Patrick

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YALE UNIVERSITY

Box 1987, Yale Station
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THE CONTRIBUTION OF EDUCATION TO GROWTH: AN ALTERNATIVE APPROACH

Howard Pack
Swarthmore College

The Contribution of Education to Growth:

An Alternative Approach*

Existing approaches to evaluating the contribution of education to economic growth concern themselves mainly with obtaining measures of the extent of increasing levels of education and using such measures either as independent variables in production functions or to adjust the nominal labor force. Typically, the contribution of education or the quality adjusted labor force is then calculated within the framework of an assumed production function, usually Cobb-Douglas.[1] However, for some economies, the major contribution of education may be to alter the actual constellation of economic possibilities. Modes of production that would have been technically infeasible become viable because of the presence of a group of highly skilled technicians. Not only does a project become technically possible, but the costs of entering production will be substantially reduced.[2] For many less developed countries an increase over a decade of 500 mechanical engineers or industrial managers may dramatically alter both the types of production which are feasible and allow production to be undertaken with different factor proportions, and perhaps greater efficiency.

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*Richard R. Nelson provided helpful comments on an earlier draft. The usual release is in order.

[1]See, for example, Edward F. Denison, The Sources of Economic Growth and the Alternatives Before Us (New York, Committee for Economic Development, 1962; Zvi Griliches, "The Sources of Measured Productivity Growth: U.S. Agriculture 1940-1960," Journal of Political Economy, LXXI, August 1963; Zvi Griliches and D. Jorgenson, "The Explanation of Productivity Change," Review of Economic Studies, Vol. XXXIV, No. 99.

[2]Many of the fundamental problems inherent in defining a production function and analyzing the role of education are considered in important new way by Richard R. Nelson and Sidney Winters in an unpublished paper, "Production Theory, Learning Processes and Dynamic Competition."

Changes in the locus of opportunities will be of importance to both capital scarce less developed countries and to the more unusual labor scarce type. While in the empirical work below we shall use Israel, a relatively labor scarce economy as a case study, it is convenient to illustrate our approach by considering a typical labor surplus economy.

Without a domestic corps of technicians to investigate existing production techniques[1] and the possibility of modifying them, the less developed economy is dependent on the salesman-cum-technician of foreign producers of investment goods or "experts" of international agencies who share the same efficiency concepts as the salesmen. Rarely is a technique recommended which will take advantage of a country's particular factor endowment. Indeed, the expert or salesman himself may not be aware of the existence of alternative techniques, or of adaptations, particularly in peripheral operations which may be undertaken in some countries. Moreover, even if he knows of them, he may be hesitant in suggesting their adoption as he is not quite certain of how the production process would really function with these adaptations, and will have limited interest in the outcome of such attempts as particular adaptations may have limited usefulness in other countries, indeed in other regions within a country. He is more secure with the more familiar and has little incentive to invest the time necessary to suggest and implement relevant changes.[2] In the purchas-

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[1]Production technique is used in its linear programming sense to denote a specific activity. A number of techniques will generate the usual isoquant. It is important for our purposes to keep the two concepts distinct.

[2]On this and related questions see Nelson and Winters, op. cit. A number of interesting case studies of the unwillingness to deviate from well known (usually advanced techniques) in Puerto Rico and Mexico are presented in W. Paul Strassman, Economic Development and Technological Change (Ithaca: Cornell University Press, 1968).

ing country this advice leads to rather narrow bounds being set to the isoquant along which an industry may operate.

The availability of a group of trained people can lead to a broadening of these bounds. First, imported techniques of production can be modified, e.g., automated methods for conveying materials within a plant may be replaced by labor intensive methods.[1] In contrast to foreign salesmen, domestic engineers who remain in the country and who can utilize the adaptations repeatedly have an incentive to undertake them. Secondly, the ability to examine a greater number of techniques (from different countries and a larger number of suppliers within them) may allow greater labor intensity than if the choice were limited to the options presented by a few foreign producers or consultants. We may term this increased "scanning" ability.

The combination of adaptation and increased scanning will change the typical isoquant from ABC_o to ABC_1 in Figure I. Assuming a factor endowment somewhere to the right of the ridge line OZ, the extension of the effective range of choice will permit an increase in output. Moreover, if there is domestic research on labor intensive techniques which increases total factor productivity in the region to the right of B, the actual isoquant along which the economy will operate will be ABC_2. But note that the isoquant ABC_2 has a higher elasticity of substitution than ABC_1 a factor which, as will be discussed below, may be of particular importance for the growth process.

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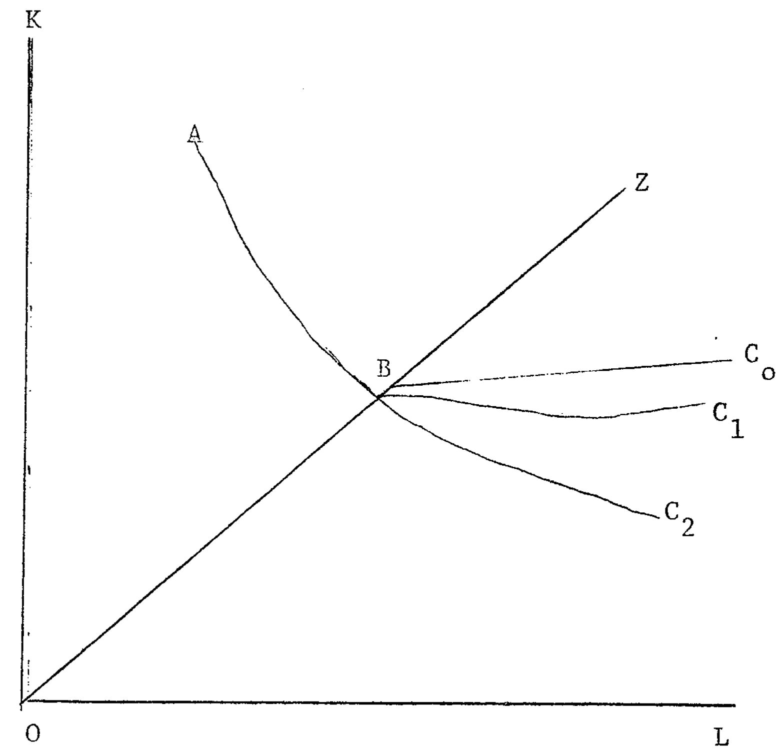
[1]There is evidence of this process in both Japanese and Russian history. See Gustav Ranis, "Factor Proportions in Japanese Economic Development," American Economic Review, XLVII, Sept. 1957, pp. 594-606 and David Granick, "Economic Development and Productivity Analysis: The Case of Soviet Metalworking Industry," The Quarterly Journal of Economics, LXXI (May 1957), pp. 205-233.

Analysis of the sources of output growth in the economy of Israel provides a useful example for highlighting the different implications of the traditional approach to education and one which emphasizes the changing nature of the production function. To anticipate our results, the usual productivity calculations indicate that changing education levels in Israel had little impact on growth, while our formation suggests that the level of education was, in fact, an important factor in the growth process.



I. Calculations of the Residual

Between 1954 and 1965 real income in Israel's total private economy (excluding government and private non-profit institutions) grew by 10.9 percent per annum (compounded), fixed capital grew at 10.8 percent and the labor force at 3.9 percent. Fitting a Cobb-Douglas with a time trend on annual data and using capital stock lagged by a period[1] yields

$$(1)\quad \log (Q/L) = -.177 + .0241t + .6483 \log (K_{t-1}/L)$$
$$(.411)\quad (.0173)\quad (.2827)$$
$$R^2 = .9970$$

Weighting factor growth by the estimated factor elasticities, the residual is about 2.5 percent per annum, roughly the same as the coefficient of t or about a quarter of the aggregate growth rate.[2]

Israel is usually considered to be a country in which the high education level both contributed to rapid growth and is an important source of high income levels.[3] However, attempts to arrive at a quality adjustment for formal education indicate no change for most of the period considered. Using years of education as an index of quality, we found no increase in the average years of education of the labor force between 1954 and 1961 and there was probably only a slight rise in this measure in the 1961-1965 period. The failure of average years of education to increase is a result of the changing composition of the labor force. In 1950 the labor force was composed mainly of European immigrants or their children, and embodied

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[1]The use of lagged capital stock implies an eighteen month lag before new capacity is fully utilized, a period which seems reasonable in the Israeli context. Use of the current capital stock, however, also yields a similar equation. Only post-1954 observations were used in the regression because of considerable year to year fluctuation in output (and probably capacity utilization) in earlier years, although during the entire 1950 to 1953 period there was a considerable growth in the capital-labor ratio.

[2]An equation with capital and labor entered as separate variables and excluding a trend term indicates that economies of scale may be present. However, the labor variable is statistically insignificant, making the formal test for scale economies more difficult to interpret. The trend coefficient may thus partly reflect economies of scale.

[3]Richard Easterlin has shown that in 1948 Israel had a higher percentage of college graduates than the U.S. R.E. Easterlin, "Israeli Development: Past Accomplishments and Future Problems," Quarterly Journal of Economics, Vol. LXXV, February 1961. A recent analysis of the sources of intercountry income differentials also emphasizes the importance of Israeli human resources; see A.O. Kreuger, op. cit.

a relatively high average education level. However, over time an increasing percentage of the labor force was accounted for by immigrants from North Africa and the Middle East, a group with considerably lower formal education. Although the average education level within both groups was increasing over this period, the overall average for the labor force remained constant as a result of the increasing proportion of new immigrants.

Another quality adjustment was also considered, namely, average length of residence in the country. Because of the high proportion of new immigrants in the labor force, there may have been "exogenous" increases in productivity as the average length of residence in the country increased. Many of the newly employed were performing jobs in which they had no prior experience, and which were often far removed from their previous occupation. They were often either unskilled or possessed skills which were not suitable for Israel's economy.[1] For the most part they had previously been artisans or engaged in the service sector, while once in Israel they were channeled, in disproportionate numbers, to agriculture and modern manufacturing. Further, a substantial percentage came from the countries of North Africa and the Middle East and had thus had little previous contact with a modern economy; this manifested itself in poor employee discipline, high absenteeism, etc. Thus, new labor force members probably exhibited considerably lower productivity when initially employed, relative to those members with previous experience, although it is plausible to assume that their rate of productivity growth may have been greater than and eventually approached that of veteran residents.

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[1]A thorough discussion of the skills and backgrounds of immigrants is given in M. Sicron, Immigration to Israel, 1948-1953 (Jerusalem, Falk Project, 1957).

Unfortunately, available data on income differentials by duration of residence (after adjustment for age and education) do not provide strong support for this hypothesis. Although it may well be that the income data[1] do not reflect differential productivity because of institutional rigidities, we are left without a theoretically justifiable way in which to adjust the nominal labor input.[2] Are we then to conclude that neither the absolute level of education nor movements in this level were of importance in explaining Israeli growth or are other approaches possible?

II. Given the much more rapid growth of capital than labor, labor would act as a brake on output growth. However, the greater the ease with which capital can be substituted for labor, the less is the restrictive effect on growth of the latter; a higher elasticity of substitution slows the onset of diminishing returns. Hence, it is of some importance in analyzing the Israeli growth process to discriminate between a Cobb-Douglas production function which involved a particular _a priori_ specification of the elasticity of substitution and a more general approach which allows the data to choose this parameter. Thus, as an alternative, a CES function was estimated directly on the same output, capital and labor series using a non-linear estimation procedure. The result indicated an unusually high elasticity of substitution, close to 2. Because of both substantial multicollinearity and a high degree of explanation, it is impossible to decide between this estimate and the Cobb-Douglas in terms of the usual statistical criteria. However, suppose the "true" elasticity is in fact greater than unity, what are the implications of this for the interpretation of the sources of growth.

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[1] An excellent survey and analysis of available data is given by G. Hanoch, "Income Differentials in Israel," _Fifth Report_ (Jerusalem, Falk Project, 1961).

[2] Although it is possible to use the duration of residence index itself as an independent variable, this too seems to lack any strong theoretical underpinning.

Richard Nelson has shown that a nonunitary elasticity of substitution will result in minor adjustments to the rate of growth yielded by the Cobb-Douglas unless there is very rapid growth in the capital-labor ratio.[1] This, however, is precisely the situation in Israel where the capital-labor ratio increased by 230 percent between 1950 and 1965 while labor productivity increased by 150 percent. Using the coefficient K_{t-1}/L in (1) as the estimate of the output elasticity of capital, the growth in the capital-labor ratio explains 85 percent of the increase in labor productivity between 1950 and 1965. However, using a CES with the estimated substitution elasticity of 2, the growth in capital intensity accounts for .93 of the change in labor productivity.[2] One half of the unaccounted for growth in productivity or the residual is eliminated if the possibility of the estimated elasticity of substitution being accurate is admitted and one third is eliminated when $\sigma = 1.5$. Part of the output growth formerly ascribed to "technical change" is now attributed to the ease with which the economy substitutes capital for labor: in effect the greater elasticity of substitution economizes on the

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[1]Richard R. Nelson, "The CES Production Function and Economic Growth, Projections," Review of Economics and Statistics, Vol. XLVII, August, 1965.

[2]The formula used is

$$\frac{\left(\frac{O}{L}\right)_1}{\left(\frac{O}{L}\right)_0} = \left[(1-\alpha) + \alpha \left(\frac{\left(\frac{K}{L}\right)_1}{\left(\frac{K}{L}\right)_0} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

where $\alpha = .65$. See Nelson, op. cit.

slower growing factor and in Israel's case has the same impact as a (Hicks) labor saving innovation.[1] Does this change in the explanation of the sources of growth simply represent the substitution of a mechanical concept for the more embarassing one of "ignorance"? We think not.

The "production function" of a country which mainly imports its equipment, as well as production concepts such as the optimal relation between buildings and equipment, depends on its ability to search for and modify alternative foreign production processes. In the introduction we suggested that one benefit of a highly educated labor force would be the generation of a more elastic isoquant through the implementation of domestic adaptation. This could generate more efficient production methods with techniques whose labor intensity was greater than that in the country producing investment goods. Not only would the isoquant be extended, but in the extended range research could lead to greater efficiency. While this is an important factor for capital scarce economies, Israel was a labor scarce economy. For such an economy, it is not adaptation of existing techniques but the "discovery" and efficient adoption of the capital intensive techniques currently in use in developed countries which is of great importance. However, the transition to capital intensive processes is far from simple.

It is well known that learning or progress functions show that hours of input per unit of output decline as cumulated production increases.[2] Usually, however, this occurs within the context of a given technique. While

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[1]If capital were the more slowly growing factor, the higher elasticity of substitution would have the same effect as a capital saving innovation.

[2]For a survey and an attempt at an interpretation, see Walter Oi, "The Neoclassical Foundations of Progress Functions," The Economic Journal, September 1967.

it is not really understood why the reduction in input occurs (is labor learning mechanically, does management improve and remember prior mistakes)[1] it is relatively clear that this learning is specific to a given technique. Thus an important strand of economic literature suggests that much of "embodied technical progress, design improvements in machinery," also occur within a relatively limited spectrum of the potential technology. It was small improvements within the basic bessemer process rather than a change to another process which led to increasing productivity in steel.[2] Much of what is learned (whatever that may be) would not necessarily carry over to much more (less) automated processes.[3] New types of learning would have to occur if there were dramatic changes in capital intensity. But the time taken for such learning may be decreased considerably by the existence of a highly skilled group which can understand professional journals and converse as equals with foreign colleagues.

Countries, then, are likely to be more efficient in techniques which they currently use, than in those which differ substantially in their capital-labor ratio (degree of automation).[4] One can then visualize the

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[1] cf. Nelson and Winters, op. cit.

[2] See Peter Temin, Iron and Steel in Nineteenth Century America: An Economic Inquiry (Cambridge: M.I.T. Press, 1964) and for another example Robert Woodbury, History of the Milling Machine (Cambridge: M.I.T. Press, 1960).

[3] A similar view is taken by A.G. Atkinson and J. Stiglitz in "A New View of Technological Change," The Economic Journal, September 1967.

[4] Atkinson and Stiglitz discuss the importance of this factor for optimum choice of technique.

isoquant from which a country experiencing capital/labor growth can choose as that in Figure II. Each country, having undergone progress relatively

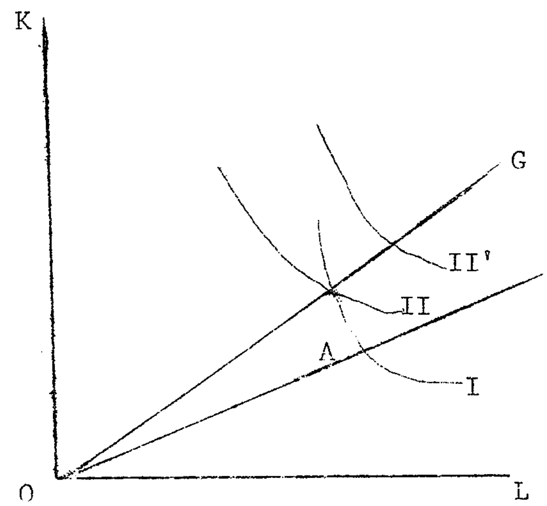

Figure II

specific to its endowment has greatest efficiency within a range around this ray. If Israel were at A and capital deepening is occurring, it is clearly more desirable to move along II (to the left of OG) rather than move along I or have to repeat the process by which another country moved from II' to II. The ability to do this is, in our view, a function of the level of education. It is in this sense that the stock of education changes the production constellation. In its absence the economy would move only along I or from I to II'. In effect, the benefit of undergoing increased capital accumulation is greatest in the presence of highly trained personnel who allow the economy to avoid duplicating earlier learning processes or being locked into one region of the potential isoquant. However, it is not simply that the switching process is more efficient. It may well be that some of the newer isoquants would not have been uncovered at all. Both the latter (scanning) function and the possibility of efficient implementation are functions of the domestic education level. Education thus enters the production function by allowing a greater elasticity of substitution, in a sense an increase in absorptive capacity.

This view of production essentially denies the independent existence of the conventional production frontier for the importing country. Rather, it posits a "potential" production frontier which may roughly be thought of as representing the limits of the current state of technology.[1] Of the existing set of available techniques only a subset are known in any country but this subset is larger the greater the ability to investigate alternate techniques. Thus the elasticity of substitution is positively related to this searching ability and thus to the stock of educated people.

Our view of the way in which education enters the production process is complementary to an approach suggested by Nelson and Phelps.[2] In their model education is productive because it allows those possessing it to adapt to new technology. Indeed, the marginal product of education in the strong version of their model is positive only if the technology is becoming more advanced. Applying this hypothesis to U.S. agriculture Welch finds that a major determinant of the differential wase between college graduates and each of two other classes of labor is the extent of agricultural research.[3] "If production were to become technically static, eventually the productive

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[1] In an unpublished paper, Yujiro Hayami suggests a similar concept which he terms a "meta production function." See his "Green Revolution in Historical Perspective: The Experience of Japan, Taiwan and Korea," mimeographed.

[2] R.R. Nelson and E. Phelps, "Investment in Humans, Technological Diffusion and Economic Growth," American Economic Review (May 1966).

[3] F. Welch, "Education in Production," Journal of Political Economy (Jan./Feb. 1970).

characteristics of all inputs would become fairly well understood. This common information would be passed by word of mouth from one generation of farmers to the next, and under such conditions it is difficult to understand how education could enhance allocative efficiency."

In this spirit, the role of education in Israel was to allow adjustment to rapidly changing factor scarcities. Education has a high product not only when the technical frontier is shifting, but even with the same (world-wide) frontier, when changes in factor availability dictate changes which economize on the scarce factor.

A further analogy may be made to the more conventional theory of production in which the short run elasticity of substitution is quite limited once a machine is in place, but when renewal occurs the new factor combination can be chosen from among a large range of choices. In this type of process, it is the passage of time, the need to replace equipment, which allows an increase in the range of factor choice.[1] Whether the new factor combination differs from the old will, of course, depend on relative factor prices. The differences between this putty-clay view and ours is that the former assumes a known set of substitution opportunities which become relevant at replacement while we assume this set is itself a function of the "scanning" and adaptation capacity of the economy.

III. Relative Factor Prices

A brief comment is in order on the inducement to search for more capital intensive techniques. Throughout the period considered, the price of

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[1]See, e.g., Murray Brown, On the Theory and Measurement of Technological Change, (Cambridge: Cambridge University Press, 1966), Chapter 5.

labor was rising more rapidly than that of capital. (Table 1) Assuming profit maximizing behavior such changes in relative factor prices would serve as an incentive to seek more capital using production methods.[1] This process, according to our view would not take the form of domestic invention insofar as Israel had only a limited capital goods industry. Rather, the factor price incentive was transmitted into a search for relevant foreign production techniques. This is analogous to induced technical progress insofar as an increase in the elasticity of substitution was in effect Hicks labor saving. This view suggests that adaptation to changing factor prices cannot be taken for granted, but is dependent on the ability of the members of the economy to undertake search procedures.

Finally, a question might arise about whether one could attribute part of the growth of other countries with similar educational endowments to a high elasticity of substitution. First, the question is not empirically important unless the capital-labor ratio is growing relatively rapidly, a characteristic not found in most developed countries of high education endowment. Even if it were, it is likely that the differences on capital intensity among advanced countries are likely to be relatively small, so that a switch may not yield much of an increase in the elasticity of substitution. The main borrowing is in terms of new processes of production, the product cycle, rather than techniques permitting factor substitution.[2]

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[1]A detailed empirical examination of the relevance of the induced innovation hypothesis in American and Japanese agriculture is provided by Yujiro Hayami and V.W. Ruttan, "Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880-1960," mimeo, Department of Agricultural Economics, University of Minnesota.

[2]For a useful summary of the product cycle literature, see G.C. Hufbauer, Synthetic Materials and the Theory of International Trade, (Cambridge: Harvard University Press, 1966).

Table 1

Industrial Wage Deflated by Price of Equipment

1955	86.7
1958	100.0
1961	110.0
1965	113.8

Note: Interest rates were constant over the period.

Source: <u>Statistical Abstract of Israel, 1968</u>, pp. 152-53, 380.