean that the workers' effort function depends not only on the wages received by other workers in other firms, but also on the return obtained by the owners of capital of the firm.[3] The adoption of such a hypothesis implies that the production technologies allow for variation in the work effort and that this effort depends

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[1]. See, for example, Johnson (1963), Jones (1970) and Rivera-Batiz (1980).

[2]. For a rationalization of this view see, among many others, Akerlof (1982), Solow (1979), Shapiro and Stiglitz (1984), Weiss (1991), et al.

[3]. For a theoretical and an empirical support of this view see Akerlof and Yellen (1990), Krueger and Summers (1988), Thaler (1989), Solow (1990) and Blinder and Choi (1990).

on the relationship between the actual wage and the workers' perception for a fair wage. If the actual wage falls short of the fair wage, workers reduce their work effort. If the fair wage exceeds the market clearing wage, involuntary unemployment may occur. It is true, of course, that social norms and notions of fairness differ from country to country, but it seems to be generally acceptable that such notions play a role in most economies, both developed and developing.

In this paper, we shall adopt the approach suggested by Agell and Lundborg (1992), with the aim of examining the effects of technical change on income distribution and unemployment. One of the main concerns for the implications of technical change is its impact, not only on income distribution but also on unemployment, which has not been dealt with in many studies in the theory of international trade, since full employment is assumed to prevail in most of them. As we shall show in the following analysis, the effects of an exogenous technical change, which occurs in a small open economy, may be different from those of the standard theory of international trade, not only quantitatively but also qualitatively.

In the second part of the paper, we lay out the basic features of our model, and derive the basic relations for our analysis. In the third part, we examine first the effects of technical change on income distribution and unemployment, in the framework of a small open economy with all commodities internationally traded. Secondly, we deal with the case of a small open economy which, in addition to the internationally traded goods, produces also non-traded commodities. Finally, in the last section we summarize the main findings of our analysis.

2. THE MODEL

Following Jones (1965), we postulate a two-sector economy which produces commodities X and Y. The production function of each commodity is assumed to be linearly homogeneous in its factors of production, capital (K) and labour (L), which are in fixed supply, and intersectorally mobile. Perfect competition is assumed to prevail in all markets. Although labour is in fixed supply, the effective labour supply (E) may vary, depending on the work effort relationship we mentioned above.

2.1. Work Effort and Fair Wages

Reproducing Agell and Lundborg (1992) we specify a work-effort function of the form

$$e=e(\frac{w_i}{w},\frac{w_i}{r_i},U) \qquad (1)$$

where e is the supply of effort of the representative worker in firm i, w_i is the wage rate in firm i, w is the average wage level in the economy, r_i is the return to capital in firm i, and U is unemployment.[1] We assume that effort depends positively on the wage in firm i relative to the average wage level in the economy. The effort depends also positively on the wage w_i relative to the return of capital in firm i. Finally, effort is assumed to depend positively on aggregate unemployment, in the sense that, for given factor returns, an increase in the unemployment rate makes workers "happier" for being employed, which improves work morale and effort.

To ensure an interior solution for the efficiency wage model, we assume that the work effort is negative whenever w_i is zero. Furthermore, a unique optimum wage requires effort to be a continuous and strictly concave function of its first two arguments; i.e.

[1]. For the microeconomic underpinnings of this effort function see Agell and Lundborg (1992) where this function is derived, and more details are provided.

$e_{11}, e_{22} < 0$. For analytical convenience we may sometimes assume that the effort function is separable in its arguments, i.e. $e_{12} = e_{13} = e_{23} = 0$.

Equation (1) is crucial to the firm's optimization problem. We assume that firms in both sectors face the same effort function e, and that they set wages so as to minimize the effective wage cost per worker, $v_i = w_i/e$. With capital being perfectly mobile between sectors r_i will be equalized across sectors and firms to the economy-wide rental r. We have, therefore, the optimization problem (with respect to w_i)

$$Min\ v_i = w_i/e(\frac{w_i}{w}, \frac{w_i}{r}, U) \tag{2}$$

subject to $e < o$ for $w_i = 0$ (3)

Solving (2) gives the first order conditions

$$e - w_i(\frac{e_1}{w} + \frac{e_2}{r}) = 0 \tag{4}$$

where e_1 and e_2 are the partial elasticities of the effort function with respect to w_i/w and w_i/r. Equation (4) can be rewritten as

$$\varepsilon_1 + \varepsilon_2 = 1 \tag{5}$$

The optimal wage is, therefore, set in such a way that the elasticities (ε_i) of the effort function with respect to its first and second arguments, sum to unity. With homogeneous labour and perfect mobility between sectors and firms, the relative wage w_i/w becomes unity at equilibrium, and the effort function reduces to

$$e = e(1, \frac{w}{r}, U) \quad (6)$$

where w is the economy-wide wage, set to fulfill (5).

Having completed the presentation of the fair wage hypothesis, we can now turn to its implications for the two sector general equilibrium model.

2.2. The two Sector Model with Fair Wages and Technical Change

On the basis of equation (6), we can reformulate the simple two-sector general equilibrium model as follows:

The production functions for the two commodities X and Y are respectively:

$$X = F_X(E_X, K_X; t) \quad (7)$$

$$Y = F_Y(E_Y, K_Y; t) \quad (8)$$

where $E_i = e(1, w/r, U)L_i$, with L_i being the amount of labour used in sector i, $(i = X, Y)$, and t is a shift parameter representing the effect of technical change. Although L is fixed, total supply of labour in efficiency units, $E^s = e(\ldots)L$ is endogenous.

The dual cost functions C_X, C_Y to the production functions are given by the following equations:

$$C_X = C_X(\frac{w}{e}, r; t)X \quad (9)$$

$$C_Y = C_Y(\frac{w}{e}, r; t)Y \quad (10)$$

where the first two arguments of the minimum cost functions C_i are the prices of capital and labour in efficiency units. Assuming that C_i is twice differentiable, we obtain the equilibrium conditions in factor markets:

$$C_{EX}X + C_{EY}Y = e(L\text{-}U) \tag{11}$$

and

$$C_{KX}X + C_{KY}Y = K \tag{12}$$

where C_{KX}, C_{KY}, C_{EX}, C_{EY}, are the derivatives of the minimum cost functions with respect to (effective) factor prices. The LHS of (11) specifies the total demand for efficiency labour units of the two sectors. The RHS of (11) defines the supply of labour in efficiency units as the total labour supply, L, less the unemployed, U, multiplied by the economy wide effort level e.

Perfect competition in product markets implies that:

$$C_{EX}v + C_{KX}r = P_X \tag{13}$$

$$C_{EY}v + C_{KY}r = P_Y \tag{14}$$

where P_X and P_Y are the prices of X and Y respectively, and $v = w/e$. In the case of a small open economy, commodity prices are exogenously determined. If, however, we assume that our economy produces one commodity, say X, which is internationally traded, and another, Y, which is non-traded internationally, then P_Y is determined endogenously. Assuming also that consumers have identical and homothetic preferences, we have:

$$D_X/D_Y = f(P_X/P_Y) \tag{15}$$

where D_j is the demand for the jth commodity ($j = X,Y$). At equilibrium in the nontraded goods market implies that $D_Y = Y$. Similarly, for the traded goods we assume trade balance, which implies that $D_X = X$. Hence, (15) can be rewritten as

$$X/Y = f(P_X/P_Y) \tag{15a}$$

Before we proceed to our analysis, we must determine the input-output coefficients, C_{ij}. We know that they depend on relative factor rewards, and the state of technology. That is

$$C_{ij} = C_{ij}(\Omega,t) \tag{16}$$

where $\Omega = v/r$. Total differentiation of (16) yields:

$$C_{ij}^* = A_{ij}^* - B_{ij}^* \tag{17}$$

where $A_{ij}^* = (1/C_{ij})(\partial C_{ij}/\partial \Omega)d\Omega$ is the change in input-output coefficient that occurs as a result of a change in the effective wage/rental ratio (with unchanged technology), and $B_{ij}^* = (-1/C_{ij})(\partial C_{ij}/\partial t)dt$ is a measure of the technical change that results in a change in C_{ij}. Since technical improvements ordinarily involve a reduction in input-output coefficients, and therefore costs, B_{ij}^* is defined to be positive.

Differentiating totally equations (6),(11),(12), and taking into account (17), we can obtain, after some manipulations, the following relationship:[1]

$$(\lambda_{EX}-\lambda_{KX})(X^*-Y^*)-[\varepsilon_2+(1-\varepsilon_2)(\delta_E+\delta_K)](w^*-r^*)$$

$$-[\varepsilon_3(1-\delta_E-\delta_K)-U/(L-U)]U^* = \Pi_E-\Pi_K \tag{18}$$

where an asterisk indicates relative change, e.g. $x^* = dx/x$, and

λ_{EX}	=	$C_{EX}X/e(L-U)$ is the share of *efficient* labour used in sector X,
λ_{EY}	=	$C_{EY}Y/e(L-U)$ is the share of *efficient* labour used in sector Y,
λ_{KX}	=	$C_{KX}X/K$ is the share of capital used in sector X,
λ_{KY}	=	$C_{KY}Y/K$ is the share of capital in sector Y,
Θ_{Ej}	=	wC_{Ej}/ePj is the share of *effective* labour cost in producing commodity j, where $j=X,Y$.
Θ_{Kj}	=	rC_{Kj}/P_j is the share of capital cost in producing commodity j, ε_3 = the elasticity of effort with respect to unemployment,
δ_E	=	$\lambda_{EX}\Theta_{KX}\sigma_X + \lambda_{EY}\Theta_{KY}\sigma_Y$,
δ_K	=	$\lambda_{KX}\Theta_{EX}\sigma_X + \lambda_{KY}\Theta_{EY}\sigma_Y$,
σ_j	=	the elasticity of substitution between E and K in sector j.
Π_E	=	$\lambda_{EX}B_{EX}^* + \lambda_{EY}B_{EY}^*$, and
Π_K	=	$\lambda_{KX}B_{KX}^* + \lambda_{KY}B_{KY}^*$.

[1]. For a detailed derivation see Appendix.

Let us assume now that technical change takes place only in the traded goods sector X, and that it is Hicks-neutral, i.e. $B_{EX}^* = B_{KX}^* = B_X^*$.[1] As a result $\Pi_E - \Pi_K = (\lambda_{EX} - \lambda_{KX})B_X^*$. It is worth noting that Π_i represents the percentage reduction in the ith factor that takes place owing to the occurence of technical progress in commodity X, when the effective wage/rental ratio is kept constant.

Differentiating totally equations (6),(13), (14), and (15), we obtain:

$$(\Theta_{EX}-\Theta_{EY})(1-\varepsilon_2)(w^*-r^*)-\varepsilon_3(\Theta_{EX}-\Theta_{EY})U^* + P_Y^* = \Pi_X \tag{19}$$

$$(X^*-Y^*)-\sigma_D P_Y^* = 0 \tag{20}$$

where $\Pi_X = \Theta_{EX}B_{EX}^* + \Theta_{KX}B_{KX}^*$ is a measure of technical change in the sector producing commodity X, and σ_D is the elasticity of substitution between X and Y in consumption, and $\sigma_D = -(\varepsilon_{XX} + \varepsilon_{YY})$, with ε_{jj} being the compensated own price elasticity in consumption.[2]

Finally, by differentiating the first order conditions underlying (5), and assuming separability we can obtain:

$$(w^*-r^*) = hU^* \tag{21}$$

where $h = U(r/w)^2 e_3/e_{22}$. e_{22} is the second derivative of the effort function with respect to its second argument.[3] If we assume that the effort function is an everywhere concave function of the wage/rental ratio, then h is negative.

Making use of (21), we can rewrite equations (18) and (19) as follows:

$$\lambda(X^*-Y^*)-\Gamma(w^*-r^*) = \lambda B_X^* \tag{18a}$$

[1]. If production coefficients are fixed, i.e. $\sigma_j = 0$, then δ_i is also zero. In the general case of variable coefficients, however, δ_i reflects the percentage change in the use of the ith factor per unit of output that occurs because of the technical change in both commodities when the efficient wage/rental ratio is kept constant. By contrast, Π_i represents the percentage reduction in the ith factor that occurs as a result of the technical change in both commodities when the efficient wage/rental ratio is kept constant.

[2]. The incidence of technical change is to lower the unit cost of production; $\Theta_{EX}B_{EX}^*$ reflects the reduction in the labour cost, and $\Theta_{KX}B_{KX}^*$ the reduction in the capital cost in the production of one unit of X.

[3]. For more details see Agell and Lundborg (1992), p.309.

$$\Theta'(w^*-r^*) + P_Y^* = B_X^* \tag{19a}$$

where $\lambda = \lambda_{EX}-\lambda_{KX}$, $\Theta' = (\Theta_{EX}-\Theta_{EY})(1-\varepsilon_2-\varepsilon_3/h) = \Theta(1-\varepsilon_2-\varepsilon_3/h)$, and $\Gamma = (\delta_E+\delta_K)(1-\varepsilon_2-\varepsilon_3/h)+\varepsilon_2+(\varepsilon_3/h)-U/(L-U)h$. It is clear that λ is positive if the X sector is relatively labour intensive, Θ is positive if the share of labour in the cost of X is higher than that of capital, and $(1-\varepsilon_2-\varepsilon_3/h)$ is positive since from (5) we have that $\varepsilon_2 < 1$, and h is negative. Thus, $\Theta'$and Θ have the same sign. With no initial distortion in our economy, it can be shown that λ and Θ have the same sign (Neary 1978).

We can now proceed to the examination of the effects of Hicks-neutral technical change in the X sector, on income distribution, unemployment, and sectoral output composition.

3. THE EFFECTS OF TECHNICAL CHANGE ON INCOME DISTRIBUTION AND UNEMPLOYMENT

3.1. Technical Change in a Small Open Economy

Suppose that our economy is a small open one in the world markets, and that both commodities X an Y are internationally traded. The prices of X and Y are, therefore, exogenously determined and so $P_X^* = P_Y^* = 0$. From (19a) we have that:

$$w^* - r^* = (1/\Theta')B_X^* \tag{22}$$

It is clear that the change in the wage/rental ratio depends on the sign of Θ', which is the same as that of Θ. Hence, if the sector in which the technical change takes place is relatively labour intensive and Θ' is positive, then the wage rate will rise relative to the rental to capital. If, however, X is relatively
capital intensive, the above result will be reversed. This result is qualitatively the same as that of the standard theory (e.g. Jones 1970). It differs, however, quantitatively by the fact that in the denominator Θ is now multiplied by $(1-\varepsilon_2-\varepsilon_3/h)$.

Another point which is novel in our model, and which does not exist in the standard model, is that fair wage hypothesis affects unemployment. Making use of (21) and (22) we obtain:

$$U^* = (1/h\Theta')B_X^* \tag{23}$$

If Θ' is positive then unemployment will fall as a result of the technical change, since h is negative, and vice versa if $\Theta < 0$.

With regard to sectoral output composition, we can obtain from (18a) and (22) that:

$$X^* - Y^* = (1 + \sigma_s)B_X^* \tag{24}$$

where $\sigma_s = \Gamma/\lambda\Theta'$, and following Jones (1965) it can be readily established that σ_s is the elasticity of substitution between X and Y on the supply side, and if we assume that ε_3 is relatively small, then σ_s is positive. From (24) it is clear that technical change will lead to the relative expansion of the sector where it occurs.

An intuitive explanation for these results could be the following: The neutral improvement in X lowers the unit cost of production of X, leading thereby to a reduction in (P_X/P_Y). The commodity price ratio, however, is given, and in order to maintain the previous commodity prices, the price of the factor employed intensively by X should rise and that of the factor used unintensively by it should fall. Assuming that X is relatively labour intensive, i.e. $\Theta > 0$, the wage rate needs to rise while the rental to capital needs to fall so as to restore the pre-technical change commodity prices. The rise in the effective wage/rental ratio (v^*-r^*) induces firms to substitute capital for labour in both industries, so that the capital/effective labour rises in both commodities, which in turn creates a situation of excess demand for capital and excess supply of labour. With commodity prices unchanged, X will expand and it will absorb labour more rapidly than capital, and the output of Y, which is in a better position to release capital, will decline. The increase in the wage/rental ratio will induce an increase in the work effort, but the fall in unemployment will work in the opposite direction. Whether effective labour supply will rise or fall is not, therefore, clear. To see how the effective labour supply is affected by the technical change, we can define the RHS of (11) as $E_s = e(1,w/r,U)(L-U)$, where E_s is the endogenously determined supply of labour in efficiency units. Differentiating E^s, we obtain $E_s^* = \varepsilon_2(w^*-r^*) + \varepsilon_3 U^* - UU^*/(L-U)$. Making use of (21), we can obtain:

$$E_s^* = [\varepsilon_2 + (\varepsilon_3/h) - U/(L-U)h](w^*-r^*) \tag{25}$$

The sign of (w^*-r^*) depends on relative factor intensities. The sign of E_s, therefore, depends on the sign of the expression in the square brackets. The first and third term in the square brackets on the RHS of (25) are positive while the second is negative. The sign of E_s is therefore ambiguous, depending on the relative strength of each term. The change in the effective labour supply, however, does not seem to affect the sign of factor-price changes, unemployment, and relative output composition.[1] It is clear that even if the effective labour supply rises, unemployment falls because the expansion of the sector producing X, which is assumed to be labour intensive, will absorb the extra supply of labour. If the effective labour supply falls it will certainly affect negatively the production of X.

It is also interesting to have a look not only at the relative factor-price changes, but also at the absolute changes in the wage rate and the rental to capital. Since commodity

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[1]. For more details about the interpretation of the expression in the square brackets see Agell and Lundborg (1992), pp. 310-313.

prices are constant the absolute changes are also real. We know that $v^* = w^* - e^*$. With commodity prices fixed, we can obtain by differentation of (13) and (14) that

$$v^* = (\Theta_{KY}/\Theta)B_X^* \tag{26}$$

and

$$r^* = -(\Theta_{EY}/\Theta)B_X^* \tag{27}$$

Differentiating also (6) we can obtain that

$$e^* = \varepsilon_2(w^* - r^*) + \varepsilon_3 U^* \tag{28}$$

Substituting (26) and (27) into the relation $v^* = w^* - e^*$, we get

$$w^* = [1 - \Theta_{EY}(1 - \varepsilon_2 - \varepsilon_3/h)B_X^*/\Theta' \tag{29}$$

From the above relationships, we observe that, with $\Theta' > 0$, the return to capital falls, the effective wage rate rises, but the wage rate may even fall if the term $\Theta_{EY}(1-\varepsilon_2-\varepsilon_3/h)$ is greater than one.

Another aspect which is worth examining is whether technical change can be immiserising or not. National income is defined as $I = w(L-U) + rK$. Differentiating totally this expression we obtain:

$$I^* = \Theta_E w^* + \Theta_K r^* - \Theta_E[U/(L-U)]U^* \tag{30}$$

where Θ_E and Θ_K are the share of labour and capital respectively in the national income. Substituting (27) and (28) into (30), we can obtain after some manipulatons the following relationship.

$$I^* = \{\Theta_E(1 - U/[h(L-U)]) - \Theta_{EY}(1 - \varepsilon_2 - \varepsilon_3/h)\}(B_X^*/\Theta') \tag{31}$$

It is obvious that a negative value for I^*, that is immiserising growth cannot be excluded. This depends on whether the values of ε_3 and Θ_{EY} are large enough so that the second term on the RHS of (31) which is positive, becomes large enough to outweight the first term. This may occur under the assumption that $\Theta > 0$. With $\Theta < 0$, immiserising growth may take place evenin the case that the values of ε_3 and Θ_{EY} are small.

We can conclude, therefore, that when a Hicks-neutral technical change takes place in a sector of a small open economy, the change in the distribution of income and unemployment depend on relative factor intensities. If the sector in which the change takes place is relatively labour intensive, the wage rate will rise relative to the rental of capital, unemployment will fall, and the sector will expand. If the sector that experiences the technical change is relatively capital intensive the above results will be reversed. The change in output composition is not affected, however, by factor intensities, but the phaenomenon of immiserising growth cannot be excluded, although we deal with a small open economy, where the terms of trade are given for the country under consideration.

3.2. Technical Change in the Presence of Non-Traded Commodities

Consider now an economy which produces an internationally traded good X, and another commodity Y, which is non-traded internationally. We have then a system of three equations (18a), (19a), and (20), which can be solved for (w^*-r^*), X^*-Y^*, and U^*, in order to obtain the following relationships.

$$w^*-r^* = (\sigma_D-1)B_X^*/[\Theta'(\sigma_D+\sigma_s)] \tag{32}$$

$$X^*-Y^* = \sigma_D(\sigma_s+1)B_X^*/(\sigma_D+\sigma_s) \tag{33}$$

$$U^* = (\sigma_D-1)B_X^*/h\Theta'(\sigma_D+\sigma_s) \tag{34}$$

$$P_Y^* = (1+\sigma_s)B_X^*/(\sigma_D+\sigma_s) \tag{35}$$

As these equations reveal, changes in all variables depend not only on relative factor intensities but also on the magnitude of the elasticity of substitution between commodities in consumption σ_D. To make our analysis tractable, we shall assume, for the rest of our analysis, that the traded commodity is relatively capital intensive (i.e. $\Theta'>0$), since the non-traded commodity may consist mainly of services, which are rather labour intensive.

It is clear from (32) that the change in the wage/rental ratio depends critically on the value of σ_D. If $\sigma_D=1$ the wage/rental ratio and unemployment remain unchanged, that is, technical change does not affect the distribution of income between labour and capital, and unemployment. At the same time the price of the non-traded commodity will rise by the percentage of technical change, and the output of the expanding sector X will rise, relative to Y, by the same percentage change B_X^*.

The above points can be further clarified graphically by making use of Figure 1.

Initially the economy is at point A, on the transformation curve PP. The technical change shifts this curve to PP'. At constant commodity prices, production moves from A to B. This move can be decomposed into two parts: a movement due to the shift of the PP, and a move along the PP', which depends on the elasticity of commodity substitution, σ_s. At point B, however, there is an excess demand for the nontraded commodity, and as a result its price will rise to clear the market. Thus, as P_Y rises the economy moves from B to C. It is also clear that the production of both commodities rises, but that of X rises by more than that of Y, so that $X^*-Y^*>0$.

The preceding diagrammatic analysis was conducted under the assumption that σ_D was equal to one. Because of this assumption the wage-rental ratio remained unchanged, and consequently unemployment and the effective labour supply did not change either. If σ_D is different from zero, the wage-rental ratio changes and the effective labour supply will also change (see eq. 25). The change in the effective labour supply will cause a shift in the transformation curve. In other words, if σ_D is greater or less than one, we shall have a shift of the PP to PP' due to technical change, but we shall also have another shift due to the change in the effective labour supply, E_s. If E_s rises there wil be a further shift of the transformation curve further out from PP'. If E_s falls, then the PP'may move back, to a position between PP and PP', or even below PP. It is obvious that the new position of the transformation curve depends on the sign of E_s and the labour intensities of the two sectors.

If σ_D is less than one, as is more likely, then the wage rate will fall relative to the rental of capital.[1] The fall in the wage/rental ratio is accompanied by an increase in unemployment. With respect to sectoral output composition, and the price of the nontraded commodity, we observe that the sector experiencing the technical change will always expand relative to the other sector. The price of the nontraded commodity will also rise, regardless of factor intensities and the magnitude of the elasticity of substitution σ_D.

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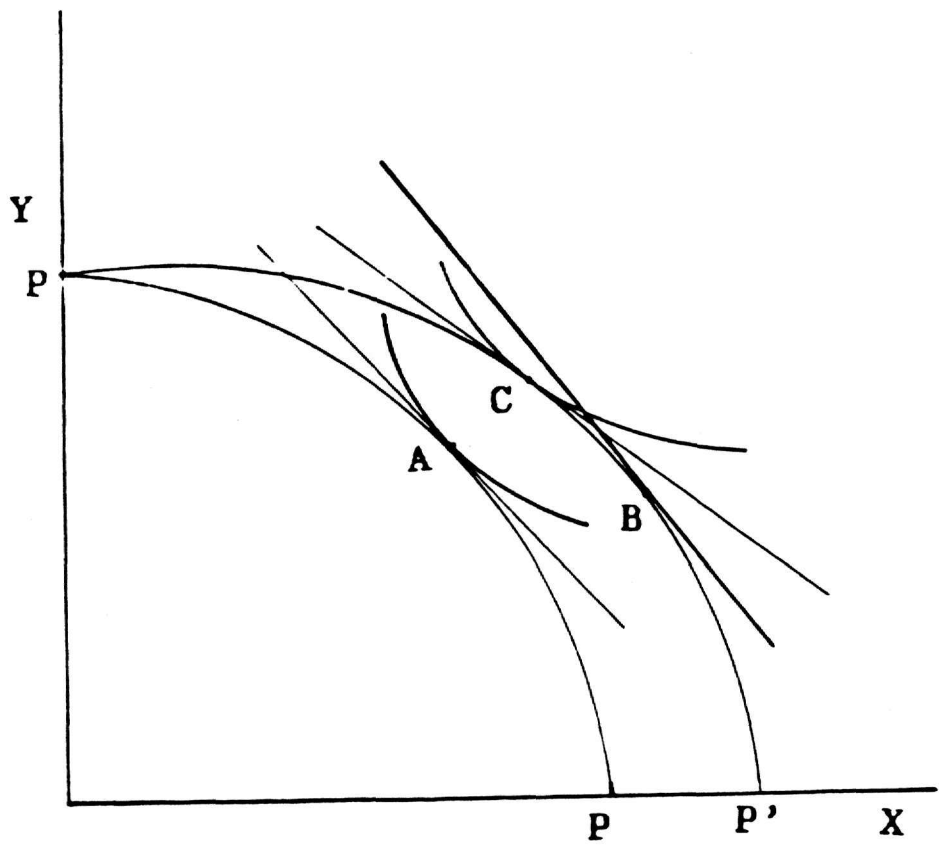
[1]. We have noted that $\sigma_D=\varepsilon_{XP}+\varepsilon_{YP}$, where $P=P_Y/P_X=P_Y$. According to the evidence provided by Kravis, Heston and Summers (1983), for a large number of countries, we can assume that approximately $\varepsilon_{YP}=0.194$. For ε_{XP}, which is the cross-price elasticity of tradeables in terms of non-tradeables, no evidence is provided. KHS, however, have estimated the price elasticity of tradeables to be equal to 0.3064. We can, therefore, assume that $\varepsilon_{XP}<0.3063$, and thus $\sigma_D<1$.

FIGURE 1



It might be interesting to examine also what happens in the wage rate and the rental to capital, in terms of the numeraire, i.e. the price of the traded commodity whose price is given exogenously. Making use of the definition of the efficiency wage, it is rather straightforward to find that:

$$r^* = \left(\sigma_S + \frac{\theta_{EX} - \theta_{EY}\sigma_D}{\theta} \right) \frac{B_X^*}{\sigma_D + \sigma_S} \tag{36}$$

$$w^* = \left(\sigma_S + \frac{\sigma_D - 1}{\theta'} + \frac{\theta_{EX} - \theta_{EY}\sigma_D}{\theta} \right) \frac{B_X^*}{\sigma_S + \sigma_D} \tag{37}$$

It is clear that with $\Theta' > 0$, if $\sigma_D = 1$ both w and r will rise by the rate of technical change B_X^*. With σ_D different than one, the change in factor prices depends not only on relative factor intensities, as in the case with all goods internationally traded, but also on the relative magnitude of σ_s and σ_D.

Since the price of nontraded commodity change, it is of interest to see the changes of factor-prices in terms of the nontraded good whose price rises. From (35), (36) and (37), we can obtain:

$$w^* - p_Y^* = \frac{\sigma_D - 1}{(\sigma_D + \sigma_S)\theta'} [\theta_{KY} + \theta_{EY}(\epsilon_2 + \frac{\epsilon_3}{h})] B_X^* \tag{38}$$

$$r^* - p_Y^* = \left[\frac{\theta_{EY}}{\theta} (1 - \sigma_D) \right] \frac{B_X^*}{\sigma_D + \sigma_S} \tag{39}$$

These equations reveal again that with $\sigma_D = 1$, the real wage rate and the real return to capital do not change. However, with $\Theta > 0$ and $\sigma_D < 1$ the real return to capital rises, but the change in the real wage rate is ambiguous depending on the size and sign of the expression ($\varepsilon_2 + \varepsilon_3/h$). If ε_2 is small and ε_3 is large, it implies that the fall in the wage-rental ratio will reduce work effort, but the consequent increase in unemployment will increase effort by more, and as a result the expression ($\varepsilon_2 + \varepsilon_3/h$) will be negative. If the magnitude of this expression is also large, then it is possible that the real wage also rises.

Finally, it is worth examining whether technical change can lead to a reduction of national income, i.e whether, in the present framework, there is a possibility for immiserizing growth. Making use of equation (30), and substituting for the values of w^*, r^*, and U^*, we obtain:

$$I^* = \left[\sigma_S + \frac{\theta_{EX} - \theta_{EY}\sigma_D}{\theta} + \frac{\theta_E(\sigma_D - 1)}{\theta'}\left(1 - \frac{1}{h}\frac{U}{L-U}\right)\right]\frac{B_X^*}{\sigma_D + \sigma_S} \tag{40}$$

If $\sigma_D = 1$, national income rises by the percentage of technical change, and there is not immiserising growth. With σ_D different from zero the outcome is not clear, and more information is needed about the values of the various elasticities and relative factor intensities. If, for example, both elasticities, σ_s and σ_D are very small, then it is likely that national output will decline.

4. CONCLUDING REMARKS

In this paper we have attempted to integrate the standard two sector general equilibrium model with the efficiency wage theory. More specifically, we have examined the effects of a Hicks-neutral technical change that takes place in one sector of a small open economy. A basic point that differentiates our approach from the classic paper of Grubert and Findlay (1959), or Jones (1970) is that we relax the assumption of full employment by introducing the fair wage hypothesis as put forward by Agell and Lundborg (1992).

We first examined the case of a small open economy, where all commodities are internationally traded, the change in the wage-rental ratio depends on relative factor intensities. If the sector experiencing the technical change is labour intensive the wage rate will rise, the return to capital will fall, and unemployment will also fall.

We consider next the case of a small open economy which produces an internationally traded good, and a home good which is not traded internationally. In such a framework, with the technical change taking place in the traded goods sector, the change in relative factor-prices and unemployment, depends not only on relative factor intensities, but also on the value of the elasticity of substitution between commodities in consumption (σ_D). If this elasticity is equal to one, the wage-rental ratio and unemployment remain unchanged. If the sector experiencing the technical change is labour intensive, $\sigma_D < 1$, then the wage-rental ratio will fall and unemployment will rise. Thus, we observe that as the wage rate rises relative to the return to capital, unemployment falls, and vice versa. In any way, the price of the nontraded commodity rises unambiguously, and the traded goods sector expands relative to the other sector.

Finally, it is worth mentioning that a Hicks-neutral technical change may be immiserizing, even in the case where all commodities are internationally traded.

APPENDIX

Total differentiation of (6), (11), (12), (13), and (14), under the assumption that L and K are in fixed supply, yields:

$$e^* = \varepsilon_2(w^*-r^*) + \varepsilon_3 U^* \tag{A1}$$

$$\lambda_{EX}X^* + \lambda_{EY}Y^* = -(\lambda_{EX}C_{EX}^* + \lambda_{EY}C_{EY}^*) + e^*-UU^*/(L-U) \tag{A2}$$

$$\lambda_{KX}X^* + \lambda_{KY}Y^* = -(\lambda_{KX}C_{KX}^* + \lambda_{KY}C_{KY}^* \tag{A3}$$

$$\Theta_{EX}v^* + \Theta_{KX}r^* = P_X^*-(\Theta_{EX}C_{EX}^* + \Theta_{KX}C_{KX}^*) \tag{A4}$$

$$\Theta_{EY}v^* + \Theta_{KY}r^* = P_Y^*-(\Theta_{EY}C_{EY}^* + \Theta_{KY}C_{KY}^*) \tag{A5}$$

We also have that $\sigma_j = (a_{Kj}^*-a_{Ej}^*)/(v^*-r^*)$, where $v^* = w^*-e^*$, and that cost minimization implies:

$$\Theta_{EX}a_{EX}^* + \Theta_{KX}a_{KX}^* = 0 \tag{A6}$$

$$\Theta_{EY}a_{EY}^* + \Theta_{KY}a_{KY}^* = 0 \tag{A7}$$

Making use of the definition of the elasticity of substitution between capital and labour, and equations (A6), and (A7), we obtain:

$$a_{Ej}^* = -\Theta_{Kj}\sigma_j(v^*-r^*) \tag{A8}$$

$$a_{Kj}^* = \Theta_{Ej}\sigma_j(v^*-r^*) \tag{A9}$$

Making use of (A1), (A6), (A7), (A8), (A9) and (17), we can get:

$$C_{Ej}^* = -\Theta_{Kj}\sigma_j(1-\varepsilon_2)(w^*-r^*) + \Theta_{Kj}\sigma_j\varepsilon_3U^*-B_{Ej}^* \tag{A10}$$

$$C_{Kj}^* = \Theta_{Ej}\sigma_j(1-\varepsilon_2)(w^*-r^*)-\Theta_{Ej}\sigma_j\varepsilon_3U^*-B_{Kj}^* \tag{A11}$$

Substituting (A10) and (A11) into (A2)-(A5), we can obtain after some manipulations:

$$\lambda_{EX}X^* + \lambda_{EY}Y^* = [\varepsilon_2 + (1-\varepsilon_2)\delta_E](w^*-r^*) + [\varepsilon_2(1-\delta_E)-U/(L-U)]U^* + \Pi_E \quad \text{(A12)}$$

$$\lambda_{KX}X^* + \lambda_{KY}Y^* = -\delta_K(1-\varepsilon_2)(w^*-r^*) + \delta_K\varepsilon_3U^* + \Pi_K \quad \text{(A13)}$$

$$\Theta_{EX}[w^*-\varepsilon_2(w^*-r^*)-\varepsilon_3U^*] + \Theta_{KX}r^* = P_X^* + \Pi_X \quad \text{(A14)}$$

$$\Theta_{EY}[w^*-\varepsilon_2(w^*-r^*)-\varepsilon_3U^* + \Theta_{KY}r^* = P_Y^* \quad \text{(A15)}$$

Subtracting (A13) from (A12) yields equation (18) of the text. Similarly, from (A14) and (A15), we can obtain equation (19) of the text.

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