

Capital Accumulation, the Choice of Techniques, and Agricultural Output

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Economic growth is achieved largely through capital accumulation and technical change. However, these two processes are not independent. Generation of technical change requires resources and in this sense can be considered to be an investment activity, as is recognized by calling cumulative investment in nonphysical capital "human capital." The implication is that the rate of growth of the economy depends, to a large degree, on the rate of capital accumulation. This chapter will discuss some aspects of the structure of this interdependence between capital accumulation and technical change. The emphasis will be on agriculture, but many of the propositions are of a general nature.

As a background for the discussion, reference is made to the green revolution. A recent empirical study by Bhalla, Alagh, and Sharme (1984) of foodgrains growth in India based on district data provides empirical evidence for some of the propositions developed here. In comparing production changes from the period 1962-65 (pre-green revolution) to 1970-73, a period when the new technology in Indian agriculture was well established, the authors conclude that the introduction of HYV has required capital inputs, that it is capital-intensive in the sense that it increases the share of capital inputs in total output, and that it represents technical change in that it increases yields and increases the productivities of all inputs including labor, whose factor share declines. Most important, it has taken a long time, and after twenty years it is far from being completed.

There is no comprehensive framework that can produce all these results. The reason is that most of the work on the production side of the economy is based on the concept of a production function. As such, the empirical evidence quoted above is dealt with under the rubric of labor-saving technical change. That is, the production function changes by factor augmentation to yield higher capital-labor ratios under given prices. Under such an analysis the production function changes, but at any time there is only one. Thus coexistence can be considered as a transitional phe-

nomenon resulting from imperfect knowledge, but this explanation cannot account for the length of time required to introduce the modern techniques and for geographical variations. The green revolution is considered here as an example—indeed, a very important one. Another example would be the motorization of agriculture. Motorized agriculture represents a different technology from non-motorized and has also taken a long time to be implemented.

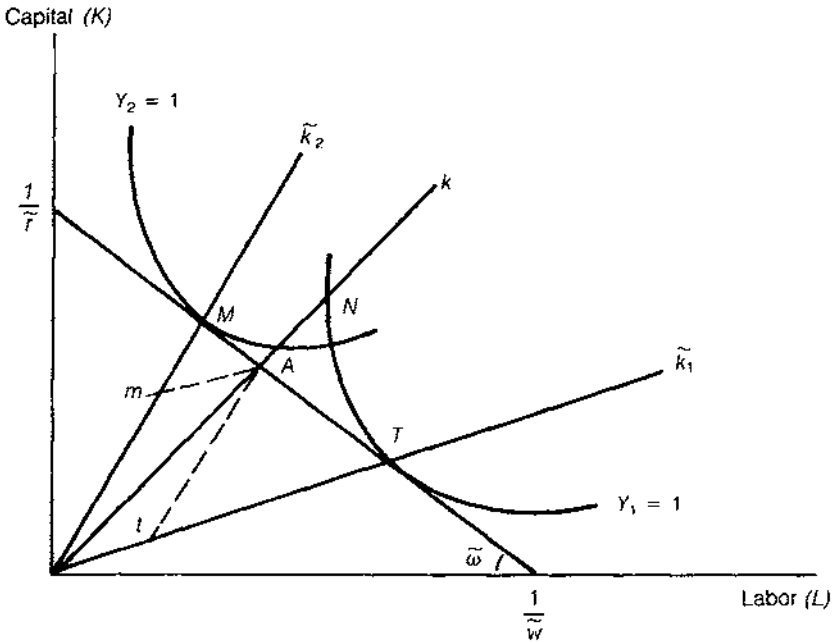
The point of departure is the recognition that at any time there are numerous production functions. Basically, a production function is a micro-concept; it describes the input-output relationship of what is referred to here as a technique. Thus, traditional agriculture and *nyv* agriculture are distinct techniques described by two distinct production functions. The production function that describes a technique relates changes in output to some changes in the inputs, holding some of the variables—such as plant variety or soil type—constant. The variables that are held constant are discrete.

The collection of all the available techniques at a particular time is referred to as technology. A change in the collection is referred to as technical change. Not all the techniques that are available are actually implemented at any time. It is, therefore, useful to distinguish between the available and the implemented technology. The foregoing comments on the relationships between technical change and capital accumulation refer to the effect of capital accumulation on the determination of the implemented technology. The framework of Danin and Mundlak (1979) is used for the choice of technique. It begins with the supply side of the economy, followed by the discussion of the choice under equilibrium of supply and demand.

For simplicity of exposition it is assumed that agricultural technology consists of two techniques, “traditional” and “modern,” denoted as 1 and 2, respectively. They are represented by well-behaved production functions, displaying constant returns to scale in the inputs. For purpose of graphical illustration, we assume that there are only two factors, labor (L) and capital (K). Alternatively, this can be viewed as a presentation of the aggregate production function.¹ The unit isoquants of the two techniques are shown in figure 10.1. The curve denoted by $Y_1 = 1$ represents the various combinations of labor and capital that result in a unit output generated by the traditional technique. A similar interpretation applies for the modern technique, as represented by $Y_2 = 1$. Note that the curves are

1. In this connection we ignore the conceptual problem of input aggregation. The qualitative nature of the results is unaffected by the form of aggregation. Thus, capital is considered as an aggregate of all components including working capital. The generalization to more than two inputs is straightforward (Mundlak 1984).

Figure 10.1 A convex combination of two techniques



drawn in such a way that the modern technique is considered to be more capital-intensive.

The choice of techniques by an individual farmer in the situation described in figure 10.1 depends on the ratio of wage rate (w) to rental rate on capital (r). At a low wage-rental ratio, $\omega = w/r$, the labor-intensive traditional technique has a lower cost of production, and therefore the modern technique will not be employed. Conversely, for a relatively high wage-rental ratio, only the modern technique is used. Under a weak assumption with respect to the behavior of the isoquants, there exists a value $\tilde{\omega}$ for the wage rental ratio at which the cost of production of the two techniques is the same. This is shown in figure 10.1 by the isocost line with slope $\tilde{\omega}$ tangent to the two isoquants. Thus, at $\tilde{\omega}$ the two techniques are equally efficient. Consequently, the farmer is indifferent to the choice of technique. He can use the traditional technique with capital-labor ratio $\tilde{k}_1 = k_1(\tilde{\omega})$ or the modern technique with a capital-labor ratio $\tilde{k}_2 = k_2(\tilde{\omega})$ or a combination of the two techniques. The values \tilde{k}_1 and \tilde{k}_2 are the input ratios that correspond to $\tilde{\omega}$ of the traditional and modern techniques, respectively.

Turning from an individual farmer to agriculture at large, let figure

10.1 represent agricultural technology. The factor endowment is summarized by the capital-labor ratio, $k = K/L$, which is shown as the slope of the ray through A . The wage-rental ratio is now determined as the slope of the isoquant for the given k . The question is which is the relevant isoquant. For a sufficiently low capital-labor ratio, specifically $k < \bar{k}_1$, only the traditional technique will be employed. In this case ω will be determined by the slope of the isoquant of the traditional technique evaluated at k , and by construction, for $k < \bar{k}_1$ we have $\omega(k) < \bar{\omega}_1$. Conversely, for $k \geq \bar{k}_2$, $\omega(k) \geq \bar{\omega}_2$. In those two cases agriculture specializes in one of the two techniques. Consequently, the two techniques coexist when $\bar{k}_1 \leq k \leq \bar{k}_2$. In this sense, \bar{k}_1 and \bar{k}_2 can be viewed as threshold values.

Under the assumption of full employment, the intensity of utilization of the individual techniques is determined by k , \bar{k}_1 , and \bar{k}_2 . This can be shown graphically by drawing a parallelogram. Thus, in terms of figure 10.1, when the economy produces at A , m represents the proportion of output generated by the modern technique, and the complement, $t = 1 - m$, comes from the traditional technique.²

While the threshold values (\bar{k}_1 , \bar{k}_2) are determined solely by the technology, k reflects capital accumulation. Thus, as the choice of techniques depends on k , it will change with capital accumulation that leads to an increase in k . Given full employment in agriculture, the intensity of utilization of the modern technique increases with k at the expense of the traditional technique; that is, the proportions of labor and capital employed in the modern technique increase or, alternatively, the proportion of agricultural output generated by the modern technique increases. This can be shown graphically by moving point A to the left along the cost line and drawing a new parallelogram.³

This simple analysis has a very important implication. Capital accumulation leads to the employment of capital-intensive techniques. In general, we view the modern techniques to be capital-intensive. Consequently, their relative importance increases with capital accumulation. The converse is also true. It is impossible to increase the relative importance of the modern techniques without capital accumulation. This result is established here in a partial analysis of agriculture, considering only the supply side. This is also true when the whole economy is considered and demand is taken into consideration.

2. The assumption of full employment of K and L can be expressed as $k = lk_1 + (1 - l)k_2$, where $l = L_1/L$ is the proportion of the agricultural labor force allocated to the traditional technique.

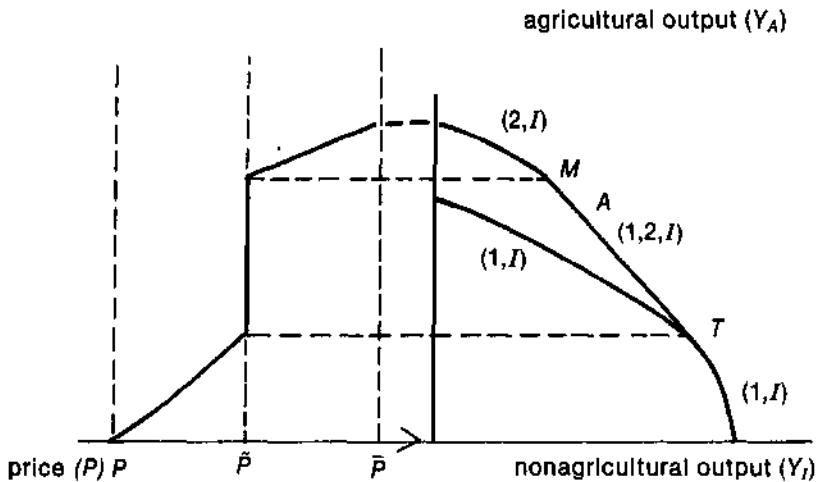
3. Analytically, solve for l from the full employment conditions given in n. 2 above and note that we deal with the case of coexistence, so that $k_i = \bar{k}_i$, $i = 1, 2$. $l = (\bar{k}_2 - k)/(\bar{k}_2 - \bar{k}_1)$. Consequently, $dl/dk < 0$.

THE ECONOMY

To extend the analysis to the economy as a whole, it is necessary to show how techniques are selected along its equilibrium path. This is the path of points at which supply and demand are equated. A point on the equilibrium path is represented here by the intersection of the transformation curve and a properly defined demand curve. To simplify the analysis, non-agriculture is aggregated into one sector, and it is assumed that it uses only one technique. Also, without a loss in generality, it is assumed that non-agriculture is more capital-intensive, so that its capital-labor ratio (k_I) is larger than that of agriculture (k_A); specifically it is assumed that $k_I(\omega) > k_2(\omega) > k_1(\omega)$.

The resulting transformation curve is shown in figure 10.2, with points T , A , and M marked on it. The curve is divided into segments identified by the utilized techniques. At low levels of agricultural production, only the traditional technique is used, but at a high level of output only the modern technique is used. In between is the region where both techniques are used. Designate the price of the agricultural product in terms of the nonagricultural product as p . Then, the segment representing coexistence of techniques corresponds to a constant price, \bar{p} . To show the relationship between agricultural output and the price p , the supply function is drawn in the lefthand panel of the figure. When the two techniques coexist, it is possible to increase agricultural output without increasing prices. This, however, re-

Figure 10.2 The appearance of a new technique and the transformation curve

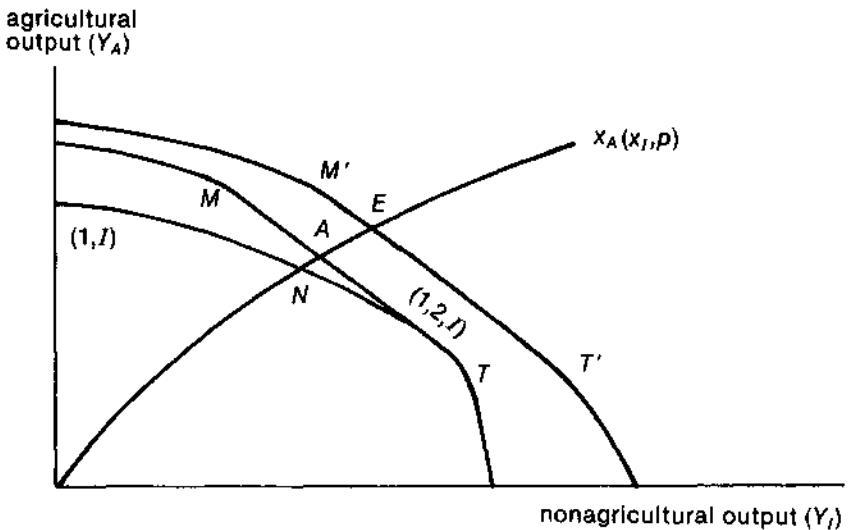


quires a shift of resources from non-agriculture to agriculture and therefore a decline in nonagricultural output (Y_I).

A transformation curve is drawn in figure 10.2 for the same economy without modern technology. Obviously, this is an inferior situation to an economy whose output plan is to the left of T .

The next step is to introduce demand functions. When there are only two products, the income consumption curve contains all the information on the demand in the economy. This curve is drawn in figure 10.3 for price \bar{p} in such a way that the demand for the agricultural product x_A is expressed as a function of the demand for the nonagricultural product, x_I . When the two products are normal, the curve is ever-increasing with respect to the two axes. The economy is initially at point A where the two techniques coexist. With capital accumulation, the transformation curve shifts outward and the equilibrium point moves from A to E , where the price remains unchanged. Consequently, capital accumulation produces only income effect and no price effect. Therefore, the increase in sectoral outputs is proportional to the income elasticities. When the two products are normal, both increase with capital accumulation. Such a joint increase in production requires a decline in the relative importance of the traditional technique. To see this, we note that the price at A and E is the same, so the capital-labor ratios \bar{k}_1 , \bar{k}_2 , and \bar{k}_I must also be the same. Then the only way to increase nonagricultural output with prices held constant is to

Figure 10.3 Product composition under capital accumulation and coexistence of techniques



shift resources from agriculture to non-agriculture. But at the same time, it is required that agricultural output also increase. This can happen only if the traditional technique in agriculture is replaced by the modern technique. Such a shift will cause an increase in the agricultural capital-labor ratio. It can thus be concluded that capital accumulation which takes place when the two techniques coexist in agriculture generates a shift of resources away from the traditional technique. It should be noted that the result is achieved for an economy that is always in a short-run equilibrium and as such reflects both demand and supply conditions.⁴

RATE OF IMPLEMENTATION OF NEW TECHNIQUES

The main point of the foregoing discussion is that an introduction of new capital-intensive techniques is subject to capital constraint, and therefore its rate of adoption depends on the rate of capital accumulation. It is clear that the introduction of a new technique in an important sector of the economy may take time.

To relate this finding to other treatments of the adoption of new techniques, refer to figure 10.1. Assume that when the modern technique is introduced, the capital-labor ratio is k and the economy is initially located at point N . Obviously, after the introduction of the modern technique, the efficient production plan is changed from N to A .

The question generally asked is what determines the pace of movement from N to A , but our concern has been the movement from T to A . In other words, we have dealt with movements *along* a newly formed efficiency frontier, whereas the movements from N to A can be interpreted as a movement *toward* this frontier. The determinants of the pace of such a movement often given in the literature can be classified as those related to heterogeneity of capital and those related to uncertainty and imperfect knowledge.

In the foregoing discussion, it was implicitly assumed that capital goods are homogenous, so that horses and tractors are the same thing. Eliminating this simplification and recognizing that capital goods are heterogenous introduces another dimension into the discussion. If the two techniques in question require different forms of capital, the pace of movement from N to A will be determined by the ease of changing the composition of the capital stock. In general, the capital good associated with the traditional technique disappears through obsolescence or discard while the introduction of the capital good associated with new technique is determined by

4. There are other possibilities where, at the initial or the end equilibrium point, there is a specialization in a single technique. These are not interesting cases from the point of view of applications and therefore are not discussed here.

gross investment. Consequently, the rate of implementation of the new technique will be determined by the rate of *gross* investment, whereas the decline in the traditional technique will depend on the rate of disappearance of the capital good associated with it. Thus, the movement from N to A would imply a gradual reduction of the capital-labor ratio in the traditional technique from k to \bar{k}_1 . In this process ω will gradually decline from its level at N , as determined by the traditional technique, to $\bar{\omega}$.

The essence of the argument on heterogeneity of capital is that the two techniques may require different compositions of the various capital goods. If this is the case, a change in the composition of the two techniques will result in a change in the composition of the various capital goods. If this process takes the economy off the efficiency frontier, the pace of the return to the frontier will depend on gross investment.

So far we have treated the modern technique as new and completely unrelated to the traditional one. In subsequent discussion, we comment on the economics of generating techniques. However, from a strictly formal point of view, once the new technique is available, it can be expressed as if it were obtained by some change of the traditional production function. Doing so may help us to utilize known results related to various forms of technical change. This, however, is of only limited value, as it does not explain the coexistence of techniques and the determinants of their implementation.

However, incorporating some known forms of technical change helps isolate the importance of the various determinants. Start by assuming that the modern technique is obtained simply by a Hicks neutral technical change in the traditional technique.⁵ In this case, there is no difference in the threshold values, $\bar{k}_1 = \bar{k}_2$, the new technique completely dominates the old, and it is therefore disadvantageous to employ them simultaneously. Yet if the two techniques use different capital goods, there will be a transition period during which the two techniques will be used simultaneously. A special case of this is in the embodiment hypothesis developed by Solow (1963). Under this hypothesis, the new technique is embodied in a new capital good, say, a machine, which cannot be applied with the old machine. Consequently, the rate of introduction of the new technique will depend on the rate of *gross* investment rather than net investment. Thus, the traditional technique will disappear eventually, even if net investment is nil.

The situation is somewhat different when the modern technique is generated by a factor augmenting technical change in the traditional technique. In contrast to the previous case, such a change generates a difference in the threshold value so that $\bar{k}_2 > \bar{k}_1$. In this case, if \bar{k}_2 exceeds the

5. Technical change that does not affect factor shares at given factor prices.

available capital-labor ratio, the rate of implementation will eventually depend on net investment. Thus, if the economy does not accumulate capital, it will not discard the traditional technique.

Another reason for coexistence of techniques is uncertainty or lack of knowledge. The new technique may be superior, but firms do not know it and may require time to sample it. During this period, the various techniques will coexist. The search process requires resources. At the farm level, the resources devoted to the search depend on their cost (Kislev and Shchori-Bachrach 1973; Feder and Slade 1984). At the industry level, the cost depends on the availability of such resources. The result of a search by a farmer depends on the time that he allocates to the search and to his ability to digest it. The latter, as Schultz (1968) postulated, depends on the level of education. Hence, the speed of implementation which reflects imperfect knowledge is also positively related to capital in the form of human capital.

GENERATION OF NEW TECHNIQUES

Firms, private or public, which spend resources on research and development generally have choices of research strategy. For our discussion, the key variable is the capital intensity of the new techniques. The foregoing indicated that capital accumulation generates demand for capital-intensive techniques. Thus, the producers of techniques should aim at the development of capital-intensive rather than labor-intensive techniques. However, overshooting is counterproductive. Since the rate of implementation depends on the rate of capital accumulation, the threshold level of the new techniques should not be too high. Otherwise, the market for them will be very limited.

This story can be told by looking at the firm level. In the absence of a new capital-intensive technique, capital accumulation increases the capital-labor ratios, thus increasing real wages and decreasing the real rate on capital. Thus, the owners of capital will be interested in investing their capital in techniques that prevent the rate of return from falling. This generates the demand for the capital-intensive techniques.

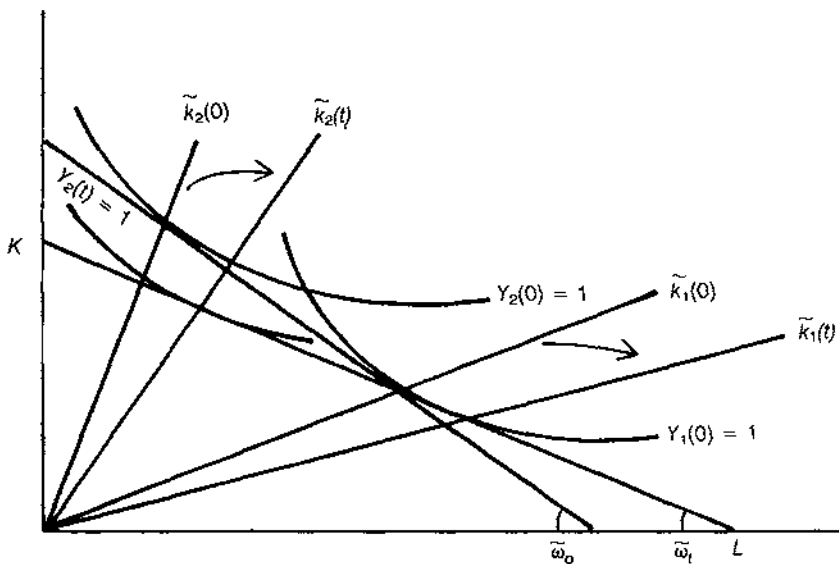
By its very nature this process leads to a decline in the labor share (S_L) and as such can be considered as laborsaving. For a constant return to scale production function in K and L we can define the following function of labor share: $\Theta = \omega/k = wL/rK = S_L/1 - S_L$. Θ is monotonically increasing with S_L . Referring to figure 10.1, the movement from T to A increases k with ω held constant. Consequently Θ , and therefore S_L , decline. The transition from N to A implies a decline in ω under a constant k which again results in a decline of the labor share.

For the purpose of simplification, we have dealt with two techniques,

traditional and modern. The appearance of additional techniques can be handled in a very similar fashion. One case, however, is worthy of examination, the case of Hicks neutral technical change in the modern technique. We have a purpose in selecting the modern technique to be the subject of the Hicks neutral technical change. It has been argued that the process of capital accumulation causes a shift in the direction of capital-intensive techniques. Then, other things being equal, the demand will call for the improvement of the modern techniques. In a more detailed framework, the cost of producing and changing techniques, as well as the required research time, should be introduced. If the required time is significant, by the time the research is completed the traditional technique may not be important. Therefore, efforts will be directed at increasing the productivity of the modern techniques. This consideration has a dynamic aspect. With time, the modern techniques become traditional, and, since the easy gains might have already been made, additional gains may be subject to increasing cost. Thus, both from the demand side and the supply side, it is likely that the effort to improve an existing technique will be aimed at the modern techniques.

An improvement in the productivity of a technique should increase its utilization. This is illustrated graphically in figure 10.4. The initial tech-

Figure 10.4 Choice of techniques under Hicks neutral technical change in the modern technique



niques are represented by $Y_1(0)$ and $Y_2(0)$ with threshold values $\bar{k}_1(0)$ and $\bar{k}_2(0)$. Neutral technical change in the modern technique shifts its unit isoquant to $Y_2(t) = 1$. The threshold values decline accordingly to $\bar{k}_2(t)$ and $\bar{k}_1(t)$. For any value of k , the importance of the traditional variety declines.⁶ The net effect of this change is again laborsaving. Thus, we have a situation where the net effect of a Hicks neutral technical change is laborsaving.

The foregoing discussion describes the changes in technology that are called for by the process of capital accumulation. They apply to all sectors of the economy. The reference to the work of Bhalla, Alagh, and Sharma (1984) at the beginning of this chapter illustrates their relevance to an understanding of the changes brought about by the green revolution.

EMPIRICAL IMPLICATIONS

The present framework has a variety of empirical implications. In discussing them it is helpful to represent the two techniques in terms of their input-output relationships rather than isoquants. Assuming constant returns to scale in terms of capital and labor, the average labor productivities are functions of the capital-labor ratios which are drawn in figure 10.5. The points on this figure correspond to those with the same designations in figure 10.1. Corresponding to figure 10.1, the envelope is identical with $f_1(k_1)$ for $k \leq \bar{k}_1$; it moves along the segment TM for $\bar{k}_1 \leq k \leq \bar{k}_2$; and thereafter, for $k \geq \bar{k}_2$ it becomes identical with $f_2(k_2)$.⁷

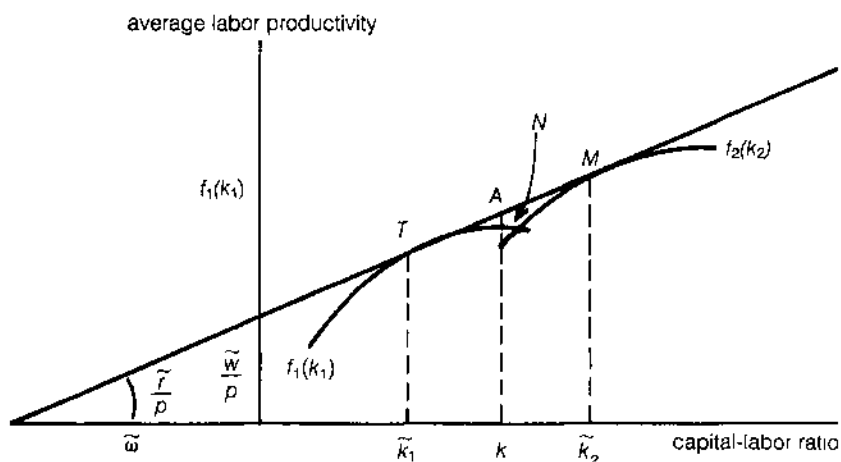
The scope for increasing average labor productivity in agriculture for such an economy consists of capital accumulation in agriculture and the introduction of new techniques which are not excessively demanding in terms of their capital requirements. To determine the role of prices it is necessary to distinguish between equilibrium and disequilibrium analysis. Both the foregoing and the following discussion are largely within the framework of equilibrium analysis. Introducing disequilibrium in the factor market will introduce additional complications but will not change the nature of the results.

The real factor prices (prices in terms of the product) are determined by the production function, and are shown in figure 10.5. Consequently, for agricultural technology which consists only of the traditional technique, the movement from T to N will imply an increase in the real wage w/p and

6. This can be shown analytically by writing the ratio of labor employed in the modern to that of the traditional technique as: $1 - l/l = k - \bar{k}_1/\bar{k}_2 - k$. This ratio is increased when both threshold values decline, as should be expected. In fact, it can be shown that, for a given k , this is the only way that $1 - l$ can increase.

7. In the literature on agricultural development, following Hayami and Ruttan (1971), the envelope production function is referred to as a meta production function.

Figure 10.5 Average labor productivity and the choice of techniques



a decline in the real rate of return on capital, r/p . The introduction of the modern technique into agriculture facilitates the movement from N to A and thereby simultaneously increases average labor productivity and rental on capital and decreases the wage rate and the labor share. All this is basically a restatement of our previous isoquant analysis and is consistent with the empirical evidence set forth by Bhalla, Alagh, and Sharma (1984).

Once point A , or any other point on segment TM , is reached, average productivity increases only with capital accumulation, with constant factor prices. This process continues until the traditional technique is completely abandoned, as indicated by point M .

Capital accumulation in the economy at large reflects saving behavior and as such may be responsive to the rate of return on capital. In this discussion the interest is in sectoral analysis, and overall capital accumulation is taken as given. The intersectoral allocation of the capital stock is done mainly through new investment. It is assumed that the share of agriculture in total investment is positively related to the ratio of the rate of return in agriculture to that in the rest of the economy. Empirical support for this assumption can be found in the analysis of the Argentinian experience by Cavallo and Mundlak (1982). Similar results are obtained by the yet unpublished work of Coymans and Mundlak for Chile and by Mundlak and Strauss (Mundlak 1979) for Japan, through the use of the flow of funds equation.

The introduction of the modern technique and the movement from point N to segment TM increases the rate of return in agriculture, and

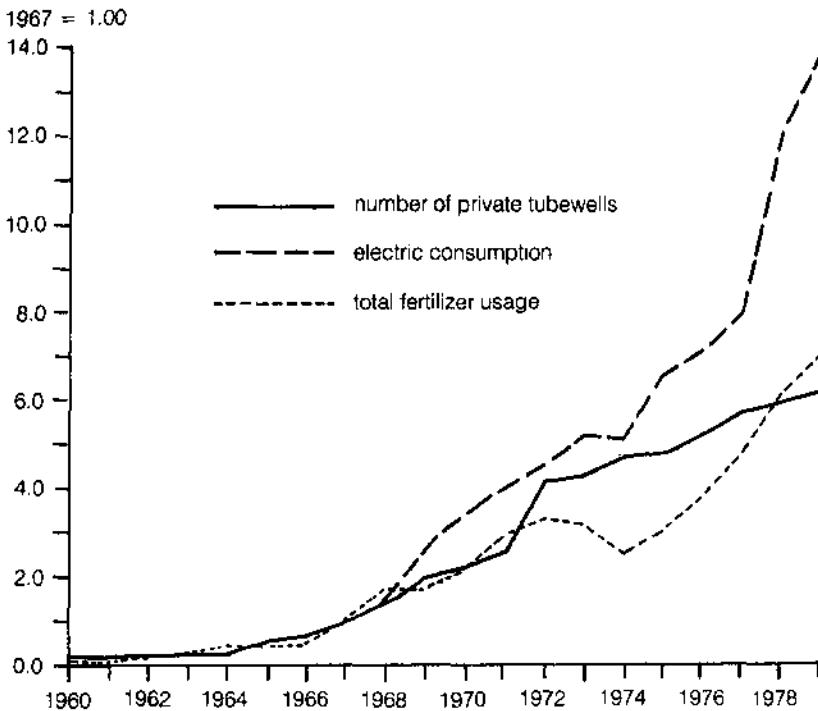
agricultural investment should increase accordingly. This then increases the rate of capital accumulation in agriculture and speeds up the implementation of the new technique.

This assumption is substantiated by the data for the Punjab, as demonstrated in figure 10.6, which shows the number of private tubewells and electricity and fertilizer consumption. It can be seen that these variables increased very rapidly from the mid-sixties once the opportunities of the high-yielding varieties were recognized.

The increase in the capital-labor ratio in agriculture is achieved not only by capital accumulation but also by the drain of labor from agriculture. The drain should be interpreted as a growth of the agricultural labor force at a rate lower than the increase in the total labor force. Thus, if the economy were in a steady state, where the overall capital-labor ratio remains constant, such a drain of labor from agriculture would increase the agricultural capital-labor ratio.

So far, the analysis has dealt only with the supply side of the economy.

Figure 10.6 Index of private tubewells, electricity consumption in agriculture, and fertilizer usage in Punjab, India, 1960-79



To complete the analysis, demand is now brought in. Again reference is made to figure 10.3 for an illustration of equilibrium determination in a closed economy. Prior to the introduction of the modern technique, the economy is located at N . After the introduction the economy moves in the direction of A merely by reallocating existing resources. Such a move involves an increase in agricultural and nonagricultural outputs and a decline in agricultural price. The decline in price is shown in two steps, first $P_N > P_T$, since they are both on the same transformation curve, and second, $P_T = P_A$ by construction. Therefore, $P_N > P_A$. Although this result may seem strange, it conforms to the data. For instance, taking the ratio of prices received by farmers to that of prices paid by farmers as an approximation of the agricultural price relative to the nonagricultural price, we find that in 1977 the ratio in the United States was 66 percent of the 1910–14 average, and in Australia it was at 56 percent of the 1961–63 average. A similar trend is observed for most other countries (FAO 1977).

Obviously a single-equation empirical analysis of supply with such data would show negative supply elasticities. This would be misleading in the sense that the movement from N to A is the net result of changes in supply and demand. The movement is initiated by the technical change, which has a direct effect on the agricultural supply. If the demand remained constant, such a change would have identified a demand rather than a supply function. However, the technical change increases income and as such, also causes a shift in the demand curve. Consequently, the curve connecting output and price is neither a supply nor a demand curve. This is an identification problem which requires a more detailed framework for empirical analysis.

The move from N to A was considered under the assumption of no capital accumulation. With capital accumulation the transformation curve moves, and, as indicated above, point E represents an equilibrium point achieved with the augmented capital. Note that the price at E is the same as in A . Consequently, a situation is generated where an increase in output is obtained with price held constant. This represents a perfectly elastic supply and this indeed is what figure 10.2 indicates. But such a situation is contrary to all the empirical evidence on supply response. Yet there is no inconsistency between this framework and the known empirical results.

To dramatize the situation, suppose that the economy in question is an open rather than a closed economy and is at point T where the price is $p_T = \bar{p}$. Suppose that the international price increases to p . Under the new price, the economy should adjust to a new equilibrium point to the left of M . Such an adjustment requires a substantial shift of resources from non-agriculture to agriculture. Such a high mobilization of resources does not occur for the following reasons. As already discussed above, the intersectoral allocation of capital is done largely through gross investment. A dra-

matic change in the share of agriculture in the capital stock thus may require many years to accomplish. Similarly, as the empirical analysis of off-farm migration indicates, this process is also time-consuming (Mundlak 1979). Thus it may take a long time for the response to materialize. However, it will materialize provided the price remains at the new level. But will the price remain stable? The movement from T to M indicates a major change in supply. That could only be absorbed by a corresponding decline in price; therefore, the new price is not sustainable. In a narrow sense, this argument does not apply to a small, open economy. However, agricultural technology is, in general, a public good, and other countries having a similar technology are expected to respond in the same way. The best example is the *HYV* of grains which are used all over. The world is a closed economy, and therefore prices decline, as argued above. By this argument, point M will not be reached unless the demand justifies production at M . The mechanism of stopping short of M can either be rational expectation on the part of farmers or simply trial and error. Since the resource adjustment consistent with the movement from T to M is timeconsuming, somewhere in the adjustment process prices will start falling and the process will terminate. It is clear that the response of agriculture to annual variations in prices is going to be weak. This is postulated as a reason for the weak supply response often obtained in empirical analyses. Yet this framework suggests that when techniques coexist the response to expected long-run prices is rather strong.

The whole discussion was conducted under the simplifying assumption of a single agricultural product. In reality, any region can grow a variety of products. Some of these utilize the same resources, and the adjustment in such cases is easier and faster. Consequently, a stronger response is expected to price variations of short duration. This is consistent with empirical analyses which report stronger response for individual crops than for aggregate outputs.

Another simplifying assumption made above is that there are no intermediate products or raw materials. The introduction of such inputs into the analysis have several dimensions. In the case of a closed economy, an increase in the demand for such inputs requires adjustments in the nonagricultural sector of the same nature as those discussed above. For instance, the increase in the demand for fertilizers brought about by the green revolution required a shift of resources to augment the production capacity of the fertilizer industry. During such a process, fertilizer availability becomes a constraint to the increase of agricultural output. This point was discussed by Desai (1982). For an open economy, the adjustment may be faster if there are no foreign exchange constraints. But again, if the same technology is spreading all over the world and there is no excess capacity, a similar delay would be expected.

The case of energy is somewhat different in that there is no availability problem, only a price problem. Thus, when the price of energy increases, it affects more strongly the price of the techniques which are energy-intensive. In terms of our graphical analysis, this can be considered as a technical decline. In this case, instead of output, the figures should report value added. An increase in the price of energy (or any other raw material) decreases the value added. Thus, applying the results stated above with respect to Hicks neutral technical change, the intensity of the use of the energy-intensive technique will decline.

If we allow for the fact that agricultural production utilizes raw materials, and that those can be changed faster than capital and labor, we can expect some price response.

To conclude the argument on supply response to prices for aggregate output subject to demand constraints, we have distinguished three major cases: (1) technical change in the form of a new technique generating an increase in output and a decline in price; (2) an increase in capital with constant technology of coexisting techniques generating an increase in output under constant prices; (3) an increase in the price ratio of output to raw materials generating a positive supply response. (However, this last response reflects the importance of the raw materials in total cost and as such will not be very strong.) Empirical analyses which do not differentiate between these effects will result in some mixture. This mixture will also reflect the fact that the response is largely to expected rather than to observed prices.

Yet it has been suggested that with the technology under consideration, a strong supply response can be expected to result in permanent price changes, but that this may take a long time. Can this claim be substantiated? As indicated above, empirical analysis of the process of intersectoral resource allocation does indeed indicate that the *rate* of allocation is price-responsive in the anticipated direction. Integrating labor migration and investment allocation with the production structure will produce the output response.

There is, however, another way to derive some evidence on the supply response as well as on some of the considerations just mentioned. It is noted that technical change affects farm income in a way similar to prices. Consequently, a 1 percent increase in yield affects income almost to the same degree as a 1 percent change in price. The word "almost" is used because an increase in yield does increase harvest and handling cost. Thus the variable that farmers respond to should be the expected revenue ($AR = p \times \text{yield} \times c$), where c is a fraction to adjust for the extra harvest cost (cf. Mundlak and McCorkle 1956). AR increases with technical change and, as such, has a permanent component which should guide

farmers' decisions. Preliminary empirical results indicate that AR produces higher elasticities than prices in acreage response equations.

CONCLUSIONS, POLICY IMPLICATIONS, AND SCOPE

The discussion has centered on the role of capital accumulation in the introduction and implementation of technical change. It has been argued that in the event of capital accumulation there will be a tendency for technical change to take the form of capital-intensive techniques. A major outcome of the analysis is that such technical change cannot be implemented without capital accumulation.

Capital is broadly interpreted. It represents the resources that the economy diverts at any period from present consumption in order to increase its production in the future. The capital goods produced by such diverted resources include physical as well as nonphysical components such as education, research, extension, or, briefly, human capital. The conclusion, then, is that an increase in the rate of capital accumulation should foster growth.

The rate of capital accumulation depends on private saving behavior, on the behavior of the public sector (government saving), and on foreign saving (borrowing from abroad). A detailed discussion of these components is beyond the scope of this chapter. However, it is important to note that foreign borrowing may be helpful if it is properly used. Recent experiences of some countries indicate that it can be misused. In what follows, it is assumed that resources are used efficiently.

Taking the overall capital constraint of the country as given, agricultural growth will depend on the generation of new techniques and on the resources available for their implementation. Policies that extract resources from agriculture will have a negative effect on agricultural growth, and the opposite is true for policies which facilitate the flow of resources into agriculture. That of course, assumes that agriculture continues to have a flow of new techniques that can be implemented efficiently. We have used the HYV as an example of growth constrained by capital availability. In this case, capital takes the form of irrigation facilities, fertilizers, insecticides, roads, and nonphysical items such as domestic research, extension, and general level of schooling.

Some of the investment necessary for the expansion of agricultural output is generally performed by the public sector. These funds are mainly directed at investment in infrastructure. Investment on farms is largely private, although in part it might benefit from subsidized finance. Assuming rational behavior, the higher the profitability of new investment, the larger the investment will be. Therefore, the price system has an important

role in influencing the rate of accumulation and therefore on technical change in agriculture. The response may be slow but it is there. Thus policies directed at the taxation of agriculture are likely to have a serious cost in terms of agricultural growth, as was the case in Argentina (Cavallo and Mundlak 1982).

In the foregoing analysis land was suppressed by assuming the agricultural production function to be constant returns to scale in capital and labor. The introduction of land would complicate the analysis without changing the main conclusion. However, the conclusion can now be extended. The size of a country is given, and that determines the size of the available land. Land varies by quality. The size of the cultivated land depends on the returns on land and on the cost of bringing more land under cultivation. These factors depend on prices and on capital availability. The return on the marginal land is zero; that is, output is absorbed by inputs other than land.

This has two repercussions. First, capital accumulation can be used for expanding the cultivated land. If, however, such an expansion becomes increasingly expensive, it can be expected that techniques will be developed to reduce land expansion. This leads to landsaving technical change, which is analogous to laborsaving technical change. Such an approach can explain the puzzling situation where on small farms the factor share of land is sometimes rather small.⁸ The second repercussion is related to the taxation of rent. Sometimes it is claimed that taxing rent, as was the case in Japan, for instance, is neutral in the sense that it should not affect agricultural growth. This approach assumes, at least implicitly, that the size of land is unaffected and that there is only one technique. Obviously imposing a land tax on marginal land will cause it to go out of production. If the investment has already been made, cultivation may continue, but expansion of cultivated land will be affected. As to the choice of techniques, taxing rent will generate a demand for land-intensive techniques, so that the rent on land will decline. That means that the ratio of land to other inputs will increase or, to put it another way, will cause resources to move out of agriculture.

The foregoing conclusions assume that farmers are rational and do utilize changing opportunities. Sometimes this assumption is questioned as a result of failure of empirical analyses to detect supply response to prices. Analysis of the possible reasons for such empirical results indicates that the response should be observed at the level of intersectoral resource flow,

8. This question was discussed in Mundlak (1964) with respect to the low factor share of land in family farms in Israel. Such farms are mostly less than four hectares. The explanation given was that in order to overcome the area limitation, farmers moved to products which require little land but are capital-intensive.

and here the empirical evidence quoted above shows that such flows are indeed price-responsive.

The reason why the resource adjustment is not easily observed by direct measurements is that it is slow, whereas the prices vary, and that variations reflect mainly transitory components. To overcome this problem, it is argued that the supply response might be better measured with respect to changes in average revenue.

The discussion was conducted largely within the framework of equilibrium analysis. It also assumes implicitly that the relevant markets exist and function. The analysis is aggregate and deals with a simple world and as such does not answer specific micro questions. That fact, however, should not dilute the conclusions.

A possible extension of the analysis that was not included is related to disequilibrium in the factor markets. Such an extension would require some changes in the analytical framework but again would not change the nature of the conclusions.

From the analytic point of view, the special feature of the analysis is in the structure of production, where the technology is allowed to consist of more than one technique. The concept of a technique is very general indeed and can be used opportunistically according to need. It was indicated above that different products are identified with different techniques. Thus capital accumulation leads to an increase in output of capital-intensive techniques, and thus the process of product cycle known in the literature of international trade is produced.

Alternatively, each firm can be considered as a different technique. Each firm has embodied in it some specific factors which are summarized by the term "entrepreneurial capacity." Entrepreneurs that have a low level of human capital can be identified or represented by capital-extensive techniques. As such they lose ground in the process of capital accumulation. Consequently, the industry will realize a concentration of entrepreneurs with a higher level of human capital. If such entrepreneurs are also more productive, then the exit of firms will increase the productivity of the industry as a whole. Applying this process to agriculture, it is postulated to have contributed to the increase in agricultural productivity in the developed economies (Kislev and Rabiner 1979).