CHAPTER III
LABOUR-AUGMENTING TECHNICAL CHANGE IN A
IN A SMALL OPEN ECONOMY

We begin with the simple dual economy model postulated by Lewis¹ to study the implications of economic development for employment and income distribution. The economy can be divided into two sectors: (i) the capitalist or modern sector, which is that part of the economy which uses reproducible capital and pays the capitalists' for the use thereof and (ii) the subsistence or traditional sector, which is, by difference, that part of the economy that does not use reproducible capital. The traditional sector is assumed to produce food and the modern sector is assumed to produce non-food products. The distinction between the two sectors lies in a basic asymmetry in productive relations. The traditional or agricultural sector does not use any reproducible capital. It uses land, which is in fixed supply, and labour to produce an output of food. This sector is said to be characterised by "disguised unemployment" and is a source of "unlimited supply of labour" for industry.

The modern sector, on the other hand, uses

¹ Ibid. Lewis.
reproducible capital and labour to produce an industrial product which may be used either as a consumer good or as a capital good. The production process in the modern sector is characterised by a continuous, twice-differentiable, single-valued, production function, which is subject to constant returns to scale. The modern sector wage is assumed to be fixed in terms of the traditional sector output. Further, the terms-of-trade between the modern and traditional sectors are assumed to remain unchanged. This assumption can be incorporated in the Lewis model either by assuming that both sectors produce the same output or by assuming that the economy under consideration is a small open economy so that the terms-of-trade are set by world prices. In this model we invoke the latter assumption to ensure that the terms-of-trade remain constant. Unlimited quantities of labour are available to the modern sector at the fixed real wage. The modern sector operates on the basis of profit maximisation and employment is determined by the equality between the fixed real wage and the marginal product of labour. The residual labour is absorbed by the traditional sector, thus ensuring full employment. Thus, the labour and food requirements of the modern sector are met by the traditional sector. Finally it is assumed that savings are
proportional to profits, the proportion depending on the rate of interest. Since the rate of interest remains constant and there is no technical progress in the basic Lewis model, savings are proportional to the rate of interest. Agricultural rent, if any, is appropriated by the landlords who consume it entirely.

The production function in the modern sector is given by

\[ Q = F(K, L) \]

\[ F'_K > 0, \quad F''_K < 0 \]

\[ F'_L > 0, \quad F''_L < 0 \]

or \[ Q = LF(K/L, 1) \] since the production function is assumed to be homogeneous of degree one.

Therefore, \[ Q = Lf(k) \]

\[ (1) \]

where \( k = K/L \).

From the condition of profit maximisation we have

\[ f(k) - kf'(k) = \bar{w} \]

\[ (2) \]

and \[ f'(k) = r \]

\[ (3) \]

where \( \bar{w} \) is the modern sector wage and \( r \) is the rate of return on capital.

Now \( k = \phi(w) \) [from equation (2)] exists so long as \( MPL_{max} \geq w \geq MPL_{min} \) holds. However, since \( w \) is fixed at \( \bar{w} \) we have \( \hat{k} = \gamma(\bar{w}) \).

And since \( k \) is fixed at \( \hat{k} \) we have a fixed capital-
output ratio. If "s" is the proportion of profits saved, we have

\[
\frac{\dot{K}}{K} = s(r) \frac{\dot{Q}}{Q} = \dot{L}
\]

(4)

given the constant capital-output ratio. Further, the rate of growth of employment, \( \dot{L} \) also equals \( s(r) \frac{\dot{L}}{L} \) as the capital intensity remains unchanged.

Therefore, \( \frac{\dot{Q}}{Q} = \frac{\dot{K}}{K} = \frac{\dot{L}}{L} = s(r) \frac{\dot{L}}{L} \) and the economy develops in a balanced growth fashion until the capitalist sector has exhausted all reserves of labour in the subsistence sector.

In the simple model at hand, an appropriate distribution measure might be based on the importance of capital income \( rK \), relative to the income accruing from urban employment, \( \bar{W}L \).

Thus \( D = \frac{\bar{W}L}{rK} \)

(5)

or \( \frac{\dot{D}}{D} = \frac{\dot{L}}{L} - \frac{\dot{r}}{r} - \frac{\dot{K}}{K} \)

(6)

In this case \( \dot{D} = 0 \) since the rate of accumulation 

\( \frac{\dot{D}}{D} = 0 \)
equals the rate of growth of employment and the rate of interest remains constant. Therefore, the relative distribution of income remains unchanged in the modern sector. But, eventually, as the unlimited supplies of labour are exhausted and the real wage rate begins to rise, the share of profits will have a tendency to fall. This model is, therefore, unable to explain a surge in inequality, in terms of a shift in the relative distribution of income in favour of profits and against labour, in the modern sector.

What then would explain a shift in the relative distribution of income towards profits? According to Williamson², a potentially powerful force behind the distribution of income is the degree to which technological progress tends to economise on some factors of production while favouring the use of others. A bias towards labour saving can widen income gaps by worsening job prospects and relative wages, while bidding up the returns to capital. Johansen³, pointed out that a once-for-all labour saving technical change has two consequences. It reduces modern sector employment and labour income levels in the short-run, but it may increase employment in the

².Ibid. Williamson.

long-run because it permits a more rapid accumulation of capital. Continuous labour saving technical change may then be unfavourable to labour even in the long-run if the employment reducing effect dominates. Further, as technical progress quickens, the pace of labour-saving will rise as well. The relative displacement of labour may accelerate over time, fostering inequality on the upswing of the Kuznets curve. Thus, the effect of increasing labour saving bias in the modern sector is to diminish both the rate of labour absorption and labour's share in that sector.

As noted earlier, technical change in Developing countries has tended to be labour saving. Since the development of innovations is expensive in the Developing economies, industrial technologies are imported from abroad, containing labour saving biases, induced by factor prices prevailing in advanced economies, in which these capital goods are produced. Part of this pattern of technical change may be explained by government policy, namely, an artificially high ratio of wages to interest rate and an artificially low foreign exchange rate. This can be seen with the help of figure 3.1. Isoquants A and B relate to the same output. Technology A is relatively more labour saving than B. The slope of the fully drawn iso-cost line expresses the factor price
Fig 3.1
ratios in the event of competitive factor hiring. In this case A and B appear equally desirable. However, if an imperfection (due to government policy) were to raise the wage rate relative to the interest rate, A becomes superior to B. The imperfection is here illustrated with the aid of an iso-cost line, which in the neighborhood of the ordinate coincides with the fully drawn line, but further down continues along the broken path.

Let us, therefore, study the impact of labour augmenting technical change for a labour abundant and capital scarce economy. Labour augmenting technical change is introduced in the modern sector, while the rest of the earlier assumptions are retained.

The labour input \( L \) would now be equal to \( L e^\lambda \) and the production function would become

\[
Q = F(K, L e^\lambda)
\]

where \( \lambda \) is the rate of technical progress.

The production function can be rewritten as

\[
Q = Le^\lambda F(K/Le^\lambda, 1)
\]

or

\[
Q = Le^\lambda f(\Theta)
\]

where \( \Theta = K/Le^\lambda \)

Profit maximising behaviour implies

\[
e^\lambda \{f(\Theta) - \Theta f'(\Theta)\} = \bar{w}
\]

and \( f'(\Theta) = r \)

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Now equation (8) is equivalent to
\[ f(\theta) - \theta f'(\theta) = \bar{w}e^{-\lambda t} \]

or \( \theta = \phi(\bar{w}e^{-\lambda t}) \) and \( \phi' > 0 \)

Therefore, \( r = f'(\phi(\bar{w}e^{-\lambda t})) \) and over time as \( \theta \) falls, the rate of return on capital, \( r \), rises.

Since capitalists' are assumed to save a proportion "s" of their income and \( s \) is assumed to be a function of \( r \),

\[ K = s(r).r.K \]

\[ \frac{\dot{K}}{K} = s(r).r \]

or \[ \frac{\dot{K}}{K} = s[f'(\theta)].f'(\theta) \]

or \[ \frac{\dot{K}}{K} = s[f'(\phi(\bar{w}e^{-\lambda t}))].f'(\phi(\bar{w}e^{-\lambda t})) \] (10)

Now \( \theta = \phi(\bar{w}e^{-\lambda t}) \).

or \( K = \phi(\bar{w}e^{-\lambda t}) \)

\[ Le^{\lambda t} \]

Therefore, \( L = \frac{Ke^{-\lambda t}}{\phi(\bar{w}e^{-\lambda t})} \)
\[
\frac{\dot{L}}{L} = K - \lambda \left[ 1 - \frac{\phi' \cdot \bar{w}e^{-\lambda e}}{\phi} \right]
\]

(11)

Substituting for \( K \) from equation (10) we get

\[
\frac{\dot{L}}{L} = \frac{s(f'(\phi(\bar{w}e^{-\lambda e}))) \cdot f'(\phi(\bar{w}e^{-\lambda e})) - X}{L} \left[ 1 - \frac{\phi' \cdot \bar{w}e^{-\lambda e}}{\phi} \right]
\]

(12)

Now \( \phi' \cdot \bar{w}e^{-\lambda e} \) is nothing but the inverse of the elasticity of the marginal product of labour with respect to \( \theta \). Therefore, substituting for \( \phi' \cdot \bar{w}e^{-\lambda e} \) we have

\[
\frac{\dot{L}}{L} = \frac{s(f'(\phi(\bar{w}e^{-\lambda e}))) \cdot f'(\phi(\bar{w}e^{-\lambda e})) - \lambda}{L} \left[ 1 + f(\theta) - \theta f'(\theta) \right]
\]

\[
\frac{\dot{L}}{L} = \frac{s(f'(\phi(\bar{w}e^{-\lambda e}))) \cdot f'(\phi(\bar{w}e^{-\lambda e})) - \lambda}{L} \left[ 1 - \frac{\sigma}{1 - sL} \right]
\]

(13)

(see Appendix A)

where \( \sigma \) is the elasticity of substitution and
\[ 1 - s_L = \frac{\theta f'(\theta)}{f(\theta)} \]

L can be decomposed into two effects. The first effect can be attributed to the increasing rate of accumulation while holding the capital-labour ratio constant. The second effect can be further decomposed into two components: (i) the labour displacement that would have resulted from labour augmenting technical change, if the relative costs of augmented labour and capital had remained constant and (ii) the effect of a fall in unit cost of augmented labour and the consequent substitution of unit labour for capital. The substitution effect depends upon the elasticity of substitution, \( \sigma \). Thus, we find that as long as \( \sigma \) is greater than \( 1 - s_L \), the share of capital, the substitution effect will dominate, and employment will be increasing at a rate faster than that of capital accumulation. The contribution of technical progress to employment would be positive not merely because of increasing accumulation, but also because, on balance, it leads to more employment per unit of capital since the cost of augmented labour is falling at the exponential rate \( \lambda \). Consequently, it becomes profitable to substitute
labour for capital at a rate which more than offsets any labour saving effects the technical progress would have had if relative costs had remained unchanged. Since \( 1-s_L \) will always be less than one, an elasticity of substitution greater than or equal to one will always ensure that employment increases and increases more rapidly than capital accumulation. A sufficient condition, therefore, for the capital-labour ratio to be falling is that \( \sigma > 1 \). It is not, however, a necessary condition for the capital-labour ratio to be falling. The necessary condition would be

\[
\sigma > 1 \quad \text{and} \quad \frac{1}{1-s_L} < \sigma = \frac{1}{1-s_L} - 1
\]

if \( \sigma < 1 \).

Over time, as \( t \to \infty \), \( \theta \to 0 \), it is possible to distinguish between two cases.

(1) \( \lim_{\theta \to 0} \sigma < 0 \)

In this case \( r \) would tend to a finite limit \( \bar{r} \) and \( K \to s(\bar{r}) \bar{r} \) and as capital becomes scarce relative to augmented labour, the share of the scarce factor will increase up to one. Therefore,

\[
\lambda \left[ \frac{1 - \sigma}{1 - s_L} \right] \rightarrow \lambda \left[ \frac{1 - \lim \sigma}{1} \right]
\]

or \( \dot{L} \rightarrow s(r).r - \lambda (1 - \lim \sigma) \)

Employment would eventually grow at a rate much less than that of capital accumulation because the elasticity of substitution, \( \sigma \), is less than one. It is also possible to envisage a situation where employment would actually decline, that is, if \( s(\bar{r}).\bar{r} < \lambda (1 - \lim \sigma) \).

(2) \( \lim_{\theta \to 0} \sigma \geq 1 \)

Here output and the average and marginal products of capital increase without limit as more labour is applied. Therefore, as \( \theta \to 0 \), \( r \to \infty \), and \( K \) will also tend to infinity. It is thus a case of infinitely rapid expansion in employment until the unlimited supplies of labour are fully exhausted.

Thus, we find that as long as the elasticity of
substitution is greater than or equal to one, employment increases at a rate faster than that of capital accumulation. Further, the relative distribution tends to shift in favour of labour and the relative share of profits tends to decline much before the turning point is reached.

Now if \( D = \frac{\text{WL}}{rK} \) is the relative distribution of income in the modern sector,

\[
\frac{\dot{D}}{D} = \frac{\dot{L} - \dot{r} - \dot{K}}{L - r - K} \tag{6}
\]

since the real wage \( \hat{w} \) is assumed to remain constant.

Now

\[
\frac{\dot{L}}{L} = \frac{\dot{K} - \lambda - \dot{\theta}}{K - \theta} \quad \text{from} \quad Ke^{-\lambda\theta} = L
\]

Substituting for \( \frac{\dot{L}}{L} \) in equation (6) we have

\[
\frac{\dot{D}}{D} = -\lambda - \frac{\dot{\theta}}{\theta} - \frac{\dot{r}}{r}
\]

Since \( r = f'(\theta) \), \( \frac{\dot{r}}{r} = \frac{f''(\theta)}{f'(\theta)} \).
\[
\frac{\dot{r}}{r} \text{ can be rewritten as } 1 - \frac{\dot{\sigma}}{\sigma \theta} (s_L)
\]

(see Appendix A)

Substituting for \( \frac{\dot{r}}{r} \) in equation (6) we have

\[
\frac{\dot{D}}{D} = (\sigma - 1) \frac{\lambda}{(1 - s_L)} \quad (15)
\]

\( \frac{\dot{D}}{D} \) will be positive so long as \( \sigma \) is greater than one. We find that, contrary to existing belief, labour augmenting technical progress would be beneficial to labour and the relative distribution of income actually improves. Both the rate of labour absorption and labour's share in the industrial sector would be increasing. In this case, therefore, we find that labour saving technical bias does not account for the rising portion of the Kuznets curve.

However, if the elasticity of substitution were less than one, \( \frac{\dot{D}}{D} \) will be negative and the relative share of profits will go on rising indefinitely. The labour saving
technical change, would, in this case result in a disappointingly low rate of labour absorption and labour share in the manufacturing sector.

The absolute share of labour in the modern sector is given by $\overline{WL}$. The growth in the absolute share of labour coincides with the rate of growth of employment, $L$ and $\frac{L}{L}$ can thus be decomposed into the three effects noted earlier, namely, the effect due to the increasing rate of capital accumulation, the labour-displacement effect due to labour augmenting technical change and, lastly, the effect of a fall in unit cost of augmented labour and the consequent substitution of labour for capital. Both the increasing rate of accumulation, as well as the effect of the fall in unit cost of augmented labour, have a positive impact on the absolute share of labour. The labour-displacement effect is, however, negative. The net effect of labour augmenting technical change on the absolute share of labour depends on the elasticity of substitution, $\sigma$. So long as $\sigma$ is greater than one, the positive impact of a fall in the unit cost of augmented labour exceeds the labour-displacement effect and the absolute share of labour grows at a rate faster than capital
accumulation. If, however, $\sigma$ is less than one, the labour-displacing effect outweighs the effect of a decline in relative factor costs and the absolute share of labour grows at a rate less than the rate of capital accumulation.

The foregoing can be illustrated by using specific forms of the production function. Consider first the case of a CES production function.

$$Q = [\alpha K^{-\varphi} + (1-\alpha)(Le^{\lambda e})^{-\varphi}]^{-1/\varphi}$$

or

$$Q = Le^{\lambda e}[\alpha \theta^{-\varphi} + (1-\alpha)]^{-1/\varphi}$$

where $\varphi$ is a parameter of substitution and $\theta = \frac{K}{Le^{\lambda e}}$

$$\frac{L}{K} = \lambda \left[1 - \sigma (1 + \theta^{\lambda/\varphi} - 1) \right]$$

where $M = \frac{\alpha}{1-\alpha}$, that is, the share of capital relative to the share of labour.

Again we find that as long as the elasticity of substitution is greater than or equal to one, technical progress is in the interests of labour.
Now since \( \frac{\dot{\theta}}{\theta} = -\lambda \sigma \left[ \frac{1 + \theta^{1/\sigma} - 1}{M} \right] \)

\[
\frac{d\theta}{dt} = -\lambda \sigma \theta \left[ \frac{1 + \theta^{1/\sigma} - 1}{M} \right]
\]

Solving for \( \theta \) we get

\[
\theta = \left[ R e^{-\left(\frac{\sigma - 1}{\lambda} \cdot \lambda t - 1/M \right)} \right]^{\sigma/\sigma - 1}
\]

(see Appendix A)

where \( R \) is the constant of integration.

Now \( \lim_{t \to \infty} \theta = \lim_{t \to \infty} \left[ R e^{-\left(\frac{\sigma - 1}{\lambda} \cdot \lambda t - 1/M \right)} \right]^{\sigma/\sigma - 1} \)

\[
= \left[ -1/\lambda \right]^{\sigma/\sigma - 1}
\]

where \( \lambda \) is the share of capital vis-a-vis labour

Again \( \frac{D}{D} = (\sigma - 1) \cdot \frac{\lambda}{(1-s_L)} \)

The results in this case conform with those obtained in the general case, namely, depending on whether or not
the elasticity of substitution, \( \sigma \), exceeds unity, the relative distribution of income in the early stages of economic development improves or worsens.

Next let us consider the case of a Cobb-Douglas production function.

\[
Q = K^\alpha \cdot (L \cdot e^t)^{1-\alpha}
\]

or

\[
Q = L^\alpha \cdot e^t \cdot \frac{\theta^\alpha}{Le^t}
\]

where \( \theta = \frac{K}{L} \).

Thus

\[
\frac{\dot{L}}{L} = \frac{\dot{K}}{K} \cdot L \cdot \frac{1 - 1}{K} - \lambda \left[ 1 - \frac{1}{\alpha} \right]
\]

since \( \sigma \) equals one and \( (1-s_L) \) equals \( \alpha \). Now \( \alpha \) is less than one and hence employment growth will be higher than the rate of accumulation. Over time as \( \theta \) tends to zero both \( \frac{\dot{K}}{K} \) and \( \frac{\dot{L}}{L} \) will tend to infinity, again because \( \sigma \) equals one. In this case the relative distribution of income does not change because of the Cobb-Douglas property ( \( \frac{\dot{D}}{D} = 0 \)).

However, the faster rate of technical progress will be in
the interests of labour since employment grows more rapidly than capital accumulation. The presence of exogenous labour saving technical progress does not account for an accentuation in relative inequality in the modern sector.

In general, we find that with labour augmenting technical progress both the growth of employment as well as the relative returns to factors depend crucially on the elasticity of substitution. As long as the elasticity of substitution is greater than or equal to one, employment grows faster than capital accumulation and over time employment growth would tend to infinity. Further, technical progress is beneficial to labour and the relative income distribution in the modern sector actually improves. A low elasticity of substitution ($\sigma < 1$), however, results in a low employment growth and over time as capital accumulation approaches a finite limit, employment grows at a rate much less than that of capital accumulation. It is also possible to envisage a situation in which employment actually declines. Relative inequality in the modern sector increases indefinitely when the elasticity of substitution is less than unity.