TECHNICAL CHANGE, PECUNIARY EXTERNALITY AND MARKET FAILURE

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ABSTRACT First, a small open economy is analysed to show that even a complete and competitive market may fail to produce Pareto-efficient outcomes under conditions of changing technology. It is mainly because price-taking agents can make the prices they face by changing their technology or technique of production. It is then shown that this result holds equally true for the regional sub-economies of this economy. A legal provision of R&D tax/subsidy based on payroll changes is shown to be a second best policy that corrects the market failure with a small dead-weight loss. This policy does not require actual tax collection or subsidy payment and may be used by regional governments to correct technological market failure at regional levels. The provision improves the functioning of the market by eliminating the mismatch between the type of production sector and the type of technological/technical change they introduce.

1. INTRODUCTION

Technical progress allows a price taking sector, no matter how small, to circumvent the restriction posed by its smallness in making *effective* factor (input) prices *it faces* even if it is incapable of affecting market clearing prices, which everyone faces. With the decision to change technology falling entirely within the domain of each single sector, whether the market outcome will still be efficient is an important question with far reaching implications. This issue is directly relevant to persons and institutions interested in regional problems and policies, particularly in regions where unemployment due to technological "redundancy" is quite high. We would like to know, for example, whether the so-called technological unemployment is an efficient outcome or is the result of market failure.

If the technical change takes place in many sectors (or in an industry, say because of national or industry-wide policy reform) simultaneously then it will affect market-clearing prices producing a series of pecuniary externalities across other sectors of the economy. Since Scitovsky (1954) these externalities have clearly been distinguished from *real* or *technological* externalities and considered welfare benign. This is because the external benefits are believed to exactly offset

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the external costs of pecuniary changes (Shubik, 1971; Anderson, 1974; and Ng, 1983). The pecuniary change is the mechanism through which the market is supposed to yield the most efficient outcome.

It has also been shown, nevertheless, that a pecuniary externality may cause the market to fail if there are imperfections in the market, such as an incomplete insurance market (Loong and Zeckhauser, 1982), or the presence of monopolistic elements (Ng, 1983) or agents holding inconsistent price information on potential product innovations (Makowsky and Ostroy, 1995). Even when markets are complete and perfect, the pecuniary externality provides an incentive to the agents to behave strategically, such as collude or merge or extract some tribute, so that some of the external benefits of pecuniary changes can be internalized (Subik, 1971; Anderson, 1974). As long as people respond to economic incentives, pecuniary externalities may also form the basis for various lobbying activities and institutional change, therefore pecuniary effects of technical change can not be dismissed *a priori*.

To the author's knowledge, the efficiency of a complete and perfect market outcome under conditions of changing technology has not been examined by previous authors. Is the outcome of a competitive and complete market socially efficient when a sector is allowed to change its production technology? In other words, would a profit-maximizing sector guided by exogenously given market prices be able to *appropriate only* its social contribution from technical progress? If not, what can be done to correct it? What determines whether there is any pecuniary trickle-down effect of a sector-specific technical change? What is the pattern of this effect? Who benefits and who loses at the new equilibrium? This is a list of interesting but as yet unanswered questions.

This paper mainly focuses on labour-saving technical change and answers the above questions with a simple specific-factor model of a small open economy, which produces traded goods only and where no new product is being introduced. The purpose of modelling this type of a small open economy is to fix commodity prices and rule out coordination failure, so that the conditions for market efficiency as stated in Makowsky and Ostroy (1995) are satisfied.

In the model, each sector employs a specific-factor, called capital, and a composite of all mobile factors, called labour. The production function of each sector is defined on *efficiency units* of the two factors, while the sector, however, buys these factors in *physical units* from fully competitive factor markets. Sectors convert physical units of the factors into their efficiency unit by a given rule and the efficiency units are then fed into a well-defined *neo-classical* production function to obtain output. A *technological change* has been defined as a shift in the production function, which implies a change in the productivity of the efficiency units of the factors. A *technical change* has been defined as a change in the rules of converting physical units into efficiency units of the factors. If a sector requires less physical units of labour, say persons, to extract the same amount of efficiency units of labour then, other things remaining the same, the sector is said to have acquired a labour-saving technical progress. In this situation, the cost of each efficiency unit of labour falls even if the market clearing wage rate is unaffected by the technical change. Sectors will make adjustments. The national output and the profit level of the sectors will change. Following Makowsky and Ostroy (1995) we examine whether or not the sectors following the price signal will be able to *fully appropriate* the social contribution of their technical change. A failure to do so implies a divergence between social and private benefits, which in turn can cause a market failure.

This paper demonstrates that whether a sector introducing a labour-saving *technical progress* will be able to appropriate its social contribution fully, less than fully, or more than fully, depends on whether the local wage elasticity of its labour demand is equal to, greater than, or less than unity. A sector introducing a labour-saving *technological progress*, however, would never be able to appropriate its social contribution fully. Therefore, we conclude that even a complete and competitive market will fail to deliver an efficient outcome if production sectors have their local wage elasticity of labour demand not equal to unity and the technical and technological progresses are not costless. Furthermore, a sector will reduce (increase) labour employment if the wage elasticity of its labour demand is less (greater) than unity. This adjustment in employment is privately desirable, but it is socially undesirable. A tax/subsidy scheme to rule out the possibility of this kind of technological market failure has been provided.

Sectors that have locally inelastic (elastic) labour demand have an incentive to 'over-introduce' (under-introduce) labour-saving technology. In the absence of corrective intervention, similar action can be expected on the part of many sectors, which can culminate in sufficient level of unemployment (excess demand) to make the market adjust the market-clearing wage rate. As the wage rate falls (rises), all sectors benefit (lose) and labour loses (benefits). Trickling-down of pecuniary effects of sector-specific technical progress starts here. Moreover, a fall in the wage rate does not eliminate the incentives to introduce further technical changes. There is also an incentive to sectors with elastic labour demand to subsidise the introduction of labour-saving technology in sectors with inelastic labour demand. Thus, an economy may plunge into the cycle of higher technology, lower wage and higher unemployment indefinitely.

The rest of the paper contains five sections. The market equilibrium under changing techniques of production is described in Section 2. The problem of appropriation in this environment and the possibility of market failure are discussed in Section 3. The relevance of this result to regional economies is shown in Section 4. How an R&D tax/subsidy scheme can correct this problem is shown in Section 5 and the paper is finally concluded in Section 6.

2 MARKET EQUILIBRIUM UNDER CHANGING TECHNIQUE OF PRODUCTION

In this section, a very simple general equilibrium model of an n-sector, small and open economy producing n-different tradable commodities is described. Each sector, representing the behaviour of a tiny part of the economy, is assumed to be a price taker in all markets and strives to maximize profit subject to its production function, defined indirectly (see below) over labour and capital. The production decision is decentralized. There is one national consumer, who finally receives all income and consumes goods at constant prices to maximize utility. No new commodity is being introduced and therefore, there is no coordination problem as shown by Makowsky and Ostroy (1995). Under these conditions we can ignore the demand side since the income generating supply side is completely unaffected by it, and the social welfare depends on total income. It is also assumed throughout this paper that labour is nationally mobile and capital is specific to each sector.

2.1 The Production Function of a Sector

Each sector produces a single commodity by employing labour and capital of given efficiency and the relation is defined by a concave production function:

$$X_j = F_j(L_j^*, K_j^*) ; \quad j = 1, \dots, n \tag{1}$$

where L_j^* and K_j^* are labour and capital measured in their efficiency units and X_j is the unit of output produced in industry j. The function F_j is assumed to describe the *hard core* technological relationship between factors, measured in efficiency units, and output in sector j. Any change in F_j reflects the real *technological* breakthrough attained in sector j.

The efficiency units of factors and their prices are determined by:

$$L_j^* = L_j / A_{Lj} \text{ and } K_j^* = K_j / A_{Kj} \tag{2}$$

$$W_j^* = A_{Lj} W \text{ and } R_j^* = R_j A_{Kj} \tag{3}$$

where, L_j and K_j are *physical* units of labour and capital employed in sector j whose prices are W, the wage rate, and R_j, the rental rate respectively. The coefficients A_{Lj} and A_{Kj} provide the current mapping between the efficiency units and the observable physical units of the factors and represent the current *technique* of production and management. Suppose both A_{Lj} and A_{Kj} are unity, then it means the efficiency units, L_j^* and K_j^*, of the factors are equal to their physical units, L and K, respectively. A fall in the value of A_{Lj} indicates that to obtain a given level of efficiency units of labour we now need fewer persons than before. In other words, this means that more efficiency units of labour now become available from a given stock of physical units of labour. Technical progress that occurred in sector j is said to be factor neutral if changes in A_{Lj} and A_{Kj} are equiproportional, otherwise it is biased.

Given a market-clearing wage rate, W, *j-specific* efficiency wage rate, W_j^*, is determined by (3). Given the product price P_j for each commodity j, a sector j *solves the following maximization problem:*

$$\max_{L_j^*} \quad P_j X_j - W_j^* L_j^*$$
$$\text{s.t.} \quad X_j = F_j(L_j^*; K_j^*, A_{Lj}, A_{Kj}) \tag{4}$$

by choosing efficiency units of labour, L_j^*. A solution to this problem satisfies the condition that

$$dF(L_j^*; K_j^*, A_{Lj}, A_{Kj}) / dL_j^* = W_j^* / P_j \tag{5}$$

which can be expressed as

$$L_j^* = L_j^*(W_j^*; K_j^*, P_j, A_{Lj}, A_{Kj}) \tag{6}$$

The condition (5) states the obvious: to maximize profit, employment of efficiency units should be chosen so that the value of its marginal product is equal to the efficiency wage rate. Once the optimal demand for efficiency-unit of labour is determined, the demand for its physical unit can easily be determined by (3) and (4). This process is illustrated in Figure 1.

The first quadrant in Figure 1 shows the marginal product curve of efficiency units of labour. The efficiency wage rate is converted into physical wage rate in the second quadrant and the efficiency units of labour are translated into physical units in the fourth quadrant. The marginal product curve of, which is also the demand curve for, the physical units of labour is finally derived in the third quadrant by noting that each sector is a profit maximizer. Profit maximization requires that the efficiency units to be so chosen that the value of its marginal product equals the efficiency wage rate (the exogenously given output prices are all normalized to unity).

To make the point clear, suppose that one person yields two efficiency units of labour per period, that is $A_L = 0.5$. If W_1 is the market wage rate then the efficiency wage rate, W_1^*, is equal to $0.5W_1$. The first quadrant of the figure shows that at this wage rate L_1^* of efficiency units of labour maximizes the sector's profit. The fourth quadrant converts this information into physical units of labour as $L_1 = 0.5 L_1^*$. We now have a point to trace the demand curve for physical unit of labour in the third quadrant. Other points can be obtained by similar arguments.

2.2 Technical Change and Technological Change

The slope of the line *TOT* that goes from the fourth to the second quadrant through the origin represents the technical coefficient A_L. A fall in the value of A_L makes the line flatter (pulling towards the *x*-axis) and an increase in the value of A_L makes the line steeper. A flatter line would mean that a person now yields more efficiency units of labour than before, whereas a steeper line would mean that the same person is now less efficient than before. Thus by rotating the line

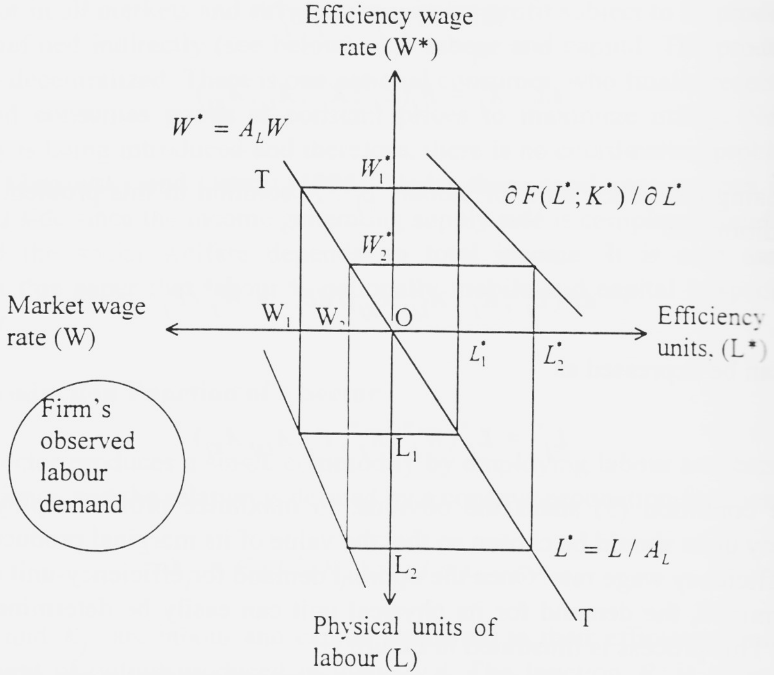


Figure 1. Optimal Demand for Physical and Efficiency Units of Labour

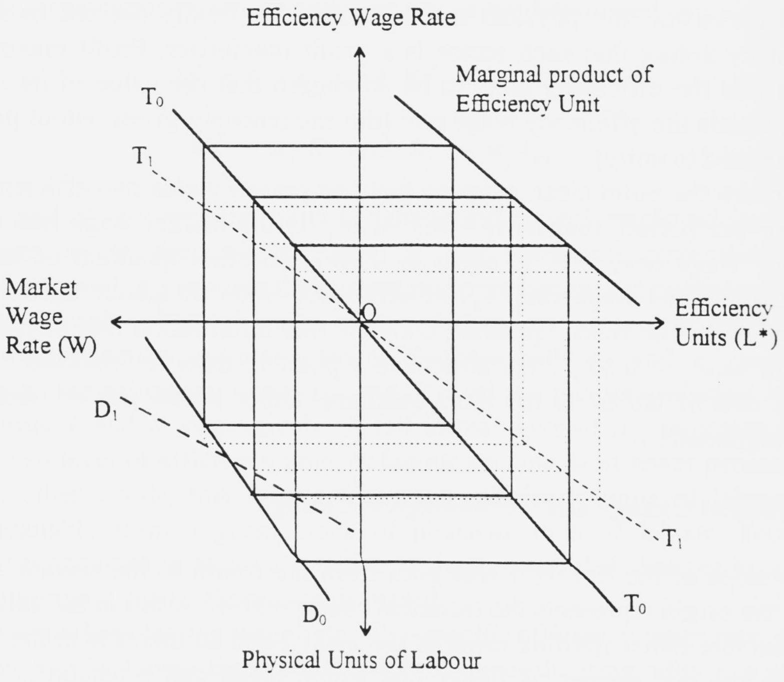


Figure 2. Technical Change and Demand for Physical Units

TOT around the origin, we can represent a particular type of labour productivity change, which we define as *technical change.* A pure technical change would leave the production function *F* unaffected, and the marginal product of efficiency units unchanged. Such a change, for example, can be brought about by improved management practices, provision of recreational and training facilities, etc., but without changing the relationship between efficiency units and output. It only changes the relationship between the physical unit of a factor and its efficiency. Thus a technical change, when unit price is given by the market, alters the price of an efficiency unit proportionately. If the (productivity) efficiency of a physical unit of labour increases by 10 per cent, then, at a constant wage rate, the price of an efficiency unit of labour falls by 10 per cent as well. The effect of a technical change on the demand for physical units of labour is shown in Figure 2.

Figure 2 is similar to Figure 1, except that the line T_0OT_0 representing the technique of production has rotated to a broken line. Labour has become more productive in producing efficiency units, which is represented by the slope of the new line T_1OT_1. Therefore, the demand curve for physical units of labour has rotated from D_0 to D_1 (see, the third quadrant). At a given market wage rate, efficiency wage rate has now fallen; demand for efficiency units has risen; and finally, the demand for physical units has, perhaps, changed. Above the point of intersection of the two demand curves D_0 and D_1 the demand for persons has increased, but below the point of intersection it has fallen. The extent of this shift in demand depends on the tilt of the new demand curve D_1, which can be explained as follows. A physical unit means more efficiency units now, say four units as against two. At the unchanged production technology *F*, the marginal product of the first physical unit is the total of the marginal products of all the first four efficiency units it produces. Therefore, the marginal product of the first physical unit has gone up. Similarly, the second physical unit now commands the less productive next four efficiency units. Its marginal product, which is the sum of the marginal products of these four efficiency units, can not rise by as much as that of the first. Continuing this process, the marginal products of physical units of labour start to fall rapidly, which is described by the tilt of the curve D_1.

The point of intersection between the two demand curves D_0 and D_1 is determined by the wage elasticity of the demand for efficiency units. If the wage elasticity of demand for efficiency units is unity, then a change in the technique will not affect the demand for physical units at the going market-wage rate. This is because, as productivity of the physical unit goes up, say by 10 per cent, the unit cost of an efficiency unit falls by 10 per cent as well. This will increase demand for efficiency units by 10 per cent, so the demand for physical units remains unchanged.

This point is illustrated in Figure 3. At the going wage rate *W*, the demand for physical units has remained the same with the technique T_1OT_1 as with T_0OT_0. In general, if the wage elasticity of the demand for efficiency units is globally unity, then no change in technique will bring a shift in the demand curve for physical units in the labour market. Alternatively, if the wage elasticity of demand for efficiency units is greater than unity over the relevant range, then the new demand

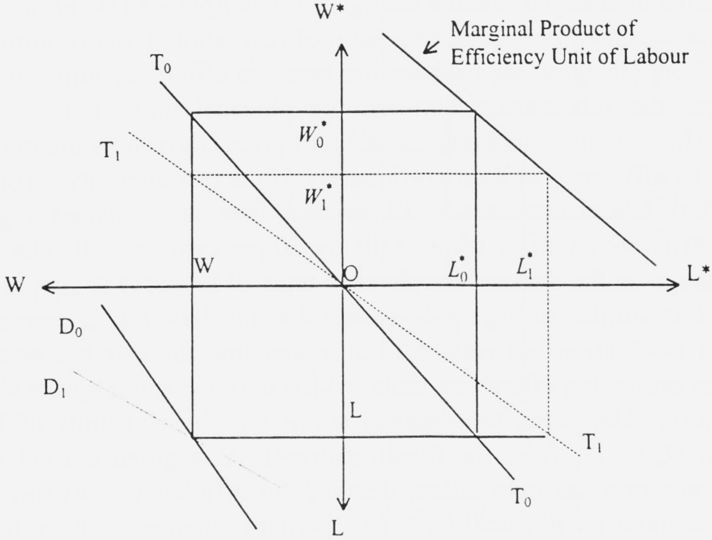


Figure 3. Wage Elasticity of Demand for Efficiency Units and Demand for Labour

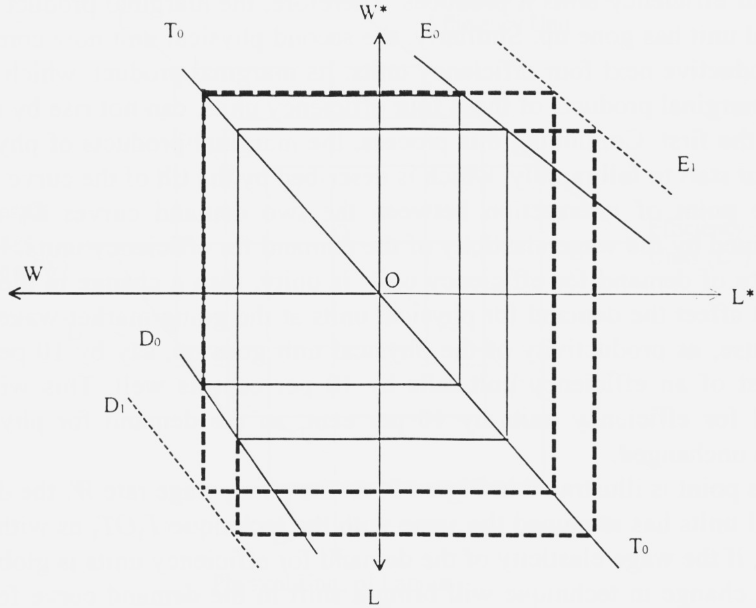


Figure 4. Change in Technology and Demand for Labour

curve for physical units will be flatter than the old one as physical units become more productive. Thus, the elasticity of demand for efficiency units plays a critical role in shaping the demand curve for physical units of labour.

Now, consider a change in the production technology, that is a shift on the production function *F*, of an arbitrary sector. The effect of a labour productivity-enhancing shift in the production function and its impact on the demand for persons is illustrated in Figure 4.

Figure 4 shows a rightward shift on the demand for efficiency units of labour, from E_0 to E_1, which was brought about by an improvement in the productivity of efficiency units of labour. This increase in productivity, in turn, was the consequence of a technological progress in the sector. Given T_0OT_0, the *technique* of extracting efficiency units from physical units of labour, the effect of this technological change on demand for person are traced by broken lines from first quadrant to the third quadrant. The demand curve shifts out from D_0 to D_1.

Figure 5 summarizes the types of shifts on the demand-for-labour curve discussed so far, which were brought about by technical and technological changes in a given sector.

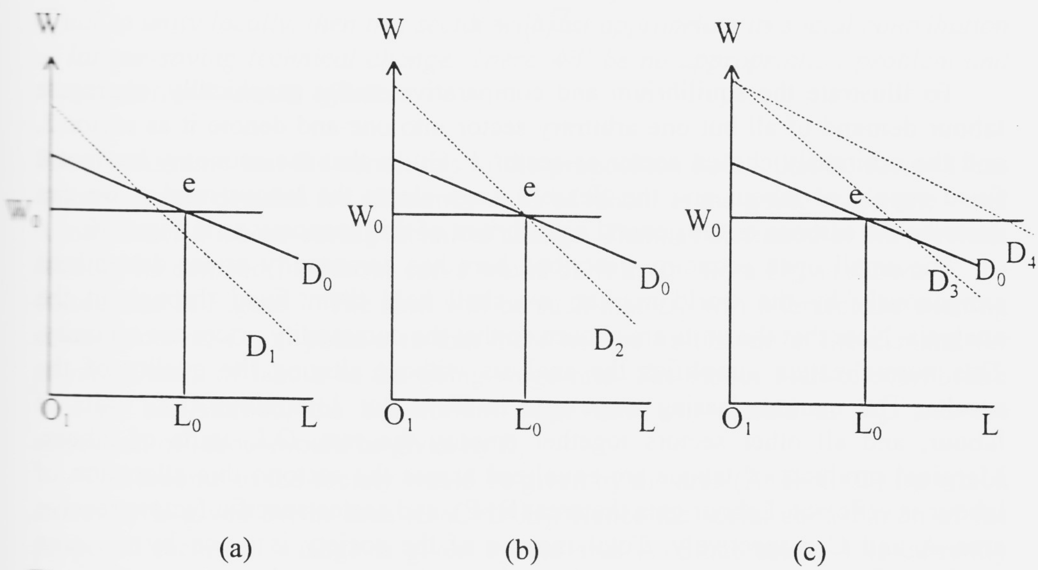


Figure 5. Technical and Technological Change, Wage Elasticity and Shifts in the Labour Demand Curve

D_0 is the initial demand curve for physical units of labour. The market wage rate is given at W_0 and the sector is currently employing L_0 persons. If a technical change takes place in the sector, then depending upon the *local* wage elasticity of demand for the efficiency units, the shift on the demand curve for persons may take any of the form shown in panel (a), (b) or (c). If the elasticity is less than unity, then the shift will be as shown in panel (a); the new demand curve will be like D_1, intersecting D_0 to the left of current equilibrium point *e*. If the elasticity is unity, then the new demand curve will be like D_2 as shown in panel (b), indicating no change in the demand for persons at the going wage rate. If the elasticity is greater than unity, then the new demand curve will be like D_3 as shown in panel (c), which indicates an increase in demand for physical units at the going wage rate. Similarly, the new demand curve would be like D_4, to the right of the curve D_0, if it is caused by a labour-saving *technological* progress. As far as the local effect on demand for persons is concerned, D_3 and D_4 are similar. Therefore, in what follows we consider only three of the four types of possible shifts of the labour demand curve that is brought about by a labour-saving technical change under three different values of the wage elasticity.

2.3 Equilibrium in the Labour Market: The Last Component of General Equilibrium

To complete the general equilibrium model of the small open economy, we now need to specify the resource constraint of the economy. We now require that the demand for physical units of labour by all sectors add up to the total supply of labour. Specifically we assume that

$$\sum_j L_j = L \tag{7}$$

To illustrate the equilibrium and comparative statics graphically, aggregate labour demand of all but one arbitrary sector into one and denote it as sector 2, and the arbitrarily chosen sector as sector 1. Given that the economy has got a fixed supply of labour and the flexible wage clears the labour market we can describe the essence of the general equilibrium of this economy as in Figure 6.

The small open economy described here has commodity prices determined exogenously by the world market; we shall hold them fixed throughout the analysis. Note that the units are chosen so that the commodity prices are all unity. This normalization simplifies the analysis without altering the quality of the results. The market-clearing wage rate is W, sector 1 employs O_1L_0 units of labour, and all other sectors together employ the rest, O_2L_0 units of labour. Marginal products of labour are equalized across the sectors; this allocation of labour is efficient. Labour gets the area (B+E), and sector-specific factors receive area A and C respectively. Total income of the society is given by the area (A+B+C+E). Now we have our tools ready for the comparative static analysis of the appropriation problem. The main results are summarized in a series of propositions.

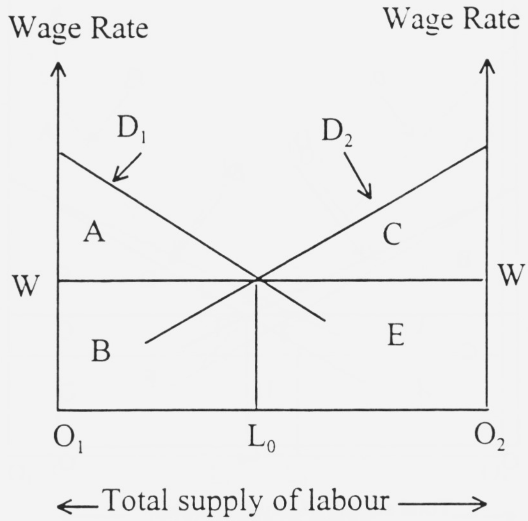


Figure 6. Equilibrium in the Labour Market

3. TECHNICAL CHANGE AND THE APPROPRIATION PROBLEM

Proposition 1: *If a sector has wage elasticity of demand for efficiency units equal to unity locally, then this sector will just appropriate its social contribution of labour-saving technical change. There will be no appropriation problem and the market will remain efficient.*

Proof: Assume that the conditions of the proposition hold - that is, sector 1 has unitary elastic demand for efficiency units of labour at the going wage rate - and it introduces a labour-saving technical change. Then, as discussed in the previous section, its demand for labour curve would shift to $D_1^{/}$ from D_1, as shown by the dotted line in Figure 7. The shift will be such that $D_1^{/}$ will intersect the existing demand curve, D_1, at point *e* so that there will be no change in the demand for physical units of labour at the going wage rate. The labour market equilibrium will be undisturbed, the equilibrium wage rate will remain at W_0, and the allocation of labour would be given by L_0.

The income of the society would be given by the area (A+B+C+D+E), which currently is given by the area (B+C+D+E). Hence the social contribution of the proposed technical change is given by the area A. Since sector 1 is currently appropriating the area B and would be appropriating the area (A+B) after the change, the private return of the proposed change is, therefore, given by the area A. Sector 1 will fully appropriate the social contribution of its technical change.

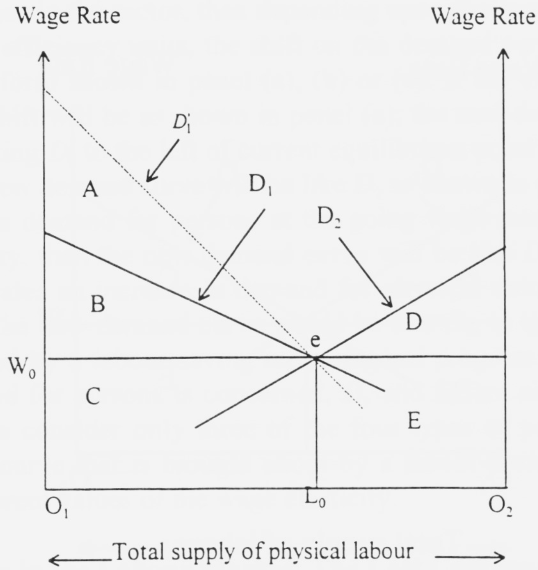


Figure 7. Technical Change and Appropriation in Sectors with Unitary Elastic Labour Demand

Given that the social and private costs of introducing the technical change do not diverge, the proposed change is privately profitable if, and only if it is socially profitable. Hence, the market remains efficient.

Proposition 2: *If a sector's local wage elasticity of demand for efficiency units is less than unity, then this sector will appropriate more than its social contribution of labour-saving technical change. There will be an appropriation problem and the market will fail in delivering an efficient outcome. Such sectors will over-introduce labour-saving technical change than is socially desirable.*

Proof: Assume that the condition of Proposition 2 holds, that is the local wage elasticity of sector 1's demand for efficiency units is less than unity. Then as a result of labour-saving technical change, its demand curve for physical units would shift to $D_1^{/}$ from D_1 as shown in Figure 8.

Since sector 1's demand for physical units of labour will fall at the going wage rate, the equilibrium wage rate would fall to W_1 and the allocation of labour across sectors would be given by L_1. Now let us examine the private and social contribution of this change.

Aggregate social output before the technical change in sector 1 is

$$Y_0 = [(B+C)+(D+E+F+G+H)] + [I+(J+K)]$$

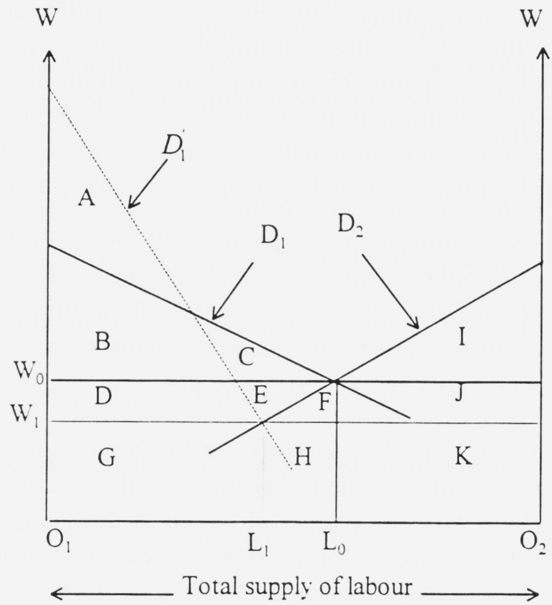


Figure 8. Appropriation Problem with Less Elastic Labour Demand

Aggregate social output after technical change in sector 1 would be

$$Y_1 = [(A+B+D) + G] + [(F+J+I)+(H+K)]$$

and therefore the social contribution of the technical change is

$$\Delta Y = Y_1 - Y_0 = (A-C-E).$$

Similarly, the profit of sector 1 before the technical change is given by

$$\Pi_0 = (B+C)$$

and the profit of sector 1 after the change would be

$$\Pi_1 = (A+B+D)$$

Therefore, private benefit of the technical change is $\Delta\Pi = (A+D-C)$.
Excess appropriation by sector 1, which is the excess of private benefit of technical change to sector 1 over its social contribution, is given by

$$\Delta\Pi - \Delta Y = (A+D-C)-(A-C-E) = (D+E) > 0.$$

Thus, sector 1 will be able to appropriate the area (D+E) in addition to its social contribution of the labour-saving technical change. Therefore, all labour-saving technical change that cost less than their private benefits will be privately profitable and will be introduced even if they cost more than their social benefits. there will be an over-introduction of labour-saving technical change. Hence, in this case, the market fails.

Proposition 3: *If a sector's local wage elasticity of demand for efficiency units of labour is greater than unity, then this sector will appropriate less than its social contribution of labour-saving technical progress. There will be an appropriation problem and the market again fails in delivering an efficient outcome. Such sectors will under-introduce labour-saving technical change than it is socially desirable.*

Proof: This proposition covers the case left out by Propositions 1 and 2. The proof follows a similar line of argument. Assume that the sector 1 has (at least locally) elastic demand for efficiency units of labour at the going wage rate. As discussed in the previous section, sector 1's demand for physical units of labour increases at the going wage rate as a result of the introduction of a labour-saving technical change. The consequent increase in the demand for physical units of labour is represented by the broken line, $D_1^{/}$, in Figure 9.

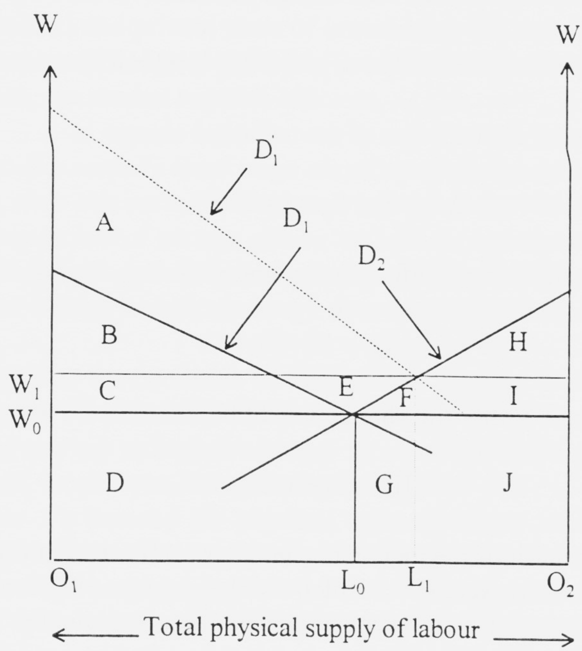


Figure 9. Appropriation Problem in Sectors with Elastic Demand for Labour

The wage rate rises to W_1 to clear the labour market, and sector 1 employs more persons and other sectors reduce their employment in the new equilibrium after the technical change. It is useful to recall that this shift in the labour demand curve of sector 1 is similar to the situation in which the sector had a labour-saving *technological* progress. Therefore, the result that follows represents both cases.

Now, let us examine the social contribution and private benefit of the change. The national output before the technical change in sector 1 is given by

$$Y_0 = [(B+C)+D]+[(F+I+H) + (G+J)]$$

and the national output after the technical change in sector 1 would be

$$Y_1 = [(A+B)+(C+D+E+F+G)] + [H+(J+J)]$$

Therefore, the social contribution of technical change is given by

$$\Delta Y = Y_1 - Y_0 = (A+E)$$

The profit of sector 1 before the technical change is given by

$$\Pi_0 = (B+C)$$

while the profit of sector 1 after change is given by

$$\Pi_1 = (A+B)$$

Therefore, private benefit to sector 1 of the labour-saving technical change is given by

$$\Delta\Pi = (A-C).$$

Clearly, the excess appropriation by sector 1 in this case is negative, for

$$\Delta\Pi - \Delta Y = (A-C)-(A+E) = -(C+E) < 0.$$

Thus, sector 1 *fails* to *fully appropriate* its social contribution of labour-saving technical change. Consequently, some projects that are socially desirable but are privately costly will not be undertaken. The market fails.

Corollary 1: *Whether or not a labour-saving technical change in a sector will produce pecuniary externality or trickle-down effects to other sectors depends on whether or not the local elasticity of labour demand of the sector is unity.*

Proof: This corollary follows immediately from Propositions 1,2 and 3.

Corollary 2: *There is an incentive to sectors with elastic labour demand to subsidise the introduction of labour-saving technical change in sectors with very low elasticity of labour demand. Such subsidization may actually take place if the size of the sector introducing the change is sufficiently large, even if all sectors behave competitively.*

Proof: It was shown in the proof of Proposition 2 that the market wage rate falls as a result of the introduction of labour-saving technical progress in sectors with inelastic labour demand. Because of this fall, all other sectors benefit, they increase their profit by the area (F+J) in Figure 8. It was shown in Proposition 3 that sectors with high wage elasticity of labour demand fail to fully appropriate their contribution to the national output and so under-invest in labour-saving technical change of their own. Suppose sector 2 in Figure 8 has elastic demand for labour. If sector 2 subsidises sector 1 up to the amount ε less than the area (F+J) to introduce a labour-saving technical change in sector 1 of the order represented in Figure 8, it will increase its profit by ε. If the change was not previously privately profitable to sector 1, it may now become profitable after the cross-subsidization from other sectors, which will further exacerbate the inefficiency of the market outcome. Therefore, the sectors with elastic demand have an incentive to subsidise sectors with inelastic demand for labour. There are two reasons not to expect such cross-subsidization to take place. First, technical change in a particular sector may have insignificant effect in the market wage rate and second, the benefit of lower wage would be shared by sufficiently large number of sectors suffering from the free rider problem. The presence of various producers' organizations, however, can serve to mitigate the importance of these two reasons and indirect cross-subsidization (such as research funding) may actually take place.

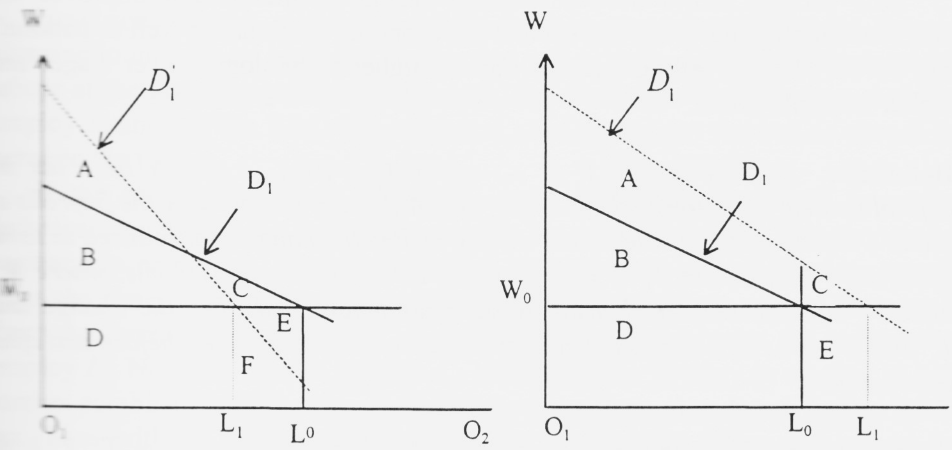
4. IMPLICATION TO REGIONAL ECONOMIES

Since a region can be considered as a small open sub-economy of the national economy, it can be viewed as a price taker in both goods and factor markets. In a model of a regional economy, a natural assumption would be to take commodity prices and the wage rate as given. It is possible to get the impression from Propositions 1-3 (Figures 7-9) that if a labour-saving technical progress does not alter the market clearing wage rate then there will be no appropriation problem. Therefore, regional markets, taken in isolation, will remain efficient. Hence, one may conclude that as far as regional economies are concerned the technological market failure of the above type is not relevant at all. This is, however, not true. We will shortly see that regional markets also fail to produce efficient outcomes when a labour-saving technical change takes place in production sectors, however small, with local wage elasticity of labour demand that is different from unity. This is because the appropriation problem is not caused by the change in the market wage rate resulting from the labour-saving technical change but from change in the demand for labour that follows the technical change.

Corollary 3: *Let there be an unlimited supply of labour at some exogenously fixed wage rate. A production sector, no matter however small, will fail to appropriate just the social contribution of its labour-saving technical change and the market fails if the local wage elasticity of its demand for the efficiency units of labour is different from unity.*

Proof: Let us consider the introduction of a labour saving technical progress in a small regional sector as represented in either of the two panels in Figure 10. The sector will be represented by panel (a) if its wage elasticity is less than unity and by panel (b) if its wage elasticity is greater than unity. Let the wage rate be fixed at W_0 and L_0 represent its initial level of employment. Its initial contribution to social output is given by the area (B+C+D+E+F) in panel (a) and by the area (B+D) in panel (b). The specific factor has received the area (B+C), and the area (D+E+F) is the wage bill in panel (a) and the specific-factor has received the area B and the area D is the wage bill in panel (b). With the introduction of a labour-saving technical change, the demand curve for physical units of labour shifts to D_1' from D_1 in both cases.

The sector would find it profitable to adjust, reduce in case (a) and increase in case (b), the employment level to the point L_1 from L_0. Since the output of the other sectors would remain unchanged, the change in national output because of the introduction of the labour-saving technical change in sector 1 is the same as the change in its own output. Therefore, the increase in social output is given by



(a) wage elasticity less than unity (b) wage elasticity greater than unity

Figure 10. Appropriation Problem in a Small Regional-Production-Sector

the area (A-C-E-F) in case (a) and the area (A+C+E) in case (b). The change in the sector's profit is given by the area (A-C) in case (a) and by the area (A+C) in case (b). The area (A-C) exceeds the area (A-C-E-F) by the area (E+F) and the area (A+C) falls short of the area (A+C+E) by the area E. There is an over-appropriation in case (a) and an under-appropriation in case (b). Thus, even if the wage rate is unaffected by the sector-specific technical change, *the regional market fails in delivering an efficient outcome if the wage elasticity of demand for labour in the regional production sector introducing the technical change is different from unity*. More importantly, the discrepancy between private gain and social contribution of a given technical change is greater when the wage rate is exogenously fixed than when it is flexible.

The above result clearly implies that a labour-saving technical progress alone, if it occurs in sectors with low wage elasticity of labour demand, can cause regional unemployment even if the economy was previously at full employment. Overtime it may build up sufficient pressure in the national labour market for the market-clearing wage rate to fall, which can be expected to eliminate the regional unemployment. In a world of ever changing techniques of production, however, maintenance of full employment through market forces only, therefore, seems rather unlikely; we may simply observe a recurring sequence of higher technology, higher unemployment and lower wage rates. Therefore, we now ask: is there a way to correct the operation of the market mechanism that breaks this cycle?

5. LEGISLATION OF R&D SUBSIDY AND CORRECTION OF THE MARKET FAILURE

This section shows how a carefully designed intervention improves the efficient functioning of the market and the economy (regional as well as national) can be saved from falling into the trap of higher technology, lower wages and higher unemployment.

Definition: *For sectors j= 1, 2, ..., n, let* $T_j = (W_0L_{0j} - W_1L_{1j})$ *be a tax on capital income of sector j, where* W_0L_{0j} *and* W_1L_{1j} *are respectively the payrolls of sector j before and after the labour-saving technical change is introduced in some arbitrary sector 1. Let* $T_L = W_1L^1 - W_0L^0$ *be a tax on wage-income, where* W_0 *and* W_1 *are the market clearing wage rates before and after the change and* L^0 *and* L^1 *are respectively the economy-wide employment levels before and after the change.*

Proposition 6: *Then the legislation of a R&D tax* $T = \{T_1, T_2, \cdots, T_n, T_L\}$ *on capital income of the n-production sectors and on the wage income of labour, irrespective of whoever introduces the labour-saving technical change, improves market efficiency. It corrects the market failure with a small second order dead weight loss. Moreover, unless the economy has unemployment and the firm introducing the labour-saving technical change is increasing its demand for* *labour at the going wage rate, the proposed R&D tax/subsidy need not require actual collection of the tax or payment of the subsidy.*

Proof: We first show that the R&D tax/subsidy improves market efficiency, when a single sector in a regional economy introduces a labour-saving technique.

As we have already seen from Figure 10, at the free market solution a sector would over-appropriate by the area (E+F) in case (a) and under-appropriate by the area E in case (b). The employment in the sector falls in case (a) and rises in case (b). The wage bill declines in (a) and rises in (b). As a result, the sector would be liable to an R&D tax equal to the area (E+F) in case (a), and a subsidy equal to the area E in case of (b). The workers are entitled to a subsidy equal to the area (E+F) in a case of (a) and a tax equal to the area E in case of (b). There is no funding problem in the scheme, since the tax exactly offsets the over or under appropriated amount. It corrects the malincentive provided by the market, therefore, only socially desirable technical change will take place.

It can now be shown that the sector actually chooses to employ L_0 amount of labour in case (a) and L_1 in case (b) with the better technique of production in place.

Consider the special case (b), in which there is unemployment and the firm is planning to introduce a technical change that will actually increase its demand for labour at the going wage rate. Because of the tax/subsidy the sector will increase employment to L_1, and collect the area (A+C+E) as increased rent as the area E will be funded by tax on the wage income. In this case, a local government, however, may have to negotiate with other regional governments or with the federal government for the collection and transfer of the R&D wage-income tax. Otherwise, it has to find some other source of income to fund the R&D subsidy. This case certainly needs a collection of the tax and payment of the subsidy.

Now consider the case (a) in which there is unemployment and a firm is planning to introduce a technical change that will actually decrease its demand for labour at the going wage rate. In this case, the sector has the following choices: employ L_1 and pay the R&D tax, employ L_0 and do not pay the tax, or choose in between the two.

If the sector chooses to employ L_1 units of labour, its payoff from the technical change and the R&D tax would be the area (A-C-E-F). If it chooses to continue to employ L_0 persons even after the technical change, then its payoff from the change would be the area (A-C-E). It will be able to recoup the area F from the increased production. Clearly to employ L_0 dominates the strategy to employ L_1. Not only that, to employ L_0 dominates the strategy to employ at any convex combination of the two. Hence the sector will employ L_0 and pay no R&D tax. Thus with the R&D tax/subsidy scheme in place, no sector will reduce its employment level, and all socially profitable technical changes will be implemented while no actual collection of the tax and payment of the subsidy is required.

Now consider this scheme in a general equilibrium (in which there is no unemployment to start with) solution of the economy. Assume that a sufficient number of sectors introduce labour-saving technical change and the labour market feels the difference. The market-clearing wage rate adjusts to clear the labour market. Will the proposed scheme be still useful in improving market efficiency?

First, consider the case of falling demand for labour and that sectors with very small wage elasticity of labour demand introduce the change. This can be analysed with the help of Figure 11, which is basically Figure 8 with the area H in Figure 8 divided into two parts, I and H.

We know that the free market solution in this case is that the sector over-appropriates by the area (D+E), the employment in sector 1 falls to L_1, and the wage rate falls to W_1. Since the payroll declines after the change, the sector is liable to an R&D tax, which is equal to the area (D+E+F+I+H). Hence, if the sector chooses to stay with the market solution its net profit will increase by the area [A - (C+E+F+I+H)] over its initial value of (B+C). If, however, the sector chooses to employ the L_0 units, then it does not have to pay the tax since the wage rate and hence its wage bill will not fall. Its profit will increase by [A - (C+E+F+I)]. Thus, by choosing to employ the original number of workers rather than L_1 the sector can increase its profit by the area H, (i.e. recover part of its R&D tax liability). Hence, the sector will choose to employ L_0.

As the pecuniary externality is controlled at its source, the external effect of technical change has been internalized.[2] There will be no effect on other sectors whatsoever of the technical change since the wage rate remains unchanged. The sector introducing the change appropriates just its contribution to the society, and the income of the rest of the society is unchanged. This is not the first best solution, however; there is some inefficiency left out. It is the area (F+I), which represents the loss in social output of labour from being employed in 'less productive' employment. The cost of being so will not be borne by the workers, though.

Finally, consider the case in which sectors with high wage elasticity of labour demand introduce the labour-saving technical change. To analyse the effectiveness of the R&D tax/subsidy scheme, reconsider Figure 9, which is slightly modified and reproduced as Figure 12.

We know that in this case the market solution implies an under appropriation of the social contribution made by the sector (Proposition 3). We want to see whether the R&D tax/subsidy scheme can correct this problem or not.

Note that the technical/technological progress introduced in sector 1 causes the market wage rate to rise; the payroll of the sector 2 will also rise at unchanged

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2 Pecuniary externality involves a change in the welfare of other agents via changes in commodity and/or factor prices faced by those agents. To produce a pecuniary externality, an action should first alter either the demand function or the supply function or both in at least one market. If, however, the prices are fixed exogenously, such as in the regional economy we have considered, a change in the factor demand and/or supply is the vehicle through which the pecuniary externality operates. It can then alter the income of agents other than the one introducing the change.

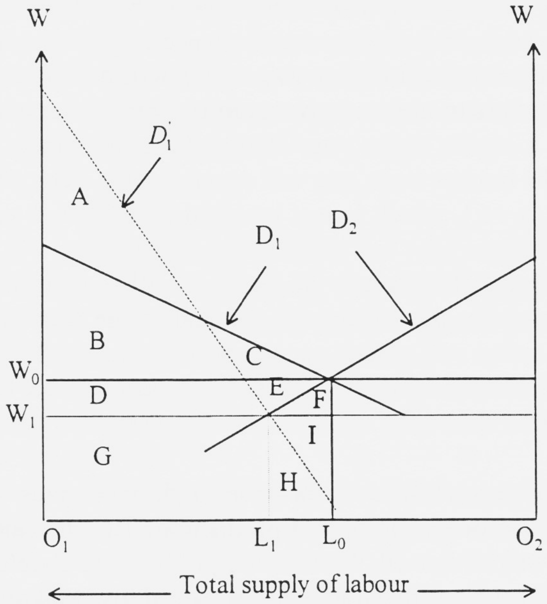

Figure 11. Technical Change in Many Sectors with Inelastic Labour Demand, Labour Market Equilibrium and the R&D Subsidy

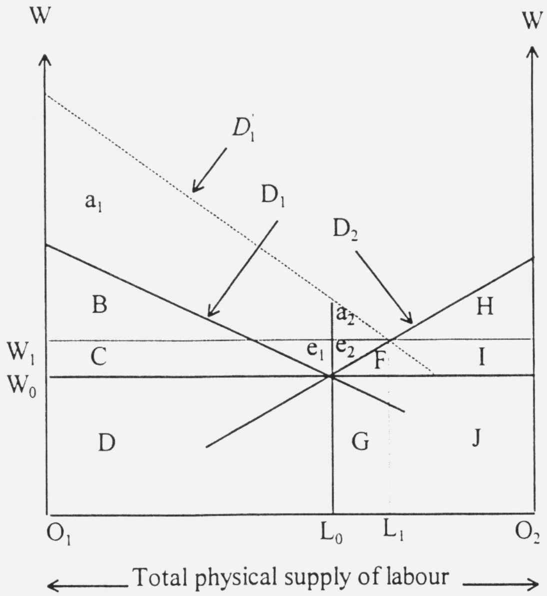

Figure 12. Technical Change in Sectors with High Wage Elasticity of Labour Demand, Labour Market Equilibrium and the R&D Tax/Subsidy Scheme

employment. Since the R&D tax/subsidy scheme provides subsidy to the production sectors to cover any rise in their wage bill at the market wage rate, sector 2 will not reduce its employment irrespective of the market wage rate. Since extra income earned via higher wage rates will be taxed away, there is no incentive to the workers to move sectors even if sector 1 wants to bid them away by offering them a higher wage rate. Hence the employment in sector 1 will remain at L_0, and the market wage rate will remain at W_0. Sector 1 will increase its profit by the area (a_1+e_1), which is just equal to its marginal social contribution via the technical change.

The marginal product of labour in sector 1 will remain higher than that in other sectors, causing the dead weight loss equal to the area (a_2+e_2). Hence, the guided market allocation will remain second best.

6. CONCLUSION

The market in general fails to provide right incentives when sectors do change their technique or technology of production. The first theorem of welfare economics, which states that all Walrasian equilibria are Pareto efficient, needs another revision. The first revision was proposed by Makowsky and Ostroy (1995). They have shown that markets can not provide correct incentives when sectors are engaged in product innovation. They suggested that private price information regarding new products held by different agents should be consistent in order for the Walrasian equilibrium with this possibility to be Pareto efficient. Here we have shown that if sectors change production techniques or technology, the Walrasian equilibrium may not necessarily be efficient. In order for the first theorem of welfare economics to remain valid, the sectors should not be allowed to change their production technology. They, however, may change their technique of production provided the wage elasticity of labour demand always remains equal to unity, which is rather stringent.

In this paper, we have demonstrated that sectors with 'inelastic' demand for labour tend to over-do and sectors with 'elastic' demand for labour tend to under-do labour-saving technical progress compared to what would be the social optimum. It happens because of the appropriation problem; these sectors fail to appropriate their social contribution of the technical change correctly and therefore they receive incorrect signals from the market.

To avoid this deficiency in the market mechanism, an R&D tax/subsidy scheme is proposed. This scheme funds all increases in the payrolls of the production sectors arising out of labour-saving technical progress and taxes away any saving made in their payrolls, irrespective of whether the sector is responsible for the change or not. This scheme also does not let wage earners suffer or benefit from the pure technical change. The most interesting aspect of this scheme is that it restores the market efficiency and only needs to be legislated. There is neither any need for actual tax collection nor a need for the subsidy being paid out unless there is unemployment already in the economy and that the firm introducing the technical change is creating new jobs.

It should be noted that there might be other ways of correcting the incentive system of the market; the proposed R&D tax/subsidy is not the only possibility. In the absence of some corrective policy, however, there is always a danger of the economy falling out of full employment, and plunging continually into the cycle of higher technology, higher unemployment, and lower wages.

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