LOCALIZED TECHNICAL PROGRESS

AND

TRANSFER OF TECHNOLOGY

AND

ECONOMIC DEVELOPMENT

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Localized Technical Progress and Transfer of Technology and Economic Development

In much of neoclassical growth theory technical progress is represented as a uniform shrinking of the unit isoquant toward the origin. In much of the development literature, however, it is emphasized that technical advances applicable to the factor-proportions of capital-rich developed countries are hardly of any use in improving techniqes of low capital-intensity in less developed countries; taking transport technology as an example, the improvements in modern jet aircraft technology do not particularly help raising the productivity of rickshaw-pullers in the streets of Calcutta or Hong Kong. In a recent paper Atkinson and Stiglitz [1] have introduced the concept of localized technical progress to capture this phenomenon of improvements in technical knowledge being specific to particular processes. Although most of their formal analysis refers to the extreme case of technical progress being completely localized to one technique, they have also mentioned the more general possibility of spillover of improvements to some other techniques near enough to the currently used factor proportions. If knowledge acquired through learning or research activity is localized, they have correctly argued that the history of the economy is important in determining its current characteristics and that planning of present activities cannot be made independently of their long run consequences. In this respect localized technical knowledge has the same characteristics as "putty–clay" capital.

In this paper we intend to pursue some of these implications further and apply them to the problems of borrowing foreign technology in a developing economy. Transfer of technology from developed to developing economies has been a relatively unexplored area both in theoretical and empirical research. Only in very recent years has some analytical attention been paid to direct and indirect costs of such transfer. A long-standing issue has been the problem of appropriate factor proportions; to quote from a popular text in economic development [2, p. 249], the question is

> whether countries at early stages of development, with capital scarce and often with labor abundant, should take advantage of the modern technology developed by advanced countries, where capital is abundant and labor scarce, or whether they should devise a technology of their own or use production methods which are obsolete in countries abroad.

The problem, therefore, is to decide whether the gains in production due

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to the increased efficiency of advanced technology ("localized" to the prevailing factor proportions of the advanced country) outweigh the costs necessitated by the high level of capital-intensity in a capital-scarce country.

We shall explore a rather simple model in which the developing nation must choose between production in which capital and labor are substitutable, or an alternative method which is more efficient, but which is available only at a particular capital–labor ratio (hereafter, a technique will be defined by its capital–labor ratio). We shall find:

(i) The "advanced" technique is, as may be expected, more likely to be employed the greater is its efficiency (vis-a-vis technology available in the developing country), and the smaller is the difference between the capital–labor ratio used in this technique and the capital–labor ratio of the developing nation.

(ii) At most two techniques will be employed at once.

(iii) The adoption of the more advanced, capital-intensive technique tends to suppress wages in the developing country.

(iv) If the wage rate in the developing country exceeds the shadow price of labor, the advanced technique may be employed under profit maximization, though from society's viewpoint this decision is inefficient. Finally, we shall demonstrate how our results can be extended to consider cases in which many alternate advanced techniques exist.

Assume that differences in production functions are due to differences in efficiency alone, and that the developing nation seeks to maximize total output Q given its resource limitations:[1]

$$Q = Q_1 + Q_2 = L\,[\gamma f(k_1) + (1 - \gamma)A f(\bar{k})];\ A > 1; \tag{1}$$

$$\bar{k} = \text{capital–labor ratio of advanced technique, taken as given;} \tag{2}$$

$$k_1 = \text{capital–labor ratio of backward technique, to be chosen;} \tag{3}$$

$$k = \text{aggregate capital–labor ratio;} \tag{4}$$

$$\gamma = (L_1/L);\ \gamma k_1 + (1 - \gamma)\bar{k} = k. \tag{5}$$

Though this problem is readily solvable by mathematical techniques, a simple graphical interpretation exists. In Fig. 1, point B represents the advanced technique, whereas the $f(k)$ curve represents the basic production

[1] If a fixed fraction of the output from the advanced technique must be paid as royalties, then the impact of this on allocational decisions is equivalent to the impact of a decrease in A.

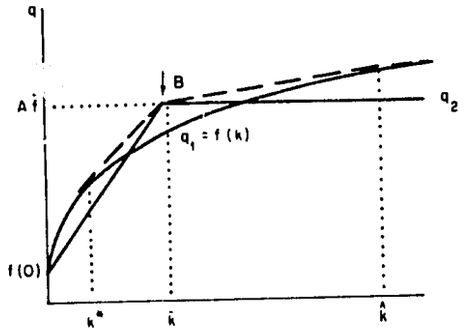

FIG. 1. Maximizing output and localized technical progress.

function. To maximize output we seek a line segment through B and tangent to $f(k)$ (assuming such a tangent exists[2]); in general, two such tangents exist—one for $k < \bar{k}$, the other for $k > \bar{k}$ (our interest is for the case $k < \bar{k}$; the other case follows by symmetry). Once these tangents are found, the aggregate production function becomes $f(k)$ for $k \leqslant k^*$; (or $k \geqslant \hat{k}$), and the (dashed) tangent lines for $k \in (k^*, \hat{k})$.

Mathematically, this is equivalent to finding $k^* < \bar{k}$ and $\hat{k} > \bar{k}$ such that

$$A\bar{f} = [f(k_1) - k_1 f'(k_1) + \bar{k} f'(k_1)]; \quad k_1 = k^* \quad \text{or} \quad k_1 = \hat{k}. \tag{6}$$

Economically, (6) states that, in order to maximize output and for both sectors to coexist, the opportunity cost of the labor and capital transferred

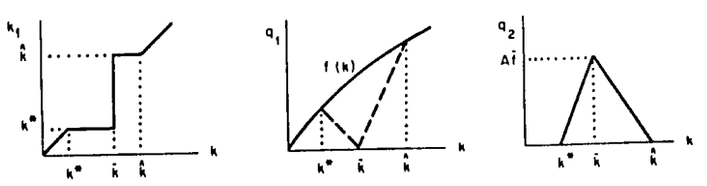

FIG. 2. Development and allocation of resources.

[2] Existence of an interior tangency for $k < \bar{k}$ requires: $Af(\bar{k}) < \lim_{k_0 \to 0} [f(k_0) + (\bar{k} - k_0)f'(k_0)]$; if this is not met then all capital should be allocated to the advanced technique. The same condition must be fulfilled as $k_0 \to \infty$ to yield an interior tangency for $k > \bar{k}$; if it is not met, then all labor should be allocated to the advanced sector. The Inada conditions suffice to guarantee existence of these tangencies; uniqueness is guaranteed by $f'' < 0$.

from the backward sector must just equal the output produced in the advanced sector by these resources.[3]

Given the interior tangencies, Fig. 2 summarizes how resources should be allocated and where production should occur (q_1 is the per capita output in the backward sector, q_2 the per capita output in the advanced sector). For $k < k^*$, the capital-intensity differences make it unprofitable to employ the advanced technique. However, increases in k lower the return on capital, until at $k = k^*$, it just becomes worthwhile to start utilizing the advanced technique. Increases in k, for $k \in (k^*, \bar{k})$, leave k_1 unchanged but cause resources to be transferred to the advanced sector, so that γ and q_1 decrease and q_2 increases. Finally, for $k = \bar{k}$, all output is produced in the advanced sector. Similar results hold for $k > \bar{k}$.

An interesting aspect of this problem is the affect of the advanced technique on factor prices. Assuming factors are paid their marginal product,[4] we can readily see either from Fig. 1 or Fig. 2 how localized technical progress affects factor prices. In particular, for $k < k^*$ factor prices are unaffected since the advanced technique is not used. However, for $k \in (k^*, \bar{k})$, it is apparent that utilization of the advanced technique holds down wages (since $k_1 = k^* < k$), while bolstering the return to capitalists. Furthermore, increases in k, for $k < \bar{k}$, have no impact on factor prices, so that capital accumulation cannot be relied upon to improve the plight of workers. These results are summarized in Fig. 3. For $k = \bar{k}$, factor prices are indeterminate;[5] comparable results hold for $k > \bar{k}$.

The above result is analogous to a two-sector world (each sector producing identical goods) in which an increase in efficiency occurs in the capital-intensive sector. In order to maintain coexistence of the two sectors, the return to the factor used intensively in the advanced sector (capital) must rise while the return to the other factor (labor) must fall.

[3] The coexistence of these advanced and "backward" (or "craft") firms has been noted in the literature; for example, see Nelson [4].

[4] Since the wage rate is frequently larger in the advanced sector, this assumption may seem implausible. However, these wage differences may be due to: (a) short-run labor market disequilibria; (b) the fact that labor in the advanced sector may embody more human capital; or (c) an effort on the part of the advanced sector, which may be foreign-owned, to mitigate the political resentment of foreign ownership.

[5] This discontinuity and nonuniqueness in R raises the possibility, that in a neoclassical growth model in which only capitalists save then: (i) there exists a range of (capitalists') savings rate that yields the same steady-state k and (ii) to some savings rate ($s_k = n/f'(k^*)$), there corresponds a range of steady-state k ($k \in (k^*, \bar{k})$). Comparably, for optimal growth, two countries may choose the same optimal k, even if discount rates differ.

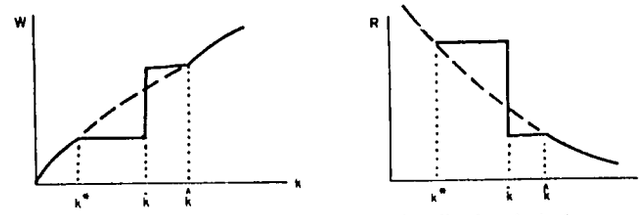

FIG. 3. Factor prices, development, and localized technical progress.

Consequently, though the advanced technique benefits the nation as a whole, workers suffer. Nor does economic development alleviate this problem. This poses a cruel dilemma for planners who must choose between increased output and the seemingly contradictory goal of improving labor's standard of living[6] (assuming no nondistortionary way of redistributing income exists).

Moreover, attempts to mitigate this problem through minimum wage legislation may cause the advanced technique to be adopted, even though its use can lead to greater decreases in output than would normally accompany this second best situation. This may occur because the minimum wage places an artificially high premium on labor, conceivably causing profit-seeking businesses to adopt the more capital-intensive advanced technique, even though this leads to higher levels of unemployment and lower total output (that this result may occur follows from the obvious distortion in the factor market). Whether or not this result occurs depends on the size of the minimum wage; if it is set below the wage rate at which the advanced technique is profitably adopted $[f(k^*) - k^*f'(k^*)]$ then the minimum wage has no impact on the decision concerning adoption of the advanced technique. Comparably, if the minimum wage is set sufficiently high (so that the average product of capital on the basic technique associated with the minimum wage is less than the average product of capital for the advanced technique), then the advanced technique, which will be used, is superior to the alternate basic technique. However, for minimum wages in between these limits, the use of the advanced technique, while privately profitable, is contrary to the interests of the society.

It is worth commenting upon factor prices in the developing country compared to those in the advanced country. Assuming that fixed proportions do not prevail in the advanced country so factors are paid their marginal product there, we readily find

$$f(k^*) - k^*f'(k^*) < \bar{W} = A[f(\bar{k}) - \bar{k}f'(\bar{k})], \tag{7}$$

$$f'(k^*) > \bar{R} = Af'(\bar{k}). \tag{8}$$

[6] A similar conflict between the interests of wage earners and the desire for capital accumulation is familiar in the development literature. See Sen [7].

(For $k_1 = \hat{k} > \bar{k}$, these inequalities are reversed.) Thus, as expected, workers in the advanced nation are better off, while capitalists in the developing nation earn the larger rate of return.

In order to see how changes abroad effect the developing economy, we must consider how changes in A or $\bar{k}$ affect the decisions made by these countries. Figure 4 greatly facilitates that task. Letting point B represent

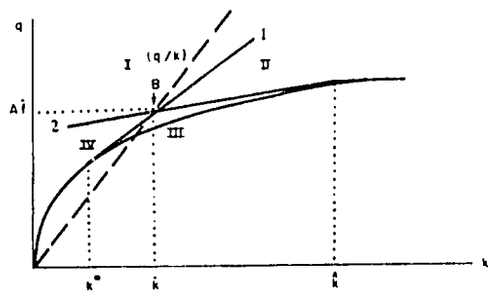

FIG. 4. Comparative statics.

the initial advanced technique, and the lines 1 and 2 be the tangent lines (with slopes $f'(k^*)$ and $f'(\hat{k})$, respectively), it is clear that a change in technique that moves B into area I (above both tangents) causes k^* to decrease and $\hat{k}$ to increase, shifting out the entire production function. Similarly, a movement into region II increases k^* and $\hat{k}$, making the advanced technique more costly to the developing country (though more beneficial to the "over-developed" country), whereas a movement of B into region IV has the opposite result. Finally, a movement of B into region III hurts any borrowing nation (thus, we can say point B dominates region III and is dominated by region I).

What economic interpretation can we give to these results? An increase in A, given $\bar{k}$, moves B into region I, benefiting any borrowing country[7] and causing more resources to be allocated to that advanced technique ($k \in (k^*, \hat{k})$). Comparably, an increase in $\bar{k}$ moves B into region II (since $f'(k^*) > Af'(\bar{k}) > f'(\hat{k})$), hurting the developing economy, though benefitting the over-developed economy. The impact of these changes on the allocation of resources and factor prices is immediately apparent from our prior discussion. Furthermore, all of this could readily be demonstrated mathematically.

The obvious question at this point is how a joint change in A and $\bar{k}$ affects (k^*, $\hat{k}$) and the allocation of resources (assuming only the new

[7] The country benefits from an increase in A, but since this decreases k^*, workers in the *LDC* are hurt, assuming marginal product pricing holds.

technology can be used). From the developing country's perspective, it is clear that an increase in A associated with a decrease in $\bar{k}$ can only be beneficial, since each change alone moves out their production function. However, increases in technology (A) are normally accompanied by increases in capital-intensity ($\bar{k}$) and the net impact of this change on the developing country clearly depends upon the magnitudes of the changes of A and $\bar{k}$. If A increases a "little," and $\bar{k}$ quite a bit, the developing country is hurt (k^* increases); reverse results hold for large increases in A and small increases in $\bar{k}$. One interesting case, often cited in the literature, is when the advanced country has been following a steady-state path, so that (q/k) is fixed (dashed line in Fig. 4). As is apparent from the figure, such changes benefit the developing country (though hurting its workers) and the new, advanced technology along this steady-state path dominates all past technology.

Once again, all of this could be demonstrated mathematically. Figure 4 tells us that the combination of increases in A and $\bar{k}$ that hold k^* constant imply that the average product of capital on the new technique must be falling; any smaller increase in $\bar{k}$, for given A, means that the new technique benefits the developing nation. Similar interpretations hold for the over-developed country.* Clearly the distributional implication of these changes in technology depends upon the impacts of these changes on k^*.

The prior discussion assumed that only one advanced technique could be considered at any time. We shall now investigate how the developing nation should choose among several alternative techniques.

As mentioned earlier, one recurrent theme of the development literature is whether the developing economies should borrow any foreign technology, and if so, should they borrow the most recent technology or technology now obsolete in the developed world? Having investigated the first question, let us now consider the latter question of choosing between obsolete and modern technology.

In order to study this problem we obviously must have knowledge of the type of advanced techniques available to the developing economy. Since presumably these different advanced techniques reflect the historical development of the now-developed nations, our need to know the specifics of these techniques reflects, to a certain extent, the Atkinson-Stiglitz [1] contention of the past as being instrumental in shaping the present and future. Moreover, in answering the question as to which advanced techniques should be adopted, we concurrently determine whether these

* Throughout we have taken technical progress as Hicks neutral in order to stress the separate roles of efficiency and capital-intensity. Obviously, the analysis can be altered to study Harrod-neutral technical change.

developing countries should mirror the development process that took place in other countries, or whether certain steps should be by-passed.

Assume that in addition to the basic production function, the developing economy has n advanced techniques to choose from, each described by an efficiency parameter and a capital-intensity

$$X_i = [A_i, \bar{k}_i]; \quad i = 1,\ldots, n; \quad X_i \in T. \tag{9}$$

For simplicity, arrange T so that $\bar{k}_1 < \bar{k}_2 < \cdots < \bar{k}_n$. As earlier, the developing economy's problem is to decide how to allocate resources in order to maximize output. The nature of this problem makes it clear that, barring singular cases, at most two techniques will be used at once (including backward techniques).

As discussed earlier, to each X_i corresponds a pair $[k_i^*, \hat{k}_i]$. From Fig. 4 it is clear that technique j dominates i, if and only if,

$$\bar{k}_j > \bar{k}_i, \qquad \text{then} \quad k_j^* \leqslant k_i^*;$$

or

$$\bar{k}_j < \bar{k}_i, \qquad \text{then} \quad \hat{k}_j \geqslant \hat{k}_i; \tag{10}$$

or

$$\bar{k}_j = \bar{k}_i, \qquad \text{then} \quad A_j > A_i.$$

If j dominates i, then i will never be used, given the availability of j, and the developing economy can exclude X_i from consideration.

Following (10), we form a subset $\bar{T}$ of T such that

$$X_{s_i} \in \bar{T}, i = 1,\ldots, r \leqslant n \rightarrow \bar{k}_{s_1} < \bar{k}_{s_2} < \cdots < \bar{k}_{s_r}$$

and

$$k^*_{s_1} < k^*_{s_2} < \cdots < k^*_{s_r} \tag{11}$$

and

$$\hat{k}_{s_1} < \hat{k}_{s_2} < \cdots < \hat{k}_{s_r}.$$

Thus, $\bar{T}$ has the property that no technique in it is dominated by any other single technique, and that every technique in T, but not in $\bar{T}$, is dominated by some element of $\bar{T}$. Note that $\bar{T}$ may have only one element, as in the case of steady-state growth abroad, or it may contain all the elements of T. Moreover, the presence of a technique in $\bar{T}$ is no guarantee that that technique will ever be used (with the exception of X_{s_1} and X_{s_r}) since, if $\bar{T}$ contains more than two elements, two elements in $\bar{T}$ may dominate a third one.

The above process greatly simplifies the decision for the developing

economy. If there is only one technique in $\bar{T}$, development proceeds as discussed earlier. If $\bar{T}$ contains more than one element, then for $k < k^*_{s_1}$ and $k > \hat{k}_{s_r}$, only the backward technique is used, while for $k \in (k^*_{s_1}, \bar{k}_{s_1})$ a backward technique (with capital-intensity $k^*_{s_1}$) and an advanced technique (X_{s_1}) should be used (similarly for $k \in (\bar{k}_{s_r}, \hat{k}_{s_r})$). Finally, for $k \in (\bar{k}_{s_1}, \bar{k}_{s_r})$, only advanced techniques should be used, and the decision regarding which ones to use is merely a linear-programming problem. Figure 5 illustrates the nature of the aggregate production function for several cases.

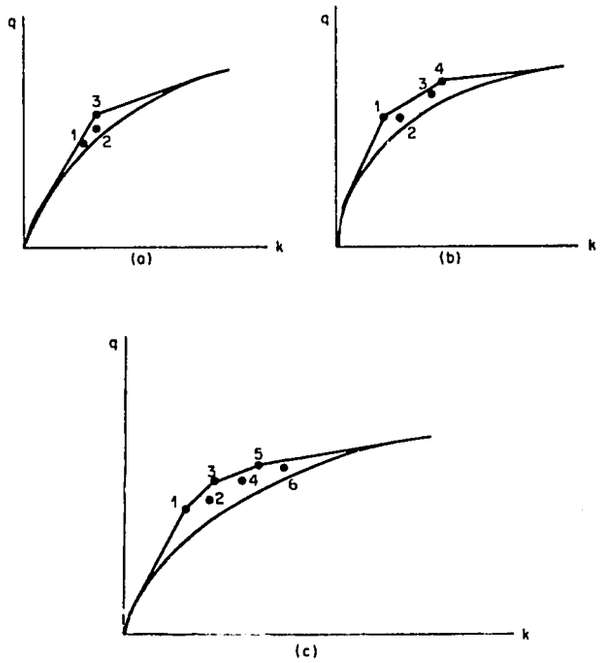

FIG. 5. Aggregate production function and alternative techniques.

Thus, without more specific information, we cannot tell whether the developing economy will use only the most modern advanced techniques or whether it will employ techniques now obsolete in the developed world. In addition, even if some of these now obsolete techniques are employed, the developing nation may skip other techniques once used abroad, so that its development process need not mirror that of the advanced world.

Moreover, the impact of localized technical progress on factor prices

now may be ambiguous.[9] If there is only one relevant advanced technique, our earlier discussion holds; otherwise, the result depends on the techniques involved. Specifically, for $k \in (k^*_{s_1}, \bar{k}_{s_1})$, the localized technical progress holds down wages, hurting labor. However, when two advanced techniques are used concurrently ($k \in (\bar{k}_{s_1}, \bar{k}_{s_r})$), it is not possible, without further information, to state how factor prices are effected, except that at least one factor must gain from the localized technical progress (assuming no distortions exist). Similarly, for $k \in (\bar{k}_{s_r}, \hat{k}_{s_r})$, capitalists are hurt by the localized technical progress. Finally, increases in the capital–labor ratio of the developing economy lead to increases in the wage rate and decreases in the rental rate (assuming no change in foreign technology), though this occurs by steps, and not in a continuous manner (that is, the production function is concave, but not strictly concave).

This paper has considered the allocational and distributional implications of localized technical progress for a developing economy. In another paper one of the authors [3] has discussed the impact of localized technical progress on the pattern of trade in a two-sector, two-country world and has shown that when technology is transferrable between nations only at specific capital-intensities, then a cyclical pattern of trade may occur. It is the authors' belief that further study of the implications of localized technical progress should prove quite fruitful.

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[9] When a backward technique is used, factor prices are determined by marginal products in that sector. When two advanced techniques are employed, factor prices are determined by the condition of zero profits; the rental rate on capital equals the slope of the production function at that point, and the wage rate is the q-intercept of this line. Finally, at a vertex, when only one advanced technique is used, factor prices are indeterminate.

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