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HIGH LEVEL MANPOWER AND DEVELOPMENT ALTERNATIVES FOR THE TANZANIAN ECONOMY

by

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PREFACE

This essay had its origin when as a middle-course graduate student, the possibility presented itself for me to return to the West Indies to undertake research in manpower planning, an activity that the islands were beginning to look to with greater earnestness in their effort at comprehensive economic planning. While I did not avail myself of the opportunity at that time to delve into the actual business of designing manpower plans for these newly independent countries, I nonetheless retained the concern that was generated through that brief encounter, at the same time as I grew more aware of the exceedingly complex nature of the process of economic development. The choice of Tanzania for eventual empirical implementation of my broader concern might be accidental, but the broader concern itself, certainly was not.

I accumulated large debts in the course of this dissertation. I would like first to thank the members of my dissertation committee for all their constructive criticism and comments. They are Dr. Felicia Deyrup, from whom I learned a great deal in economic development; Dr. Robert Heilbroner, who gave needed encouragement at a critical stage in the writing of this thesis; and Dr. Thomas Vietorisz, chairman, whose eye for precision helped to steer me clear of otherwise serious errors.

I would also like to thank Professor Charles Frank, Jr., of Princeton University for making available to me Segal's unpublished dissertation <u>East African Common Market Inequities of the 1960's: An Arbitration Scheme</u>, presented to Yale University in 1969, from which the twelve sector input-output model of Tanzania used in this thesis was derived; to Professor Larry Westphal also of Princeton, for providing the MFOR-360 linear programming code used to solve the Tanzania planning model; to Mr. Michael Klein, computer scientist at The University of Akron's computer center, for his invaluable programming assistance; to The University of Akron for making computer time available.

I would like finally to thank my family, both here and in other places for continued encouragement and help throughout what has been a rather long process. I must, however, single out my wife, Joan, (who is already celebrating the conclusion of this thesis), for, in almost every way, this work is as much hers as it is mine.

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Chapter I

INTRODUCTION

It has increasingly been recognized that the growth process, to the extent that it involves not only an amount of tangible capital, but also a growing sophistication of all productive factors, is essentially a multi-dimensional process, and to that extent, requires the continued upgrading of the capacity of the work-force to adjust to, and to foster, technological change. This appreciation has pointed quite strongly to the need for a more direct recognition of the function of human capital in the growth process, and for a more inclusive theoretical as well as practical treatment of the capital formation, now redefined to include human as well as non-human elements.(1)

Perhaps the single most important landmark in this development has been the evidence from the work on aggregate production functions, that a significant part of the growth process of already industrialized nations over time, was not explained by the factors capital and labor defined in the conventional sense, and that it became necessary to augment the tangible factors of production with the intangible element-technical change, in order that theoretical production functions could be used to explain the growth process. Robert Solow estimated that only about 12% of growth measured could be accounted for by physical resources and population growth, leaving substantially greater part of the total amount of observable increment to the explained by technological progress identified as a

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(1) For an evaluation of the analytic significance of the concept of human capital in economic theory and policy, see, Harry Johnson, "The Economic Approach to Social Questions," Economica, Vol. XXXV (Feb. 1968), pp. 6-8.

residual.[2] Despite the fact, as Solow later indicated,[3] that technological change is not independent of the process of capital accumulation, the relevant effect was not discovered to be as great as to invalidate the previously derived result indicating the importance of some "residual factor" in the growth process. Several other authors, working with different data, but asking essentially the same question, obtained results which were strikingly similar. Thus Aukrust, studying Norwegian data for the period 1900-1955 came to the same conclusions as did Solow regarding the importance of hitherto unexplained factors,[4] while B. Massel was able to document the significance of the residual factor using data for U.S. manufacturing industry.[5] The work of Denison[6] among others, was to carry this development further by imputing to level of skill and education a large share of the source of measured technological change observed. The implication for planning in underdeveloped countries of this development was unmistakable. The development process could now be

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(2) R. Solow, "Technical Change and the Aggregate Production Function," Review of Economics & Statistics, Vol. XXIX, No. 3, (August 1957).

(3) _____, "Technical Progress, Capital Formation and Economic Growth," American Economic Review, Vol. LII, (May 1962).

(4) O. Aukrust, "Investment and Economic Growth," Productivity Measurement Review, No. 16, 1959, pp. 35-50 (Paris, OECD).

(5) B. Massel, "Capital Formation Technological Change in U.S. Manufacturing," Review of Economics & Statistics, Vol. XLII, No. 2 (August 1960).

(6) E. Denison, The Sources of Economic Growth in the United States and the Alternatives Before Us. Committee for Economic Development, Supplementary Paper No. 13, (1962).

looked at, not as hitherto in terms of a purely tangible capital accumulation process, in the tradition of the Harrod-Domar growth model, but now, in the richer and more expanded view of a system, in which absorptive capacity as well as tangible capital accumulation play significant roles. H. Correa has been able to document a not insignificant degree of complementarity of capital intensity and education of the labor force, using United States data.(7) A number of important conclusions follow from this result.

In the first place, results relating to economic growth using the Harrod-Domar model have to be modified in the direction of indicating the pattern of educational capital accumulation that is relevant for a particular rate of tangible capital formation. Secondly, observing that the already industrialized nations achieved their levels of wealth and economic growth on the basis of a cruder capital stock, it immediately becomes evident that historic patterns of education of the labor force in relation to tangible capital stock, and the resultant productivity parameters must necessarily understate the level of educational investment required to maintain a specific level of economic growth for the now developing countries, due to the fact of a more modern and sophisticated capital structure in use today. This would be true even if it were assumed that underdeveloped economies could easily use capital which is not of the very latest vintage, since this could only be a temporary situation. Eventually, the developing country would be compelled to update its capital stock, given the many and forceful reasons for being competitive.

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(7) H. Correa, The Economics of Human Resources, (North-Holland Publishing Company, Amsterdam: 1963), Chap. XIII. In this regard, see also E.S. Phelps, "Investment in Humans, Technological Diffusion, and The Golden Rule of Education." Golden Rules of Economic Growth, (New York 1966), pp. 158-165.

To the extent that this issue became recognized at the level of planning for growth, the problem assumed some very real dimensions, for the planning of education along with planning in the non-educational sectors had to draw on the same resources. The allocation problem loomed large, since on the one hand, not unlike non-educational allocations, capital investment in education has a long maturation period, but on the other, educational investment has a consumption as well as a productive dimension.

There is another sense, however, in which the importance of education in the growth process has forced explicit attention in the exercise of economic planning, and that is in the relation of education and the educational system to the level of integration of the emergent society. Education may provide skills, but the capacity of the economy to absorb those skills, and the climate of acceptance that newly educated citizens face determine very much whether the educational system will be functional or dysfunctional for societal integration. This issue has great significance in the quality aspect of educational planning (about which this paper is not concerned), but it is relevant for purely quantitative considerations.

The relevance of all this for developing countries is obvious, for here the supply of skilled labor emerges in most cases as one of the most serious of limiting constraints on the rate of economic growth. Rolf Vente puts the matter this way:

> In order to reach certain economic goals a sufficiently large and sufficiently qualified labor force must be available. Or expressed the other way round: The manpower resources represent a constraint on economic growth. In this respect the magnitude and nature of manpower corresponds to that of other factors, e.g. of capital. Simply to determine an optimal allocation of resources with a given target such as that of the maximizing of national product, investments in the "manpower sector" are thus to be

> included in the calculations from the onset and to be brought into relationship with the investments in other sectors - such as industry and agriculture. Education and training in this way represents a process of production which like production in other sectors exhibits costs and returns and necessitates investments.... In other words: decisions concerning questions of education and training cannot be taken without consideration of the decisions concerning "purely economic" questions and vice versa. An intricate network of mutual independence exists.[8]

For Tanzania after independence, the question of the scarcity of high-level manpower became a serious one. The answer to this question took the form of a policy decision to be fully self-sufficient, by 1980, in all types of high-level labor. This policy in turn had implications for the educational system since it was now going to be necessary to alter the shape of that system so as to allow it to meet manpower targets, and it also had implications for broad development policy since it placed a priority on developing a sufficient supply of highly skilled labor entirely domestically. If the view expounded by Vente is taken, then manpower policy must be viewed as interdependent with broader economic policy in all aspects, and the test of that manpower policy should be how well it works within the framework of broader development policy. This thesis is an attempt to look at the implications of different levels of available high-level manpower for Tanzania's economic development and to relate priorities identified in one part of the development program with priorities identified in another.

In Chapter 2, an analysis of the issues raised by considering the effects of education on economic growth will be pursued, to be followed in Chapter 3 by a review of the important programming models which have been

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(8) Rolf E. Vente, Planning Processes: The East African Case, (Weltforum Verlag. Munchen, 1970), pp. 74-75.

used to investigate the interconnections between educated or skilled labor and economic growth. Chapter 4 is a brief review of Tanzanian planning experience with specific reference to manpower planning, and in Chapter 5, a programming model is constructed to investigate the implications for a country at Tanzania's level of development, of variations in the availability of skilled labor on consumption maximization as an indicator of societal welfare. Chapter 6 includes an analysis of the solutions to the model together with suggestions for further work. The data of the model are presented in two appendices.

Chapter II

ECONOMIC GROWTH AND EDUCATION

In the course of this chapter, the several methods which have been used to identify the role of education in economic growth, will be reviewed and a critical evaluation made of them. These involve, broadly, the rate-of-return approach, the manpower planning approach, the approach using the production function, and various methods which can be grouped under the general title of the correlation approach. The literature is extensive in each case, and the attempt is made to deal only with those parts of it which have direct relevance for the main thrust of this essay. This means that I will survey the central theoretical issues which underscore the various approaches, and these will be evaluated in terms of how well they are able to specify the relationships between education and economic growth.[1]

Rate-of-Return Approach

It was Solow in his DeVries lectures,[2] who gave the rate of return on investment in relation to capital theory, its most thorough and substantial support. But while the Solow approach allowed capital theory to dodge several of the theory index-number problems with which that theory had been beset, it failed to be inclusive enough, and to the extent that human capital increases in importance in its effect on growth and development, the Solow approach while elegant, is nonetheless incomplete.

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(1) The literature here is very large, and still growing. The latest bibliography on the economics of education will contain almost 1000 items. (See Mark Blaug, The Economics of Education: A Selected Annotated Bibliography, Pergamon Press, (1969).

(2) Robert Solow, Capital Theory and the Rate of Return, (Rand McNally and Company, Chicago, 1965).

The rate of return approach is essentially meant to answer the question: how much does investment in education pay-off, and to whom? Essentially, one can separate the private rate of return from the social rate and this distinction will in fact be made later in answering some delicate questions affecting the efficacy of the method.

Being essentially a cost-benefit kind of concept, the rate of return, as it relates to education, necessitates the calculations of returns to investment in education, as well as the incurred costs. The usual approach is to regard incomes earned as some function of the level of education. Hence for a system in which there are several educational levels, the approach calculates the incremental lifetime income that is related to the extra schooling (as a proxy for education) that has been bought. If PV_{E_i} represents the present value of a stream of lifetime (t periods) income related to educational level "i" , and A represents the additional annual income generated by the additional amount of education, then

$$PV_{E_i} = \sum_t A / \sum_{V=1}^{t} (1 + t)^V, \quad V = 1, 2, \ldots, t \qquad (1)$$

This indicates that, in the benefit-cost calculus, PV_{E_i} represents the discounted stream of lifetime benefits which accrue to a particular level of educational investment, discounted by an external rate "r".* Costs are usually defined to include actual, as well as opportunity costs or foregone earnings.

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* An alternative method is to find by iteration the discount rate that will cause the present value of income in the future derived from education to be exactly equal to the cost of obtaining the education. This is the so-called internal rate of return.

Despite the substantial amount of work which has been done in refining the technique of rate of return, there remain many problems with the approach, which raise significant doubts as to its efficacy in treating the education-growth problem. In the first place, the educational system should be looked at as a series of interrelated steps, the successful completion of one step having some effect on the income related to the completion of the following step. But the rate of return approach does not yet incorporate this exceedingly important "neighborhood effect" or externality. Typically, the measures that one derived are average productivity measures for each new level of educational attainment, but these do not include the effect of the completion of one particular stage on the earnings prospects related to the completion of the following stage. Hence, the typical measure tends to understate the rate of return related to investment in education particularly at the lower stages. Burton Weisbrod[3] in recognizing the value of the option to receive further education, accordingly raised his estimate of the grade school rate of return in 1939 from 35% to 52%,[3] a not insubstantial amount.

The function for education, relating education to income is usually written:

$$Y^i = f(S^j) \tag{2}$$

where Y^i is income for individual i, and S^j is schooling related to grade j completed. More properly, it would be stated as

$$Y^i = f(S^j, S^{j-1}) \tag{3}$$

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(3) Burton A. Weisbrod, "Education and Investment in Human Capital," Journal of Political Economy, (October, 1962), pp. 106-123.

to reflect the fact that it is the additional income that is related to additional schooling that is important. Here the S measures the additional cost of the extra education. However, the function omits important explanatory variables. Schooling is by no means the only factor which is responsible for income. Age, training, wealth or privilege and intelligence being among the more significant excluded variables. Properly specified, the function should include these other factors, thus:-

$$Y^i = f(S^j, A, T, W, IQ) \quad (4)$$

where A identifies age, T measures training construed broadly, W as an indicator of wealth, and IQ to represent intelligence. The argument is that an individual attains a certain grade and hence income, not only because of schooling, but also because of wealth (or privilege) and intelligence. Hence measures of rate of return to education should properly be revised downward if the effects of these factors were computed. Hence Becker[4] has adjusted for the existence of other explanatory variables, and Chipman[5] has devised a method whereby the effect of wealth and intelligence, approximated by drop-out ratios can be brought into the analysis. Giora Hanoch[6] has lumped together various of these additional factors into one variable[7] Z in the estimating equation for the marginal internal rate of return to the sth school year:-

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(4) Gary Becker, "Underinvestment in College Education," American Economic Review, (May, 1960), pp. 346-354.

(5) Cited by Higgins, in Economic Development, (Revised edition, 1968).

(6) Giora Hanoch, "An Economic Analysis of Earnings and Schooling," Journal of Human Resources, Vol. II, No. 3, pp. 310-329.

(7) This variable is common for a homogeneous group.

$$\sum_{t=0}^{N} (1 + R)^{-t} D_t (s, Z) = 0 \qquad (5)$$

where "s" refers to schooling, "t" age, $D(s, Z) = y_t (s, Z) - y_t (s - 1, Z)$ where y_t is flow of net earnings that an individual expects to receive at some specific time, and assumed to be a function of age. D (s, Z) thus measures the marginal effect of the s^{th} school year on earnings at age t. It is then used in equation (5) to determine the marginal internal rate of return to the same s^{th} school year. The earnings function is:-

$$y(t, s; Z) \qquad (6)$$

and is estimated within a group that is homogeneous with respect to the Z variable, but in which there are variations in actual schooling, s, owing to varying tastes, and other conditions. Since the internal rate can be defined as the rate of discount that makes the present worth or value of streams of income exactly equal to zero, R in equation (5) is defined as that rate.

The inclusion of hitherto excluded explanatory variables is an important step in the right direction, but empirical evidence is still small as to the nature of the effect of social privilege and intelligence on education received. Should the new variable exert substantial influence on the demand for schooling, then an important revision of rate of return estimates would be necessary. Some indication of the magnitude involved can be had from the important work by Carnoy on rates of return in Latin America.(8) Carnoy's study, using cross-sectional sample data for 4000 male urban wage-earners taken in 1963, demonstrates the significance of non-schooling variables in explaining the variance of income. By

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(8) Martin Carnoy, "Rates of Return of Schooling in Latin America," Journal of Human Resources, Vol. II, No. 3, (Summer 1967).

including age, occupation, numbers of years of formal schooling, and father's occupation, Carnoy shows that while education still explains a significant part of the income differences among Mexican wage-earners, when other variables are included, the total variance must be severely reduced. When schooling alone is used, 43% of income variance is explained by it. However, when age is added schooling accounts for only 36% of income variance, and this drops to 29% when age, city, father's occupation, industry and attendance are included as explanatory variables.(9) Schooling remains however the single largest determinant of income differences.

With these refinements Carnoy was able to conclude that it might be the case that profitability of educational investment and the rate of growth of the economy are closely related. Specifically, rates of economic growth appear most closely related to rate of return to primary and university education. Carnoy's explanation runs in the direction of suggesting that these educational levels are least responsive to the structure and pattern of skill demand. He then suggests that economies planning growth should concentrate on these two skill classes. While however the analysis is careful and more complete, it would be optimistic to expect governments planning economic growth to limit investment in human resources through education in the manner suggested.

An important assumption in deriving rate of return estimates is that earnings or income are a good proxy for productivity.* However,

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(9) Ibid.

* This is the neoclassical argument which supports the production function approach to income distribution.

earnings may not measure productivity due to "market failures,"[10] or to the tendency for higher education to lead to preferred jobs, hence creating a divergence between income and productivity, and social returns to education may be and perhaps are substantially greater than private returns, hence making personal income a poor measure of the value added due to increased education. Finally, "tradition-bound" and "conspicuous production" wage structures,[11] in which earnings bear no specific or necessary relation to productivity, may exist to create discrepancies between income and productivity.[12]

It is clear then that despite the thrust of much of recent research, the measure "return" leaves several important questions still unanswered. This does not mean that the estimates are entirely without value, but that some caution must be employed in the use of these estimates of return. If this is true for more developed economies, it is particularly true in the case of developing countries where the primary objective and movement is in the direction of broad structural change.

As indicated earlier, costs of education have to be derived for any comparison to take place. The costs of education include, besides the actual costs involved, the opportunity costs, or earnings foregone during the educational process. Here again, we are not clear as to whether costs

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(10) See Francis Bator, "The Anatomy of Market Failure," The Quarterly Journal of Economics (August 1958), pp. 351-379.

(11) William G. Bowen, Economic Aspects of Education (Princeton University 1964), p. 18.

(12) In the same view, monopoly elements will similarly result in wages exceeding value marginal productivity.

which are identified with lost opportunities for earning income are entirely relevant, and secondly whether, what are called "consumption costs" should be excluded or included, and how.

Education can be looked at, not only as an investment good but also as a consumption item. In that case the concern is not only for future income streams, but also for present satisfaction. Typically, then, in order to relate returns to identifiably relevant costs, consumption costs should be excluded in deriving the relevant cost estimates if the concern is with education as an investment, not consumption good. Schultz(13) supports the view that these costs should be excluded from the costs of education and the rate of return calculated on the basis of the revised figures. Hence if the cost of the consumption component in the total cost of education is of the order of 50%, the rate of return would double on the basis of the revised estimates. But Bowen,(14) reasons otherwise, indicating that the return should be increased by adding the return related to consumption since education has an undeniably consumption aspect. Thus, while there is some agreement concerning the need to account for this consumption component in some way, there is no consensus on how this should be done.

The issue can be shown by use of a simple formula. Let V be the value to be received from additional education, conceived as an investment, and C, be the cost of that benefit. Then the decision rule involved here can be stated:

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(13) Theodore W. Schultz, "Investment in Human Capital," <u>American Economic Review</u>, (March 1961).

(14) Bowen, <u>op</u>. <u>cit</u>., p. 26.

$$I = f\ (V - C),\ f' > 0 \qquad (7)$$

Equation (7) states that investment in education varies directly with its profitability, identified by the excess of returns over cost. If V includes only the rewards identified with investment in education, namely earnings, and if in addition to those earnings, satisfaction or utility is derived simply from having a higher level of education, say university training in the arts as opposed to primary education, then the V should be increased. On the other hand, if it is necessary to clearly separate the income stream directly associated with the educational level from all other benefits associated with that level, then the V would in this case be smaller than in the previous case. If we should designate the V for the former case V*, then

$$V^* \geq V \qquad (8)$$

But this discussion has served to highlight another, perhaps more significant issue, and that is that the investment and consumption components may be inseparable, hence it would be impossible to derive separate estimates for purposes of policy. It may also be the case that society does not value the consumption component of education as highly as it does other consumables. If this is the case, and there is no way yet to make that comparison, then the force of the argument in favor of separating the consumption component from the more directly investment aspect of education, is severely weakened.

Smythe and Bennett estimated rates of return on education for Uganda. Their method was to determine earnings in a future period, discount those earnings to get a present value, determine net benefits from education as approximated by differentials between different levels or grades of education, and then related costs to these benefits to form cost/ benefit ratios. The costs include earnings foregone, capital repayment, recurrent costs and these were summed over the length of the relevant schooling. These benefit/cost ratios were in turn used to generate internal rates of return for each level of education. Their results indicate low rates to university education and to lower secondary training, much higher returns to primary education and highest results for higher secondary schools.(15) The question that should be asked is whether or not the ratios and return calculated represent real scarcity values, or whether the figures are biased in one direction or the other. Smythe and Bennett only touch on some of the issues. They rightly question the differentials in rates of return, suggesting that returns for university training should be raised and those for primary education be lowered to reflect the positive effect that highly skilled workers have on the productivity of lower skilled workers. But these adjustments are unlikely to account for the 5 to 1 ratio of primary rates of return to university rates of return. Their results suggest at least short run concentration on primary and higher school education and deemphasis of univeristy training in particular.

Where(*) however rates of return reflect pre-independence governmental wage scales and structures, they do not necessarily reflect post-independence productivity co-efficients and this long-term and even short

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(15) John A. Smythe and Nicholas L. Bennett, "Rates of Return on Investment in Education: A Tool for Short-Term Educational Planning, Illustrated with Ugandan Data," in George Z. F. Bereday and Joseph A. Lauwerys, (Eds.), Educational Planning, (1967), pp. 299-322.

(*) for established colonial territories.

term policy cannot be made to depend for support on these calculated rates.

What then are the fundamental limitations of the method which make it highly suspect as a method for aiding in the formulation of economic policy in underdeveloped economies? First, present earnings may not measure productivity, hence the use of earnings data for purposes of resource allocation would lead in several cases to resource mis-allocation. Secondly, present earnings may not measure lifetime earnings, earnings profiles may differ markedly,[16] and changes and differentials in earnings measure scarcity value (defined here to include scarcity determined by monopoly elements, etc.), and not only productivity equivalent. Third, the existence of strong externalities leaves the approach in doubt since market data in the face of externalities would cause a misallocation of resources, (specifically under-utilization for the case of external economies). Finally, the discount rate used to derive the present value of a future stream of earnings is a crucial variable, and rates of return are exceedingly sensitive to parametric variation of these rates.

Essentially, then, despite the improvements which have been achieved in the measurement of rates of return to educational investment, the method is still very far from satisfactory for purposes of educational planning in the broader context of planning for economic development and growth.

Manpower Planning

Economic development has been defined in several ways. One way of looking at it is in the differentiation of the industrial structure of the

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(16) This is precisely the issue that invalidates the pay-back period as a true measure of ranking investment alternatives.

economy of our time. In short, economic development can be described by the increasing inter-connectedness of the industrial relationships characterizing an economy, as a process by which the cells of an inter-industry table get filled in with positive entries. This increasing inter-connectedness of the inter-industry structure must essentially be associated with and require an increasing variety of skills. Development planning has sought to relate this need for skills to fit a prescribed industrial structure through varied kinds of skill projection, or what is otherwise called manpower planning. On the face of it, manpower planning might appear to be somewhat unrelated to the issue of the effect of education or economic development, but on closer view, it becomes clear that education contributes to the development process by providing skills as well as the aptitude to acquire skills.

It is obvious that education construed as manpower planning is not to be narrowly defined as classroom instruction, but should be construed more broadly to include vocational and on-the-job training.

Manpower planning is one of the most direct methods of relating education to development and growth, in that explicit recognition is made of the contribution of education, broadly conceived, to the increase of knowledge and skills acquired by the labor force. It asks the simple question: what is the proportion of various skills necessary to sustain economic growth at a certain level X years in the future? It typically includes (a) an analysis of the present situation (the initial conditions); (b) a general appraisal of the educational system; (c) a survey of programmes for on-the-job training; (d) an analysis of the structure of incentives; and (e) an inventory of job requirements over the short-term. Estimating future requirements can be done by one or a combination of a number of methods, and can be direct or indirect, that is either relating educational level to GNP in fixed proportions, or relating education to skills and productivity in the first place, and then making the connection with level of output. Manpower planning methods are thus based on the view of the education/economic development process as uni-directional, and rest on the assumption that if present skills were developed out of an educational system over a period of years, it should be possible, if future skill requirements can be known, to determine the present structure of educational requirements. There are thus two fundamental sets of calculations to be made: first, calculations of the occupational breakdown of the work force; second, to relate these occupational characteristics to their educational counterpart.

There exist several ways of going about determining the occupational characteristics of the work force, and most of these have been used at one time or the other in different manpower planning exercises. First, it is possible to obtain estimates of skill demands or requirements by employer estimates of those demands. This was the method followed by Tanzania in the Tobias survey.(17) The method was used also in manpower studies for Iran(18), in the Philippines(19), and in Jamaica.(20) In all cases,

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(17) Survey of the high-level manpower requirements and resources in Tanganyika, 1962-1967. Tanganyika.

(18) G. B. Baldwin, "Iran's Experience in Manpower Planning: Concepts, Techniques and Lessons," in F. Harbison & C.A. Myers, <u>Manpower and Education</u>, (1965).

(19) A. S. Bhalla, "Manpower and Economic Planning in the Philippines," <u>International Labor Review</u>, Vol. 94, No. 6, (1966).

(20) From private correspondence.

the degree of accuracy of the method was later questioned at least by the demand patterns that were forthcoming, that were different from the estimates, and which neglected the largely unforseen developments in the form of new industries and processes. This is perhaps the most serious criticism of that method in that for countries that are developing most rapidly, it can be expected that entirely new demands for labor skills will always arise to confound the most careful estimates made by employers.

A second approach involves the extrapolation of certain trends observed in the past, and can be of trends in individual occupations or trends in the distribution of occupations in the labor force as a whole. Examples of these are the Chile study[21] and the study of manpower requirements for Hungary.[22] Here again, sharp changes in the trends identified are part of the process of development, thus it stands to reason that past trends are not going to be good guides to the future demand for qualified manpower.

A further serious problem associated with extrapolating trends is the assumption of equilibrium in labor market. If trends observed in the past are used for projections, then it must be that it is assumed that the observed proportions, whether they be labor-output ratios or occupation-sector ratios, are somehow optimal in some sense. Otherwise, the existing disequilibria are being projected into the future. But the process of

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(21) R. C. Blitz, "The Role of High-Level Manpower in the Economic Development of Chile," in F. Harbison and C.A. Myers, op. cit.

(22) J. Timar, "High-Level Manpower Planning in Hungary and Its Relation to Educational Development," International Labor Review, Vol. 86, No. 4, (1967).

development is usually conceived of as a movement from disequilibrium to equilibrium in several markets as structural rigidities of one kind and another get displaced through properly functioning markets. Otherwise there would be no need for manpower policy in developing countries. Hence projections into the future of observed patterns must be regarded as somewhat suspect, since in all likelihood disequilibrium patterns are being used to determine future states. It is therefore anomolous to conceive of extrapolation as an important part of the technique of manpower planning since manpower planning makes sense only if the market cannot be allowed to allocate resources, in the future, as it did in the past, or does in the present.

By far the most elaborate of all manpower requirements studies attempted was the MRP or Mediteranean Regional Project.[23] The project, carried out by the OECD in cooperation with each of the countries, Greece, Italy, Portugal, Spain, Turkey and Yugoslavia used one method of computation which was common to all the countries in deriving required manpower. There are at least four steps involved. On the basis of a development plan, output targets for each of the relevant sectors were established. These targets were then used to determine sectoral employment levels by the application of labor/output ratios to the previously determined output targets. These employment estimates by sectors were then broken down into occupational categories, and finally these occupational requirements were translated into the educational needs necessary for their

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(23) OECD, The Mediteranean Regional Project (1965). Specific Reports on Greece, Italy, Portugal, Spain, Turkey and Yugoslavia.

attainment. A simple formula can be used to demonstrate the logic of the MRP approach:

$$Y \cdot \frac{Yi}{Y} \cdot \frac{Ni}{Yi} \cdot \frac{Nji}{Ni} \cdot \frac{Nj^e}{Nji} = Lj^e \qquad (9)$$

where Y represents gross domestic product, Yi represents product in sector or industry i, Ni the labor force in sector or industry i, Nji the occupation j/industry or sector i labor distribution, Nj^e the labor force with education e in occupation j. Lj^e is therefore the numbers of workers with education e in occupation j in sector or industry i. Total labor is thus defined to be at least as great as the sum of all labor with education e, in occupations j in all sectors or industries i in the economy.

The method just outlined has been used in various planning exercises, and it is interesting to see how sensitive the results can be expected to be, given the format used in their determination. Hollister[(24)] using what he calls "sensitivity analysis" and "source of change analysis" has shown that (i) manpower requirements have a significant impact on educational output, as over relevant periods, more than 50% of the change in required educational output was determined by manpower requirements over and above the need to maintain a constant education/labor force intensity; (ii) substitution possibilities appear important in view of the diversity of occupation/output ratios; (iii) planning of output should take into consideration the possibility of a variety of skill mixes in output, and should estimate the costs of these alternatives; (iv) the "most serious"

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(24) Robinson G. Hollister, A Technical Evaluation of the First Stage of the Mediterranean Regional Project, (Paris: OECD, 1966).

problem which the evaluation has shown was that estimates of educational outputs were extremely sensitive to the assumed occupation/education relationships.(25) As Blaug has shown this is most probably due to the concept of educational attainment used. Here the numbers of years of schooling, as an average is used to express the educational requirements. But it seems highly unlikely that educational requirements can be represented so easily as in a single number. Rather a vector of types of education seem appropriate. Indeed, the work of Blandy(26) in showing the need for occupational classification and that of Eckaus(27) in deriving educational requirements for different sectors in the economy have confirmed the long-run upgrading of both education and skill requirements, while Scoville, working with occupational rather than industry bases, found that the rate of increase in educational levels had itself increased since 1950. The instability in important parameters used in the MRP approach therefore weakens its viability.

Educational planning is essentially a long-term exercise. The maturation period of educational capital lasts anywhere from ten to twenty years, hence must be undertaken with a great deal of uncertainty, yet manpower planning forecasts appear to be capable of being made only for short

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(25) Ibid.

(26) Richard Blandy, "Some Questions Concerning Education and Training in the Developing Countries," International Labor Review (December 1965), pp. 476-489.

(27) R. S. Eckaus, "Economic Criteria for Education and Training," Review of Economics and Statistics, May 1964, pp. 181-190.

periods.[28] While it is possible to influence the "working capital" already in process of formation into final output (students already in school) in the short-term, this constitutes only a small part of the total need. Manpower planning therefore fails precisely at the point at which it is most needed, that is in not being able to be used for the truly long-term forecasts which are essential for educational planning as part of long-term perspective planning.

The development process cannot be assumed not to involve the effect of technical progress on factor productivity, yet manpower forecasts have not usually included estimates of technical progress and the effect of this on the demand for education. Despite the importance of this factor manpower planning exercises have not been able to quantify the essential relationship. A modest attempt at theoretical formulation of the problem has been made by Von Weizsacker, but full empirical implementation of his model will perhaps take some time. Von Weizsacker applies the concept of embodied technical progress to human capital in an optimization framework where the decision is between work and education. He finds that, given the sensitivity of earnings to education and training and the assumption that knowledge depreciates through time, under certain conditions it is optimal to undertake education exclusively in one period and then work exclusively in the next (if we divide life after compulsory education into full-time education, part-time education and full-time employment), under

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(28) Mark Blaug, "Approaches to Educational Planning," Economic Journal (June 1967), p. 278, puts the matter this way: "All the evidence shows that we do not yet know how to forecast beyond three or four years with anything remotely resembling the 10% margins of error that are regarded as just tolerable in general economic forecasting."

other conditions it is optimal to undertake education, then part-time employment and then full-time employment. This is an interesting result, but the model is too abstract, (using results from control theory and the calculus of variations) to solve the problem in specific terms.[29]

The issue of externalities generated by educational investment has already been raised. In that context, it was indicated that there was an important consumption aspect to education which should be recognized in any attempt to use market data to determine true rates of return on educational investment. It was also indicated that the effect of the completion of one grade in school on the possibility of completing the succeeding grade should theoretically be recognized, and in computing rates of return this externality identified in getting true rates of return. These issues arise again in manpower planning, and their non-recognition by this method constitutes serious shortcomings.

Skill acquisition is not costless. Educational planning should therefore explicitly recognize the budget limitations inherent in any planning situation. But manpower planning specifically in the MRP tradition tacitly assumes that the acquisition of skills is justifiable at any price, since, as has been shown, it is the skill structure that is being forced to adjust to the industrial structure. The fact that labor skills are assumed to be the adaptive variable indicates that the acquisition cost of these skills is assumed not to vary that much so as

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(29) C. C. Von Weizsacker, "Training Policies Under Conditions of Technical Progress," Mathematical Models in Educational Planning, op. cit., pp. 245-257. See also in this regard, the note by Sheshenski, Eytan Sheshenski, "On the Individual's Lifetime Allocation Between Education and Work," Metroeconomica, (1968), pp. 42-49.

to alter the profitability of any alternative pattern of allocation.(30) Yet this is an extremely heroic assumption particularly in a setting of scarce resources. It effectively highlights the absence of optimization as an allocative mechanism in manpower planning, and this robs the exercise of an essential economic rationality.(31)

Finally, the manpower approach to educational planning assumes the absence of skill substitution ex ante.(32) To the extent that skills can be substituted, the manpower projection becomes less crucial. As the economic structure becomes more differentiated, there may be an a priori argument for a decreasing substitutability among skills, but it cannot be easily defended that skill substitution is zero even in the economic structure of advanced economies.(33)

Essentially then, the manpower approach to educational planning may be possible or even desirable in the short-run, during which structural changes will be slight, but when the necessity is for the long-term either because economic planning involves long-term planning, or when fundamental structural changes can be envisaged, the rigid assumptions which underscore the method tend to weaken the justification for the projections. It is however not indicated that the use of some kind of parameter is entirely

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(30) Henry J. Bruton, Principles of Development Economics

(31) Mark Blaug, op. cit., pp. 262-287.

(32) C. Arnold Anderson and Mary Jean Bowman, "Theoretical Considerations in Educational Planning," in Don Adams (ed.), Educational Planning (Syracuse 1964).

(33) M. Blaug, M.H. Peston, A. Ziderman, The Utilization of Educated Manpower in Industry, (London: Oliver & Boyd, 1967).

inadmissable,[34] but that in setting of planned and unplanned change, rigid relationships as those employed in manpower planning have somewhat less economic justification.[35]

Production Function Approach

The third method which has been systematically applied in educational planning utilizes the neoclassical production function in which the contribution of the factors labor and capital to the total change in output is subtracted from that change, and the residual identification as in a certain sense, the contribution to "total factor productivity" of technical change of a "disembodied" variety. While the insights that this approach allowed were significant, the method can be demonstrated to yield either over-estimates or under-estimates of the contribution of education, broadly conceived, to the increase in total factor productivity.

John Kendrick[36] proceeded along the lines of subtracting a constant price weighted input series from a constant price aggregate output series, and then identifying the residual, also called a "third factor." On the basis of his research, Kendrick was able to state that between 1889 and 1957, almost half of the increase in total output could be ascribed to this residual, as the combined (weighted) index of input factors increased at a rate of 1.9% per year, out of a total output growth of 3.5% per year.

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(34) Richard S. Eckaus, "The Factor Proportions Problem in Underdeveloped Areas," American Economic Review, (September 1955), pp. 539-565.

(35) Eckaus, op. cit.

(36) John W. Kendrick, "Productivity Trends in the United States," Princeton University Press for the N.B.E.R., 1960.

Alternatively the contribution of the residual to the growth in labor productivity can be approximated by the ratio of the size of the residual to the growth of output per unit of labor. Here again, by far the greatest portion of labor productivity growth was explained by this "third factor."

This general conclusion was amply substantiated by the work of Solow[37] and Massell[23] despite the use of a somewhat different analytic technique. Using a linear and homogeneous production function of the Cobb-Douglas variety, and assuming neutrality of technical change in the sense that output changes, do not affect factor proportions, the contribution of the residual still accounted for over 80% of the growth in labor productivity.[38] The size of the residual calculated by Denison[39] was substantially reduced, but only after direct estimates of the contribution of several other factors to growth in labor productivity, including education, and adjustments for economics of scale, had been made. Focusing on education as a factor in economic growth, Denison was able to estimate the contribution of education to U.S. economic growth during the 1929-57 period of 23%. Actually, if specified for employed persons, the contribution of education to economic growth is even more impressive.[40]

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(37) See footnotes in Chapter I.

(38) See Evsey Domar, "On the Measurement of Technical Change," Economic Journal (December 1961), pp. 709-729, for a discussion of Solow's model.

(39) Edward Denison, The Sources of Economic Growth in the United States and the Alternatives Before Us, Supplementary Paper No. 13, (CED, 1962).

(40) Ibid., p. 73. Note also that David Schwartzman, "The Contribution of Education to the Quality of Labor: 1929-1963," American Economic Review (June 1968), pp. 508-514, derives estimates of the contribution of education to increases in labor productivity which are much below those of Denison, due largely to measurement: Denison used annual data while Schwartzman used hourly earnings.

But the analysis thus far, in a certain sense, proves too much for the efficacy of education in the productive process. For as Nelson has shown[41] if it is assumed that all technological change was of the "design" variety that needed to be embodied in new capital, then capital formation could explain a substantial part of the growth in total factor productivity. Nelson calculated the residuals using a simple Cobb-Douglas model, for the period 1929-1960 in selected sub-periods. He found that, assuming factor shares do give good approximations to output elasticity, the "unexplained residual" explained approximately 60% of the growth in output over the period. If a more complex model, perhaps along the Solow lines with capital improvements considered, is used, embodiment of technical change due to new capital (design change) formation increases the sensitivity of the rate of growth or total output to changes in growth rate of capital stock. If however changes in labor quality are introduced into the modified Cobb-Douglas production function, the conclusion is that the embodiment effect of the Solow model could not be so large as to so fully explain variations in the growth rate of potential GNP over the 1929-1960 period. Since however the rate of growth of capital is so highly correlated with the rate of growth of total factor productivity, a reasonable hypothesis is that there may be a number of important interaction among the variables of the Cobb-Douglas model. Sources of these interactions are education, technical change and improved allocation. Thus, the analysis indicates the possibility that interaction phenomena play a great part in the production process, and

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(41) Richard R. Nelson, "Aggregate Production Functions and Medium Range Growth Projection," American Economic Review, September 1964, pp. 675-706.

with specific reference to the results achieved by Denison, the assumption of independence of the main contributors to the growth of total factor productivity may constitute a serious theoretical weakness. There is therefore a great need for the inclusion, in a more general model of growth, of a production function, in which technical change, improved quality of the labor force and allocative efficiency are viewed not independently, but as being complementary, one to the other.[42]

Finally, there is the possibility that there are serious "errors in measurement" problems in isolating the residual, and that if notice is taken of the contribution of changes in the structure of capital, the size of the residual would be substantially reduced. Identification of the unexplained residual with the contribution of education would grossly overstate the effect of knowledge and skills on economic growth.[43]

Summary

In summary, the formulation of economic policy on the basis of any of the methods outlined would be subjected to the introduction of large errors. Educational-manpower policy based on the rate of return approach can be expected to be sub-optimal from a social point of view; that based on manpower planning can be expected to result in misallocation as the length of the planning period increases and that based on the production

(42) See Richard R. Nelson and Edmund S. Phelps, "Investment in Humans, Technological Diffusion and Economic Growth," A.E.R. (May 1966), pp. 69-75, for an elegant demonstration of the effect of the pace of technological change on the rate of return to increased education.

(43) Zvi Griliches and Dale W. Jorgenson, "Sources of Measured Productivity Change," American Economic Review, (May 1966), pp. 50-61.

function approach could be expected to be over-optimistic with respect to the gains to be had from increasing education of the work-price, if the analysis is presented in a form which does not permit important interactional phenomena.

Perhaps, more fundamentally, each approach represents a kind of partial equilibrium analysis. In the first place, the prices used as allocative devices are assumed to represent equilibrium values, when the existence of fundamental disequilibria is one of the pervasive facts of the profile of developing countries.[44] Secondly, and no less importantly, the partial models are solved apart from the development pattern or structure of the economy as a whole. This assumes, in the case of manpower planning, that the pattern of skills is the adjusting variable, that there is a zero opportunity cost in training labor, and that the elasticity of substitution between capital and labor, and between different skill categories approaches zero. It also assumes, in the case of rate-of-return analysis, that the demand function for labor is stable and that shifts in the supply curve will not cause the appearance of nasty "identification" problems. What is needed therefore is a more powerful technique whereby interaction between the educational and non-educational sectors can be explicitly observed, and

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(44) Indeed it is quite possible that labor markets for qualified persons are characterized by cobweb phenomena where the length of time that it takes to train highly qualified labor may cause the supply to over-reach the equilibrium demand following the recognition of inadequate supply, and to under-reach in a period of excess supply. The time path of the adjustment process may oscillate without ever coming to an equilibrium position, hence the proces generated would be disequilibrium values.

where prices, which represent a perfectly competitive solution can be generated. It is to this class of mathematical models of the linear-programming and input-output types that we turn in the next chapter.

Chapter III

PROGRAMMING MODELS OF EDUCATIONAL PLANNING

The thrust of the argument in the previous chapter was this: that while each of the approaches to educational-manpower planning does provide some insight into the contribution of education to economic growth and development, the approaches remain essentially partial in scope. Indeed it was maintained that while each method was incomplete in and of itself, in combination, they could be used not only to gain knowledge of the economic contribution that education can make to growth, but also, they would constitute a superior planning framework of the kind needed for purposes of directing the formulation of policy for developing countries where the educational sector is important. Educational planning should properly be done within the framework of broad economic planning, and this requirement forces attention to the explicit mathematical inclusion of the educational sector or activity in a more general programming formulation.

In this chapter, a series of econometric models will be surveyed, and the contribution that they have made toward the understanding and more complete treatment of education in economic growth and development will be stated. In the course of the chapter, the Tinbergen-Correa model[1] will be presented, along with the contribution of Samuel Bowles,[2] the Adelman

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(1) H. Correa, J. Tinbergen, "Quantitative Adaption of Education to Accelerated Growth," Kyklos, Vol. XV (1962), pp. 776-786.

(2) Samuel Bowles, "The Efficient Allocation of Resources in Education," Quarterly Journal of Economics, (May 1967), pp. 188-219.

models,[3] the deWolff model,[4] and the Benard optimization model.[5]

As will become clear, activity in the direction of formulating models of the educational system which display characteristics of interdependence or optimization is increasing rapidly, although still in its infancy. As is to be expected from this development however, the approaches which tend to be followed vary greatly in comprehensiveness as well as concern, from the elaborate models of Adelman[6] and Benard[7] in which the educational system is viewed as one activity among a number of activities in a programming format, to the less ambitious Bowles[8] model of Northern Nigeria in which resource demand flows from the non-educational sectors are assumed given, and to be efficiently allocated by the educational sector, on the one hand, and from the combined manpower - rate of return model of

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(3) Irma Adelman, "A Linear Programming Model of Educational Planning: A Case Study of Argentina," The Theory and Design of Development, (ed.) Irma Adelman, Erik Thorbecke, Johns Hopkins Press (1966), pp. 385-412; and I. Adelman, M. Geier, F. Golloday, "Education and Economic Development: An Optimizing Approach," a paper read at the December 1967 meeting of the American Economics Association in Washington, D.C. This second model refers to Morocco.

(4) P. de Wolff, "Models for Manpower and Educational Planning," a paper read at the December 1965 meeting of the American Economic Association in New York.

(5) Jean Benard, "General Optimization Model for the Economy and Education," Mathematical Models in Educational Planning, OECD (Paris, 1967), pp. 207-244.

(6) Adelman, op. cit.

(7) Benard, op. cit.

(8) Bowles, op. cit.

Benard,[9] to the simple manpower oriented Tinbergen-Correa[10] and deWolff models,[11] on the other.

Structurally, all the models use an interindustry or input-output framework in which the production of skills involves intersectoral flows or inter-level flows, while for the Adelman approach in addition to the disaggregated production of skills, the production of non-educational output uses skills of various kinds.

The main problems that are considered by Tinbergen and Correa in their Kyklos presentation[12] are (a) the structure of the educational system appropriate to different patterns of growth - the "balanced growth" question; (b) what are the adaptations which are needed by the educational sector if accelerated growth is required, first in the presence of foreign aid, and secondly, without foreign assistance?[13] The model assumes that a fixed relationship exists between national output and educational attainment of the work force, that depreciation of the labor force can be approximated by the formula for radio-active decay, and that the present input-output co-efficients are somehow appropriate.[14] On the basis of

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(9) Benard, op. cit.

(10) Tinbergen-Correa, op. cit.

(11) deWolff, op. cit.

(12) This basic model has appeared in several other places including H. Correa, The Economics of Human Resources, North-Holland Publishing Co. (1963) and J. Tinbergen and H.C. Bos, "A Planning Model for the Educational Requirements of Economic Development," Econometric Models of Education, OECD, Paris (1965), Part I.

(13) Tinbergen-Correa, op. cit., pp. 776-777.

(14) This last assumption is more implicit than explicit.

these assumptions Tinbergen-Correa derive, with the aid of a basic six equation model, the requirements of the educational system for balanced growth at a fixed exponential rate - and for the transition from one rate of growth to a higher one.(15) Extensions of the basic model include a more general demand for education production function, sectoral dis-aggregation, and the inclusion of innovation in the production of skills. The model has been implemented empirically.(16)

While it cannot be said that the authors are unaware of the weaknesses of the model, it must nevertheless be stated that these weaknesses do limit the usefulness of the approach. In the first place, it can seriously be questioned whether production processes are characterized by fixed education output co-efficients as are implicit in the model, and even more fundamentally, whether on-the-job training, and hence skills, are not more direct and important in this context. To argue otherwise would be to place formal education too squarely in the center, when it can fairly be reasoned that formal education contributes much more to the ability to acquire a variety of skills and to the flexibility of educated work force to adapt to changing skill requirements, particularly in the setting of developing societies.

As was indicated in Chapter II, it is implicit in the manpower planning approach that the costs of training labor are minimal in relation to alternatives, and that the pattern of skills must be assumed to be the adjusting variable. This is true also for the Tinbergen-Correa model,

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(15) Tinbergen and Bos, _op. cit._

(16) _Econometric Models of Education_, _op. cit._

for the emphasis here is rather on the appropriateness of the pattern of education than on whether in relation to some clearly defined welfare function, this pattern is deemed optimal. The authors are not unaware of this,(17) but the thrust of the main model is on balance, rather than on optimization.

The optimizing model by Bowles follows in the tradition of the Tinbergen-Correa model by not treating a variety of skills, but breaks new ground by implanting a rate-of-return orientation within an optimizing approach.(18) Essentially, Bowles addressed four questions namely: (a) what amount of resources should be devoted to the creation of education; (b) what should be the optimal distribution of the resource made available by society to various types of education; (c) what kinds of educational technologies should be chosen; (d) what should be the optimal level of importation of labor for use in the educational system. The model's objective function defined a discounted rate of return attributable to various educational levels, and the model seeks to maximize this "net benefit for education" function, subject to a number of constraints in the form of an input-output model of the ecucational system and exogenously specified boundary values of a number of instrument variables. Parametric variation of arbitrary specification in the model determines the sensitivity of the optimal results to these changes.

The net benefits to education can be defined as

$$Z_j = Y_j - Y - C_j \qquad (1)$$

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(17) Tinbergen and Bos, op. cit., pp. 17-21.

(18) Samuel Bowles, op. cit.

where Y_j represents the present value of estimated stream of lifetime income which is attributable to labor with education j, Y is the measure of discounted earnings foregone during the acquisition of that education, and C_j is the measure of present value of direct costs sustained in the purchase of education level j. The objective function is then

$$Z^* = \sum_j \sum_\rho Z_j^\rho \; X_j^\rho \tag{2}$$

where Z* is the sum of product of net benefits to education j, and X_j^ρ, the number of students admitted at level j. The superscript ρ identifies the year of the planning period. This function is maximized subject to resource constraints which are of three types: (a) those inputs of stocks of teachers generated by the educational system itself, (b) those student flows within the educational system itself, and (c) those inputs from the non-educational sector of the economy. Boundary conditions on the use of instrument variables round out the set of constraints.

The assumptions of the model identify how closely the model comes to reality. For the most part these assumptions are the typical ones for a linear programming formula, but Bowles made a number of interesting changes to bring the model a bit closer to reality. Constant student-teacher ratios were assumed, but the supply-price of two types of teachers was allowed to rise after being constant over a range of supply. The resulting supply curve is thus a step function indicating the increased cost of acquiring teachers of certain types if these teachers have to be imported from abroad.

The model uses, as co-efficients in the objective function, estimated future earnings, discounted at an appropriate rate, of the various levels of education. It has been pointed out in Chapter II, that in the setting of developing societies, this assumption may not be very reliable as earnings may reflect dis-equilibrium conditions rather than equilibrium ones, and that the assumption of constancy of income differentials over time is rather heroic. It is quite possible that as the labor market condition changes from tightness to one of ease, that employers upgrade the quality of labor, by using labor of a higher educational quality in a specific occupation than was used before. This would certainly destroy the constancy of income differentials due to education. An approach based on productivity would perhaps be a better means of capturing the effect of increased education.

It was also assumed that income differentials were entirely due to education, that is, that factors such as family background, wealth, ability, did not play a significant rate in the generation of income differentials. The unreality of this assumption has already been discussed, but knowledge on this score that is amenable to quantification is still quite meager, and hence the assumption would almost certainly have to be made.

Finally, the objective function identifies only those benefits to education which are measurable in terms of higher earnings to individuals, and, specified as it is, as a linear function of activity levels, the net benefits do not enter as a function of output levels of the various activities. In the former case, as has been indicated, the total returns to educational levels may be understated since the external effects have not been included, nor have consumption aspects of education been accomodated in the model and in the latter, as Bowles correctly points out,[19] the elasticity of demand for labor is assumed infinite. While the opposite assumption of zero elasticity implicit in manpower studies is somewhat

[19] Ibid., p. 214.

strong, infinite elasticity on the other hand is no less heroic.

Initial conditions neglect the state of the economy at the beginning of the planning period, but the terminal conditions must be specified so as to force the model to provide a certain profile of post-plan conditions. Specifically, the capital structure that is bequeathed to future generations is highly sensitive to the terminal conditions required by the model. Bowles stipulated that the activities related to teacher training and for the production of continuing students be at levels, just prior to the end of the planning period, that will support post-plan rates of growth similar to those attained during the plan.

Parametric variation of some of the important assumptions in the model indicate that these assumptions are not that crucial in determining the optimal solution. This is an interesting kind of result when the specific assumptions are reviewed, but his result may have been true only because the model runs only for 7 years. It might very well be true that for educational-cum-manpower planning done over a long term period, which it should be, the model would prove sensitive to the particular assumptions used. In any event, Bowles was able to (a) determine the optimal pattern of enrollments and resource use within the educational sector, (b) determine the choice of educational technology, (c) determine the optimal pattern of importation of educated labor, and (d) determine the optimal total resource use by education.[20]

While the model has been able to provide information about the educational sector with richer detail than the Tinbergen-Correa model,[21]

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(20) Ibid., pp. 203-214.

(21) ...particularly in the choice of educational techniques.

it should not be forgotten that the educational system was considered apart from the non-educational sector, and this necessarily raises questions about the assumption of an appropriate fixed pattern of demand coming from the non-educational sector. Ideally, one should work with a model in which the optimal allocation of investible resources is viewed over as wide as possible a list of alternatives. In other words the ideal kind of model would consider the pattern of demand for labor and the production of skills simultaneously. It is to these models that we now turn.

The Adelman Models[22]

The Adelman models identify a new point of departure for the programming models involving the educational sector in that unlike the previous attempts, they explicitly involved optimization simultaneously in the education and non-education sectors. This innovation allowed the demand for education to be generated endogenously by the development of the optimal pattern of non-educational as well as educational growth. This approach, as Professor Adelman has indicated,[23] was suggested by the highly sensitive nature of the optimal solution to a programming model of Argentina, when the availability of technical and managerial manpower was raised. The optimal profile of the economic structure was changed in the direction of a higher degree of industrialization, as well as a greater concentration of manufacturing in heavy - rather than light industry.

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(22) Adelman, op. cit., Footnote 3, page 34. For ease of reference, the Adelman Argentina model will be called Adelman (I), and the Adelman Morocco model will be called Adelman (II).

(23) Ibid., Adelman (I).

The model is in the form of a dynamic linear program, covering several time periods.[24] It represents a compromise between the "manpower planning" approach and the "rate of return" approach, in that fixed labor-output coefficients are used and the desirability of labor is a function of the earnings which one related to the level of schooling. The significant departure however which the approach takes is in determining the "rate of return" along with the production profile and the pattern of education rather than in the use of historical data, as was done in Bowles. The approach also shifts the emphasis from the unilateral determination of labor requirements typical of the more conventional manpower planning approach, and allows instead for the optimal determination of supply and demand.

In the convention of the linear programming format, the model specifies an objective function to be optimized subject to a set of constraints. The objective function that is maximized can assume many forms, and three such functions were considered: (a) maximization of the discounted sum of GNP; (b) maximization of the change in GNP over the plan period; (c) minimization of the discounted sum of net foreign capital inflows. The constraints are of several types and refer to the educational system and the productive system. For the educational system, the constraints involve the usual initial conditions (supply of students and teachers and school buildings), production function for the educational system in which it is specified how students move through the educational

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(24) My remarks here will refer to Adelman (I). Both models are fundamentally alike except for better data, greater disaggregation, more thorough treatment of terminal conditions, and the possibility of importing labor (skills) in Adelman (II).

system, and a set of exogenously specified lower limits to enrollments in each type of school, to prevent radical shifts in the pattern of school enrollments during the program. For the productive sectors, the constraints are embodied in an input-output model which specifies the technological conditions of production and investment, and the usual programming requirement limiting the use of resources, both labor in the form of skill, and sectoral capacity, as well as foreign exchange and savings are specified. Behavioral constraints and terminal conditions complete the list of constraints.

Maximization of the objective function subject to the constraints results in identification of optimal levels at which the various processes should be operated in each period of the program. In addition to that the dual of the linear programming problem generates "efficiency prices" with which to evaluate constraints in the optimal program. In short, there is significant relation between the number of limited resources and the number of processes in the solution of a linear programming problem. Resources which are not binding in the sense that they are not used to capacity will have a zero shadow price in the dual. If the number of resources is greater than the number of processes, some of the excess resources will have zero shadow prices in the dual; if the number of limited resources is exactly equal to the number of processes, all resources will have positive dual values; if the number of processes is greater than the number of resources in limited supply, some processes will not be used in the optimal program.[25] For the Adelman model, the dual of the program gives shadow

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(25) For a full statement on the interpretation of the dual see for example, Dorfman, Samuelson, Solow, Linear Programming and Economic Analysis, (1958), Chap. 7; William J. Baummol, Economic Theory and Operations Analysis, (1965), Chap. 6; Saul Gass, Linear Programming, (1958) Ch. 5.

prices for the graduates and drop-outs of the various schools (or school levels) used in the system for each optimization problem. These values are used to determine social costs and benefits of education, and also to identify the subsidies that are justifiable to encourage drop-outs to remain in school. Other results of the experiments include determination of investment in education, and the educational level of the labor force. Perhaps the most crucial part of the model comprises the "labor force change" equations which provide the link between the educational and non-educational sectors. Labor demand per class of labor ((a) workers, (b) managers, white collar workers, and professionals, and (c) proprietors)[26] is translated into demand for education via productivity differentials for different schooling levels within each skill class. Professor Adelman assumed that labor within each skill class was highly substitutable, but even with equivalent education, substitution of labor between skill classes was not possible. Productivity parameters which were used were merely "questimates" of the true parameters.

Several aspects of this model, some of which were corrected in Adelman (II) warrant critical comment. In the first place, as Professor Adelman has indicated, the linearity assumptions comprise an essential limitation on the usefulness of the model, though they do not entirely invalidate its insight. Other perhaps more crucial issues involve the economic reality implied by the assumptions governing the productivity co-efficients, and the issue of substitutability of skills in the production function. While on the one hand, it may not be entirely costless

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(26) In Adelman (II), there was further disaggregation.

to convert, for example, proprietor skills into manager skills and that it is perhaps more true that, the relevant isoquant is convex, though not necessarily strictly convex over the relevant region, than is indicated by the particular assumption about non-substitutability, on the other hand it is not easily defended that productivity differentials are constant, which is implied by a constant marginal rate of substitution for different levels of education within a given skill class.[27] Labor market conditions would eventually be the deciding factor and perhaps earnings differentials would have to be used as an indicator of productivity differentials, despite their obvious limitations.[28]

Given these issues, Adelman found that with respect to the optimal educational allocation, the model was quite insensitive to changes in industrial structure and to the goals of the planners in that the alleviation of the high-level manpower bottleneck emerged as the policy of highest priority.[29]

In addition to testing the properties of the model via the use of different objective functions, Adelman could have combined the true objectives in any number of ways, perhaps by giving values to each objective in a composite preference function as was done by Van Eijk and Sandee,[30] or by regarding one of the three forms as the maximand, and

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(27) In Adelman (II), lack of skill substitutability is less severe due to the specification of sectors in terms of factor intensities.

(28) See Chapter II.

(29) This result however cannot be viewed independently of the productivity differentials assumed.

(30) C. J. Van Eijk and J. Sandee, "Quantitative Determination of an Optimum Economic Policy," Econometrica, (1959), pp. 1-13.

listing the others as among the constraints of the model. While the first method would involve some real difficulties in the specification of the parameters, the second method would lend itself exceedingly well to the quantification of the costs of alternate levels of the "instrument" variables on the attainment of the specified objective of the program. Other parametric studies which could have been made, include variations of several groups of parameters for example, teacher/student ratios, passing rates, duration of schooling, and the establishment of universal primary education.(31) Perhaps also one could study the effect of out-migration on the demands to be made on the educational system. A major departure would be to introduce non-convexities into the model so as to study the problem of scale economies.

The Benard Model(32)

In some fundamental ways, the Benard model differs from the Adelman formulations, though both share a common analytic structure. The model, again, is a linear programming model in which a preference function is maximized subject to the endogenous and exogenous constraints of the system. Its purpose is essentially similar to that of the Adelman formulations: to determine the optimum allocation of resources between education and the non-educational sectors or activities in the economy over time. There are however some important points of difference.

(31) Intuitively, one feels that this is a must for developing societies since it perhaps is true that this provides the labor force with the kind of flexibility required for large-scale structural change.

(32) Jean Benard, "General Optimization Model for the Economy and Education," Mathematical Models in Educational Planning, OECD, Paris (1967), pp. 207-243.

Unlike Adelman (I), but very much like Adelman (II), the objective function includes a specification of the post-plan production potential. The function is actually "made up of numerical indices of the standard of living of the population throughout the years considered and of the production potential at the end of that period."[33] The set of constraints can be divided into those relating to resources and uses of commercial goods and services produced, and of available labor (where commercial goods are those goods which are marketed); those defining production capacity limits; those linking training activities to the demand for skilled manpower; and exogenously specified constraints on minimum growth for education, and on budgetary ceilings.

Benard also treats the educational sector or activity, differently. The output from this sector is regarded as entirely "intermediate" in the sense that a notional activity is defined, whose function is the training of skilled labor, and the output of the educational system defined in terms of number of students, when this output is "final" (in the sense that there are not students completing one grade and going on to the next), is regarded as an input into this notional activity. The link then between education and the commercial sectors is defined in terms of transition ratios between education levels and skill levels, parameters specifying the shift from one skill level to another based on "occupational upgradings and professional experience acquired in actual practice,"[34] and an incidence ratio, indicating the number of students who, out of the number completing

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(33) Ibid., p. 208.

(34) Ibid., p. 219.

a certain level of education, will likely join the labor force. Benard then completely by-passes the thorny issue of productivity co-efficients which is central to the Adelman approach.

Another important departure in the Benard approach, though it perhaps is a result of the specification of the objective of the model, namely consumption, was the inclusion in the preference function (through the addition of a constraint) of a lower limit to the number of students who continue their education, this to insure what the author calls "educational 'end use' consumption."(35) It is recognized that the social optimum would be reduced if this constraint became effective, but this could be regarded as a kind of "cost of the educational surplus."

The model presented by Benard was not implemented in the richness of detail contained in the theoretical model, but a smaller program was worked out to test the characteristics of the main model. The data for the full implementation of the model are only now being collected. It can clearly be stated however that the model does hold out much hope for empirical implementation. It is also of a form which makes it exceptionally amenable to the parametric variation of several sets of crucial constants.

Summation

The programming models which we have looked at vary greatly in the kind of detail and in the kind of problem viewed, but in several respects, they embody important similarities. Significantly, they provide the "broad" view which was lacking in the previous attempts at the quantification of the role of education in the development process, and they indicate the

(35) Ibid., p. 211 (See Chapter II for justification of this).

scope of the problems which can be handled, when these problems are posed in a certain fashion. Programming methods perhaps will not be able to rigidly determine economic policy because of the well-known but nonetheless serious departures from reality embodied in them, but they can go a long way to indicating interdependencies showing the results of action. Perhaps, no less significantly, they can be used by planners to quantify for the decision-makers the cost of alternative courses of action. In this way they perform a useful purpose.

Appendix to Chapter III

Market Failure, Non-convexities and Research Allocation in Education

In this chapter, an analysis of the more important programming models was undertaken. It was observed that programming techniques have vastly expanded the scope of analysis related to the general problem of education, training, and economic growth. Despite their obvious advantages, some important aspects of economic reality as they relate to the issue of educational allocation were not taken into consideration, and hence the usefulness of these models is somewhat called into question. It is not here maintained that a model is useless if it does not take into view all relevant aspects of the reality in question (the revival of interest in questions of economic methodology has indicated the deep philosophical problems which beset this attempt at a total catalogue). What is, however, maintained is that policy conclusions drawn from models which push aside pervasive elements of economic reality must be regarded as eminently suspect.[1] In this appendix, we will note some of these elements, and indicate the problems introduced by their non-recognition.

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(1) The literature on methodology is quite extensive. A good flavor of the whole can be gleaned from S. R. Krupp (ed.), The Structure of Economic Science, Prentice Hall (1966). See also, Adolph Lowe, On Economic Knowledge, and Tonu Puu, "Some Reflections on the Relation Between Economic Theory and Empirical Reality," Swedish Journal of Economics, (1967), pp. 85-114. It should be remarked however, that virtually all of the methodological discussion is confined to the sphere of private goods; the public goods question is still to be addressed.

It may be worthwhile to recapitulate, in capsule form, the conclusions of Chapter II of this study. With respect to the rate of return approach and manpower planning approach to educational allocations, it was concluded that:

(a) because of disequilibrium, prices do not necessarily reflect productivity at the margin, and price signals thus cannot be trusted;

(b) since the production function reflected a static orientation, dynamic considerations are left out, and to the extent that growth is a dynamic phenomenon, the production function approach mis-states the reality;....

(c) To the extent that distributive shares are not necessarily determined by marginal productivity of the factors alone, the use of earnings data introduces a bias into the estimates of productivity. In econometric terminology, this becomes the "excluded variables" question.....

(d) Traditional methods assume separability of factor returns, but the question of complementarity of factors in the production process serves to cast serious doubt on this assumption....

(e) Whether technical change is embodied or is disembodied is an important issue, which cannot be decided only at the level of measurement.

(f) The identification of total factor productivity with the residual is perhaps more a measure of our ignorance than a measure of the contribution of a "third factor." Put in another way, could not the residual be substantially reduced if we were better able to provide more representative measures of capital input and labor input, and is not this residual dependent on the specification of the production function?

(g) The narrow definition of education used, quite despite the efforts of Mincer and Becker to include on-the-job training in that definition, presents an overly optimistic view of skill creation through formal education.

(h) The possibility of cobweb phenomena in labor markets over time leads to the very real danger of using disequilibrium values to represent equilibrium ones, with consequent misallocation of resources.

These issues have served to highlight important cases of "market failure," and in so doing can help to demonstrate the weakness of the linear programming techniques as used in the models considered in Chapter III.

It has been very well demonstrated that in order to be able to work back, in a constrained maximization problem, from the position of "constrained bliss" to determinate prices, wages and rent, convexity is a necessary requirement in both the consumption and production spheres.[2] Linear programming solutions depend crucially on the notion of convex sets and the fundamental theorems do not hold in cases where non-convexities are present. Increasing returns to scale constitute an important kind of non-convexity, in the face of which, the duality theorem does not hold. Length of schooling probably does exhibit increasing returns to scale. The

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(2) Francis Bator, "Simple Analytics of Welfare Maximization," American Economic Review, (March 1957), pp. 22-59; and Koopmans, Essay I, in Three Essays on the State of Economic Science, (1957).

crucial dependence of ease of adjustment for a community facing a new technology indicates that the greater the education at least for the primary and secondary levels, the greater the gain per unit of expenditure for the acquisition of the new technology. This has been well demonstrated in the case of agriculture where it has been observed that the better educated farmers tend to adapt to, and to adopt, more up-to-date techniques of production than their less educated peers, and this no doubt could be true also for industry.[3] Hence, since the production function for linear programming necessarily assumes constant returns to scale, allocations which are indicated by the solution to a linear programming problem will be sub-optimal in an area characterized by pervasive economies of scale.

Indivisibilities constitute a limitation on the viability of linear programming allocation methods no less significant than the existence of scale economies. These arise frequently in location problems[4] for example, and in areas where the solution to the programming problem cannot be allowed to vary continuously and retain meaning. Examples of this in the field of economic development can be cited quite easily. The extension to the field of education is fairly obvious, particularly with respect to higher education. Linear programming methods have obvious limitations when indivisibilities occur and the more powerful technique of integer programming becomes necessary.

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(3) It perhaps would be harder to demonstrate for industry due to particular institutional set-up.

(4) T. C. Koopman and M. Beckmann, "Assignment Problems and Location," Econometrica, XXV, No. 1 (January 1957). See also the full analysis in Charles R. Frank, Jr., Production Theory and Indivisible Commodities, Princeton University Press.

Traditional programming techniques have all assumed constancy of technical co-efficients. This device has appealing support in terms of ease of manipulation. However, the development process itself is nothing if it does not somehow provide for the evolution of improved technologies over time. This necessitates the recognition not only of the possibility of, say, lower capital/output ratios over the span of a perspective plan, but also, significantly, an increased labor productivity over time, if the emphasis of policy lies in the direction of improving the stock of human capital through education and training. Yet despite this, all the models have continued to use constant ratios over time. A fairly frank admission would, no doubt, lead to the writing of stochastic programming models. Short of that, if the time trend of improvement of technical co-efficients is known, this could simply be programmed. However, this is not likely to be the case. Nonetheless an attempt could be made to include some estimates of these changes in programming allocation models. The improvement in technology over time, quite apart from the existence of newer capital has been recognized and treated analytically,(5) but remains to be included in actual planning models. This could be done again using integer programming methods to solve the sequencing problem.

An issue bearing on the question of economies of scale, but separate from it, and which when operative, causes a divergence between private and social costs and benefits, is the existence of externalities of a

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(5) Ingvar Svennilson, "Economic Growth and Technical Progress: An Essay in Sequence Analysis," The Residual Factor and Economic Growth, OECD, Paris (1964), pp. 103-131.

technological nature.[6] The presence of external economies of a technological nature leads to extremely nasty pricing problems, as in the case of non-corner optima or even worse, in the case of interior optima, and clearly under conditions like these, the price system becomes highly inefficient as a resource allocation device.

It was demonstrated earlier that in the area of education and training externalities are almost always present: in the increased probability to succeed at a higher grade if success was achieved at the lower grade; or, the improved productivity in the non-educational sectors due to achievement of some level of activity in the educational sector. Given these pervasive externalities, the "efficiency" prices generated by the dual of the programming problem will in all probability provide the wrong kinds of signals, whether they are used to determine rates of return to educational investment alone, or whether they are used by individuals or by the planning agency as allocating devices (shadow prices).

In the face of this "non-classical" kind of environment in which indivisibilities are present and where there are external effects, decentralization of decision-making is not guaranteed to give efficient results and some other method of allocating resources has to be found. It should be noted however that a particular kind of decentralization is appropriate only to its related partitioning rules, and in the same way that mergers or other types of business combinations could conceivably internalize the previously existing externalities, different types of socio-economic partitioning which are in a sense coarser would probably

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(6) See Bator, "The Anatomy of Market Failure," Quarterly Journal of Economics (August 1958), pp. 351-379.

succeed in eliminating these troublesome external effects at the macro level.(7) This consideration becomes extremely relevant in cases where government participation, through the use of tax funds, is necessary to augment purely private efforts at upgrading education and training so as to achieve a higher rate of income growth. In this case the use of tax funds to finance at least a part of the cost of training represents an attempt to spread the appropriate cost over the entire range of beneficiaries of higher grade skills in the community and not only over those whose skill levels are directly affected by the new education and training.

It has been stated that in those cases where economies of scale or indivisibilities or externalities exist and are relevant,(8) the market mechanism misallocated resources. When our concern is with planning, it becomes necessary to move somewhat away from the traditional and much the simpler technique of continuous linear programming, and to employ the more difficult, but much more realistic device of integer programming. This matter will now be taken up.

It was stated earlier that the allocation problem concerning education and training finds almost everywhere present cases of technical externalities and economies of scale, and these non-convexities place added burden on the computation of correct values to be used for resource allocation if the computational device assumes perfect competitive conditions. In this situation, it becomes necessary to move to integer programming as

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(7) Leonid Hurwicz, "Efficiency of Decentralized Structures," Value and Plan, Gregory Grossman, (ed.) (1960, pp. 162-175.

(8) James M. Buchanan and Will Craig Stubblebine, "Externality," Economica, (November 1962), p. 371, for a definition of relevance with respect to externalities.

the most feasible alternative. An attempt will now be made to restate some of the already mentioned problems, using, this time, integer programming. These models are not intended to be exhaustive, but are meant to indicate some of the problems which the technique is capable of addressing.(9)

The general linear programming model can be written:

$$\begin{aligned} \text{Maximize:} \quad & z = cx \\ \text{Subject to:} \quad & Ax \leq b \\ & x \geq 0 \end{aligned} \tag{1}$$

This problem in matrix form states that the objective is to maximize the linear functional subject to a set of linear constraints and non-negativity requirements on the values of the x's in the solution. The columns of the matrix can be regarded as activities or processes and the objective is to find levels of activity operation which maximize the value of the objective function. Here, if some specific x is used (is >0) in the solution, the corresponding activity is used. In continuous programming, the activities may be used at any non-negative level; in integer programming, the activity levels are further constrained to be integer valued, being 0 or 1. The

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(9) Integer programming methods are well explained in George Dantzig, Linear Programming and Extensions, Princeton (1963); G. Hadley, Nonlinear and Dynamic Programming, Addison-Wesley (1964); and Michael Simonnard, Linear Programming, Prentice Hall (1966). A thorough survey of the subject was made by M. L. Balinsky, "Integer Programming: Methods, Uses, Computation," Management Science, Vol. 12, No. 3, (November 1965), pp. 253-313. For the application of the method to investment planning, see D. Kendrick, Programming Investment in the Process Industries, M.I.T. Press (1967) and T. Vietorisz, "Industrial Development Planning Models with Economies of Scale and Indivisibilities," Regional Science Association; Papers XII (1964), pp. 157-192.

specification of the optimization problem in this latter form is necessary for a wide group of economic problems exhibiting indivisibilities or economies of scale. Integer programming problems may be mixed, in which some not all, of the variables must take on integer values, or they may be full integer problems where the entire solution set must satisfy the integer requirement.[10]

The solution to integer programs entails great difficulties which have not yet been fully overcome. In several articles, Ralph Gomory outlined a method for the solution, first of full integer programs, then mixed integer programs. The computational experience has not been too favorable however due to the slow convergence characteristic of the method of integer forms which uses the theory of fractional part operators to integerise the variables after a non-integer optimum solution had already been formed. The method is thus practical only for very small programs and very soon becomes very costly in terms of computational effort.[11] In this chapter, no attempt will be made to get solutions to any model. The examples given serve only to indicate possibilities in respect of education and training allocations.

Possibility 1: Time sequence of improved technology through learning curve phenomena:

Earlier in the paper it was indicated that models which use constant technical co-efficients, particularly in a setting in which learning will

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(10) A full list of the problems which can be set up as integer programming problems is given in Dantzig, op. cit.

(11) See for example, Ralph Gomory, "Outline of an Algorithm for Integer Solutions to Linear Programs," Bulletin of the American Mathematical Society, LXIV (1958), pp. 275-278.

materialize at an accelerated rate, stand to distort the real time path of the economy in question, and should important allocative issues rest on the solutions of those models, decision makers may be misguided. Hence, the question of changing co-efficients over time becomes an important question. Whereas this issue however may assume only marginal proportions for models of short horizon, as the time lengthens, more explicit recognition should be made of these important changes. It is however noted, that data problems will likely restrict any effort at a closer representation of this aspect of the development process, particularly in the setting of developing nations.

In order to express the fact that the growth process involves "Learning curve" phenomena which make resource allocation based on fixed ratios very suspect, we can explicitly include in an activity analysis model changes in technical co-efficients over time which express the fact that in period t + 1, a certain technological level is achieved which was not available in period t, entirely without new investment.

Let α_{ij}^{t} be the amount of input i used to make one unit of j, or to do job j in period t. Assume also that β_{i}^{t} is the availability of input i in that period. Let α_{ij}^{t+1} and β_{i}^{t+1} represent the factor requirements and availabilities in the following period. x_{j}^{t} represents activity level j in period t. There are j activities 1, 2, ..., J and t periods 1, 2,...,T. Requirements that factors used be restrained by availabilities can be represented:

$$\alpha_{ij}^{t} \cdot x_{j}^{t} \leq \beta_{i}^{t} \tag{2}$$

$$x_{j}^{t} \leq 0 \tag{3}$$

This is true for period t. If it is also required that one achieves a "more favorable" technical co-efficient in the following period as a result of learning, then this requirement can be stated:

$$\alpha_{ij}^{t} > \alpha_{ij}^{t+1} \tag{4}$$

We wish to restrain the use of technology represented by α_{ij}^{t+1} to a period subsequent to the one in which the technology represented by α_{ij}^{t} obtained. This could be done by saying that $\alpha_{ij}^{t+1} = 0$ unless $\alpha_{ij}^{t} > 0$. Integer programming methods can be used to express this kind of zero - one, either - or constraint pattern.

Let us define a new variable δ, such that

$$0 \leq \delta \leq 1, \ \delta \text{ an integer.}$$

Note that if technology represented by α_{ij}^{t} is used, then:

$$\alpha_{ij}^{t} > 0 \tag{5}$$

Remembering that α_{ij} is appropriate to x_j^t, α_{ij}^{t+1} to x_j^{t+1}

and so on, then the condition that $\alpha_{ij}^{t+1} = 0$ if $\alpha_{ij}^{t} \nmid 0$ can be represented:

$$\alpha_{ij}^{t+1} \leq \delta_{ij} \tag{6}$$

$$\alpha_{ij}^{t} \geq \delta_{ij} \tag{7}$$

If then $\delta_{ij} = 1$ then $\alpha_{ij}^{t} \geq 1$ or $\alpha_{ij}^{t} = 1$ in (7) and equation (5) is also satisfied, and α_{ij}^{t+1} is required to be ≤ 1 in equation (6). If however, $\delta_{ij} = 0$, then in equation (6) $\alpha_{ij}^{t+1} \leq 0$ or $\alpha_{ij}^{t+1} = 0$ and $\alpha_{ij}^{t} = 0$ is a possibility from (7). Hence the only way to ensure that $\alpha_{ij}^{t+1} > 0$ or $\alpha_{ij}^{t+1} = 0$ is if $\alpha_{ij}^{t} > 0$. The integer restraints can thus be stated for any

$$x_j^{t+1} \leq \delta_{ij}$$

$$x_j^{t} \geq \delta_{ij} \tag{8}$$

$$x_j^{t} \geq 0$$

$$0 \leq \delta \leq 1 \text{ , } \delta \text{ an integer.}$$

Capacity constraints would be as indicated in (2), and maximization would be carried out with respect to $\sum_t \lambda^t x_j^t$, λ^t being weights in the function. Notice however that the problem would become quite complicated for a large program, and this effectively limits the applicability of this type technique.

Possibility 2: Education and training allocations in an urban economy:

One of the problems in urban areas is the high incidence of unemployment. Along with this, the existence of ghetto structures imposes a low potential for any individual to break out of this pattern once in it. There tends to be then high unemployment along with low potential for growth. The problem is not unlike that observed in low income countries where only massive attacks will serve to break the low level equilibrium trap. It has therefore been suggested, (and several government programs of one type or the other have been designed to meet it), that only massive efforts will ever succeed in changing the situation due to the several self-reenforcing tendencies of a poverty structure. The nature of that attack can be formulated as a programming problem in which the decision-maker is assumed to have a clear idea of what it is he intends to seek.

Assume that: (a) Government is concerned about the existence of high unemployment in its constituency; (b) it can get funds to finance training programs; (c) it can then set up government training programs in specifically designed centers to train different kinds of labor (skills); (d) business firms can use existing facilities to train labor, but could run into many problems in implementing this (specifically, unions may reject labor which did not get apprenticeship through them, or the labor that firms may train may acquire skills that are not unique to that firm but may be highly marketable and the training investment may not return to the firm appropriate rewards); (e) the Government could subsidize companies which do training, to varying degrees. Then the objective of employment policy could be to increase the skill level of the urban population with a view to setting in motion the potential for sustained productivity gain. This can be set up as a programming problem. Let:

x_i^t be type i of skilled labor in period t

x_i° be type i of skilled labor in period zero.

Then without definitive effort, the rate of growth of skilled labor i will be of a certain level which could prevent equilibrium between demand and supply of other categories of skilled labor. Let:

p_j represent the discounted lifetime earnings of labor of type skill j (j = 1, 2, ..., n)

x_j represent labor of type j which has been gotten by training labor (retraining) of type i

a_{kj} represent the amount of resource k required to produce a unit of labor skill j

This formulation of the problem would seem to indicate the use of continuous linear programming. However there usually will exist some zero-one decisions which will call for a modification of the solution technique. Certain skills will require for their inculcation the prior satisfaction of certain other requirements (for example, high level manufacturing skills require a certain level of general and technical education, and the creation of administrative skills requires yet other types of education). Secondly, assuming that the demand is forthcoming, community income would be maximized if certain activities are undertaken jointly rather than if they were done separately. In other words, important cases of joint maximization should be noted. These will therefore require the use of integer programming techniques, and the skill creation allocation problem can be stated:

$$\text{Max:} \quad f(x) = Px \tag{1}$$

$$\text{Sub. to:} \quad Ax \leq c \tag{2}$$

$$x \leq 0 \tag{3}$$

$$(0 \leq x_{int} \leq 1) \subset x_j \tag{4}$$

$$x_{int} = \text{integer}$$

The objective function (1) is a linear function of the x_j with the weights being discounted lifetime incomes of the newly created labor skill classes j. (2) specifies the capacity restrictions for the resources c to be used in the creation of these skills. (3) states the usual non-negativity requirements, and (4) indicates that a certain subclass of the x_j must take on integer values due to tied relationships or because of external effects.

The above problem, it should be noted, is of the mixed variety of integer programs, and if small enough, could be solved by any of the known techniques.

Chapter IV

DEVELOPMENT PLANNING IN TANZANIA

In this chapter a brief review of Tanzanian planning experience is made. The broad objectives of the first Five Year Plan will be specified and the problems introduced by the need to interface the manpower and economic development plans touched on. In the following chapter a linear programming model is constructed to represent what appears to be the objectives and constraints embodied in current development policy. Chapter VI will detail the solutions to the model, together with evaluation of the results, and suggestions for improvement of the model as well as other indicated research will be made in a final chapter. An appendix will contain the data used in the model.

Economic Planning in Tanzania

Tanzania was the result of a merger between Tanganyika's vast territory on the eastern side of Africa with the tiny island of Zanzibar. Tanganyika had already become an independent state when the merger created the United Republic of Tanganyika and Zanzibar. The total area covered is in excess of some 360,000 square miles, and population is estimated at some 10 million. The land is extensively eroded due to the very heavy rainfall, and despite the rainfall, water shortage is a fact of some critical importance.

Germany began its rule of the country in 1885, and in the three decades of German occupation, some attempt was made to establish important items of economic infrastructure. The emphasis on sisal which persists even until today began during this period. Due to destruction and neglect, Tanganyika's agriculture suffered very severely during World War I, and thus the British inherited a country which had been almost devastated, when in 1919 the League of Nations made Tanganyika a mandated territory.

The Twenties were years of some measure of economic growth but the country suffered setbacks again in the Thirties due to the world economic crisis as well as the grave uncertainties concerning a possible return of German rule during the Hitler period. After the war, the uncertainties lessened and serious effort was made to establish and foster the growth and development of agricultural cash crop production. The early lead of sisal was not broken, but in addition coffee and cotton began to grow in importance. Other crops began to emerge and a small manufacturing sector was established.

Tanzanian economic planning is perhaps best understood against the background of economic disequilibrium which is clearly represented in its structure of production. The economy is essentially agricultural, with almost 60% of GDP contributed by agriculture and primary products.[8] Primary product exports dominate the export sector and this fact has led to the high sensitivity of the country's economic growth to the pattern of export growth and terms of trade.[9] Though these statistics refer to the period immediately prior to the current development plan, the existence of structural disequilibria has persisted for some time and has been the fundamental motivating force behind the several attempts at economic planning.

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(8) Tanganyika, Five Year Plan for Economic and Social Development 1st July 1964 - 30th June 1969, Volume I, Dar es Salaam (1964), p. 107.

(9) Ibid. See in this regard also: David Walker, "Problems of Economic Development of East Africa, "Economic Development for Africa South of the Sahara, E.A.G. Robinson (ed.) St. Martins Press (1964), pp. 89-137.

In 1946, a Ten Year Plan was formulated. The Plan represented more an expenditure budget aimed at financing infrastructure. Communications and education figured prominently in this early plan. The Plan was soon to be revised however, due to several circumstances, not the least of which were the establishment of the East Africa High Commission, and the fact that expenditure tended to run quite high. A new plan was eventually drawn up and was put into operation a full year before the 1946-1956 plan was scheduled to end.

The 1955 plan was a five year plan, and involved expenditure at more than double the old plan level despite the fact of its shorter plan period. Increased expenditure on education and on medical services, as well as on agriculture forced an increase in total plan expenditures when the plan was only a couple of years old. By 1961 attempts were being made to give some formal structure and sophistication to the planning mechanism by the creation of a separate planning body, and a new plan was drawn up to span the 1961-1964 period. Expenditures again ran quite high for social and economic infrastructure, roads, power and education constituting the areas of high plan expenditures.[10]

In view of our now more sophisticated sense of economic planning, it is easy to identify the areas of weakness in the early attempts at the formulation of development plans for Tanzania. Clark[11] has identified

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(10) See Fred G. Burke, Tanganyika Preplanning, Syracuse University Press (1965), for a good statement on early attempts at planning in Tanzania. Paul G. Clark, Development Planning in East Africa, East Africa Publishing House, (1965), gives a good comparison of early plans of Kenya, Uganda and Tanganyika.

(11) Ibid.

three basic weaknesses: (a) the plans were not centralized; (b) they represented attempts more at expenditure budgeting than at serious broad economic planning; (c) they were not comprehensive in the sense of being based on explicit quantitative analysis of the desired objectives of the economy as a whole, embracing the public as well as private sectors, nor in stressing plan fulfillment behavior or methods for the implementation of the plan. It is not hard therefore to recognize that the old plans never had much effect on the growth or structural configuration of Tanzanian economy. Real serious comprehensive planning only began with the current plan.

The new plan is an extensive document. It represents however, only one phase of a perspective plan to run until 1980. Explicit goals were set for the economy and the paths by which that economy is expected to attain the plan objectives are identified. The goals of the plan are" (a) to raise income per capita from approximately Ł19.0 to Ł45 by 1980; (b) to make Tanzania self-sufficient in trained manpower by 1980; (c) to increase life expectance to 50 years in 1980 from 35-40 years at the beginning of the plan period.[12] These objectives are perspective plan objectives and the Five Year Plan is meant to get the economy on that path that will lead to those goals by 1980. The economy is divided into thirteen sectors, and sector targets are identified for 1970 and for 1980 the final year of the perspective plan.[13]

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(12) Tanganyika, Five Year Plan for Economic and Social Development 1st July, 1964-30th June, 1969, Vol. I (1964); p. viii. (Hereafter called Tanganyika Five Year Plan.)

(13) The plan does not include the explicit statement of the input flows which are crucial to the formation of consistent estimates for a future year.

The Five Year Plan represents a serious attempt at being comprehensive. Due recognition is made of the inter-connection between the public and private sectors, all major decisions are quantified, and means for plan fulfillment are specified. One of the most crucial aspects of the perspective plan as already identified was the stated goal of self-sufficing in trained manpower by 1980. This is the so-called "ization" problem identified by Tinbergen.(14) In the words of the plan document, "... one of the most serious obstacles to accelerated economic growth lies in the lack of balance in the education and in the technical training of the people... For this reason the Government has decided to bring about a change in the structure of education and vocational training so as to adapt it to the needs of the economy and of Government for high level manpower and auxiliary personnel."(15) Clark, in looking at the potential constraints on the size of development programs, identified four. Of these four, government finance emerged as the most restraining in the period up to the start of the new plans in East Africa (including the new Tanzania plan), but due to the more ambitious nature of the new plans, government finance is joined by educated manpower as the most serious limiting constraints.(16) It is essentially this condition which forms an important point of departure for the subsequent programming evaluation, in this essay, of the effect of the supply of skilled labor on the structure and pattern of Tanzanian

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(14) Tinbergen, op. cit.

(15) Tanganyika, Five Year Plan

(16) Paul G. Clark, op. cit., pp. 22-29.

economic development during the 1964-1974 decade.(17)

In this regard, it is perhaps also instructive to observe that the rate of growth of gross domestic product for the period 1960-1962 to 1970 is set at 7.7% compounded yearly compared to 4.5% for the 1954-1961 period. Within this total, the growth of the monetary GDP is expected to quadruple that of the subsistence GDP in the period to 1970 compared to just over a factor of two in the previous seven years.(18) When it is recognized that of the Ŀ102 million expenditure budget of Central Government, that Ŀ79.5 million represent external financing the real dimensions of the added foreign exchange constraint on development become revealed.

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(17) For studies on the nature of the skilled labor bottleneck in East Africa, see E.R. Rado and A.R. Jolly, "The Demand for Manpower - An East African Case Study," Journal of Development Studies, (April 1965), pp. 226-250, and E.R. Rado, "Manpower Planning in East Africa," East Africa Economic Review, Vol. 7, (New Series), No. 1, (June 1967), pp. 1-30.

(18) Tanganyika, Five Year Plan..., Vol. 1, p. 10.

Chapter V

MANPOWER AND ECONOMIC PLANNING:

THE CASE OF TANZANIA

The model developed and analyzed in this study is a fairly simple model. One of the objectives of the formulation of this type model was to demonstrate how meaningful can programming models be for the range of questions which face developing countries in their manpower planning, and yet remain fairly simple. The need for simplicity is demonstrated by low level of complexity in countries at the stage of development as Tanzania is, perhaps identified most dramatically by the number of cells in the input-output model which are empty.[1] It would seem anamalous to use a highly complex and sophisticated model for policy purposes for simple economies. The use of simple models is justified therefore by their transparency, by their ease in manipulation and by the unique characteristic that a wide variety of solutions can be obtained from the parametrization of many policy or otherwise key variables. Since programming models are costly to run, this is a decided advantage for simple over highly complex ones.

In addition, since mathematical programming models can only represent the reality that has been built into them, the simplicity of a model of the type used in this study facilitates the ready analysis of the effect of the inclusion of the variety of assumptions made.

Within the constraints of these simpler models, what appears needed is a search for other hypotheses which would capture the essence of decision-making in matters affecting the interfacing of manpower policy and broad

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(1) See the input-output model in Appendix A, and Alan T. Peacock and Douglas G.M. Dosser, The National Income of Tanganyika, 1952-1954, Colonial Research Studies, No. 26, Her Majesty's Stationary Office, (1958), Chapter 2.

economic planning, at the same time that some more fundamental issues of economic growth are being addressed.

Some years ago, Branko Horvat, in an important article, addressed a question which to that time had not had the treatment it deserved in terms of its importance to the development process.[2] The concept of "absorptive capacity," its effect on growth and its determining components were studied. While, however, the theoretical significance of absorptive capacity was established, the measurement problem was not addressed in full. The question was: how do we get a measure of a country's absorptive capacity? Through a number of publications, notably the work of Adler[3] and the work of the OECD,[3] the foundation for a start in the direction of measurement was made. Absorptive capacity could be viewed as setting some limit to the amount of development assistance that a country could efficiently utilize at any moment, or over some specific period. If this is so, then it is possible to record the different levels of usable aid for any country, and this could constitute some measure of the underlying concept.[4] While there are difficulties with this, it at least leads to the identification of skill limitations as constituting an important barrier to rapid economic growth.

Specifically, if labor availability is identified through skill units, and if these skill units grow non-linearly as a function of educational

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(2) Branko Horvat, "The Optimum Rate of Investment," Economic Journal (December 1958), pp. 747-767.

(3) J. H. Adler, Absorptive Capacity - The Concept and Its Determinants, Brookings Institution (1965), and Quantitative Models as an Aid to Development Assistance Policy, OECD, Paris (1967).

(4) H. B. Chenery and Alan M. Strout, "Foreign Assistance and Economic Development," American Economic Review, (September 1966), pp. 679-732.

expenditures and time, then the limits to investment in productive sectors would expand, and we could identify the expansion of these limits with educational expenditures and time. Since we do explicitly include time, we also include "learning" phenomena, the effect of educational expenditures could thus be viewed as expanding absorptive capacity by raising limits to investment in specific sectors. It now becomes possible to incorporate questions of scale economies in a highly aggregative model in which education and learning effects are incorporated. It is significant, in this respect, that, as David Granick[5] argues, the view that development results from accumulation of real capital and in big lumps can be called into question by the kinds of inefficiencies which arise when "best level" technology imported into developing countries result, not in the achievement of optimal allocations, but in inefficiencies due to supply bottlenecks inhibiting the most efficient operation of large scale plants, and managerial inefficiencies due to the absence of high-level manpower. Some of the flavor of this emerged from the literature on the question of "choice of techniques" where capital intensive methods of production were shown to lead in important cases to an increase in demand for high-level manpower rather than substituting for it. In view of this, and in view also of the possibility of transporting best-level technology to developing countries, it appears even more strongly that the key to growth may very well be in creating the appropriate kind and amount of labor skills so as to push the economy's absorptive capacity outwards.

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(5) David Granick, Metal Fabricating and Economic Development: Practice vs Policy, University of Wisconsin Press.

A second issue which has emerged from our study of the optimizing techniques used so far in planning models where education is included, relates to the structure of these models. These models assume implicitly that economic policy runs in a direction which establishes a priority to educational planning. In other words, the question of centralization vs decentralization in economic policy is avoided by the implicit assumption that decentralization decisions somehow coincide with decisions at the center, and that what emerges as optimal for the educational sector is also optimal for the economy as a whole. This need not be, and most likely is not, the case. A more appropriate model might show educational policy to be "instrumental" in the sense that once broad macro policy is decided on, the implication for educational policy gets determined. The importance of this second viewpoint is that it leads to the formulation of a different kind of model, a model in which an assumed welfare function is optimized given a list of constraints, but significance lies not in the single optimal result, but in transformation surfaces which help the decision-makers to determine trade-offs in the attainment of multiple objectives. Once decision-makers have selected a particular optimal solution micro-decisions become somewhat clearer.

The essence of the approach outlined can be stated briefly:

$$\text{Max.:} \quad f(x)$$
$$\text{S.T.} \quad g(x) \leq b \qquad (1)$$

This linear program states the planning framework. If supply of skilled labor is exogenously specified, it then becomes possible to vary this restraint and observe the effect on the welfare maximum. For any optimal solution vector x*, there corresponds a skilled labor supply, l*. This may then be used to find the appropriate output of skilled labor total output which is necessary for the provision of this "final demand" specification. Assume that x*, is one solution from (1) then appropriate to x*, will be l_1*, the exogenously specified amount of skilled labor used in that run of the model. But the exogenously specified level of high-level manpower contains certain implications for the educational system. If a system of flows can be identified relating requirements of one type of labor per unit output of another type, then it becomes possible to determine the output of the educational system given the original policy determined welfare maximum. This can be written:

$$L_1^* = h\,(l_1^*) \tag{2}$$

where h could have the form of the inverse of the Leontieff matrix, or

$$L_1^* = (I - A)^{-1}\, l_1^* \tag{3}$$

where L_1* is the total output of the educational system with respect to the optimum solution x_1*. Since significance attaches to the schedule of welfare optima, we would then have a schedule of optimal L_i*.

The method permits important interaction between the center and the educational sector in a manner it is believed planning takes place in the real world, for if a certain L_i* is too expensive or requires too drastic a reshaping of the educational sector, this information could be transmitted to the responsible decision-makers and a new solution tried. This new solution may be a new x_i*, but it may also represent a change in certain strategic variables in the educational system, such as teacher-student ratios for example.[6] It also embodies what Lowe calls "instrumental inference" in economic policy, and its ensuing benefits.[7] Finally, it permits a certain degree of learning since the final solution is not necessarily the solution with which the process began. In this sense, it does achieve a certain amount of relevance, if compared to actual planning practice.

In the sequel, a single period model is used to study some of the macro-economic policy results to be derived from consideration of supply of high-level (skilled) manpower in the production function. At least two questions appear significant in terms of the broad issue of economic development: (a) the effect of the variation in supply of skilled labor on the welfare maximum; and (b) the effect of policy-determined rates of localization of the labor force, given patterns of foreign exchange availability. No attempt will be made to relate these macro results to the characteristics of the school system that would be consistent with them.

A model of this type gives recognition to the seriousness of the limitational constraint that high-level manpower can constitute for newly developing countries especially, as in the case of Tanzania, where the development program is quite ambitious, not only in terms of rate of growth, but also in terms of the broad structural transformation that is built into the development plan.

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(6) For a recent attempt at modelling the interaction process in manpower, education and economic planning, see Paul M. LeVasseur, "A Study of Inter-relationships Between Education, Manpower, and Economy," Socio-Economic Planning Sciences, Vol. 2 (1969), pp. 269-295.

(7) Adolph Lowe, On Economic Knowledge, Harper & Row, Chapters 5 and 10.

A Programming Model of Tanzania 1964-1974

General Description:

The model to be presented here traces lineage to the programming models of Manne,[1] and to the model by Chenery and Kretschmer for Southern Italy.[2] It is addressed to the following proglem: given the objective of the economic development plan and the constraints within which the development effort must work, find those activities which when operated at their appropriate levels would lead the economy to an optimum state in terms of that stated objective in the final year of the plan.

In the model, skill constraints are operative. Skilled labor is specified exogenously. The model is then used to trace out transformation surfaces through parametric variation of strategic exogenous and policy variables, identifying, crucial macro-economic policy trade-offs.

The model exhibits the following broad structure: a linear objective function is optimized subject to a set of linear constraints; since the model is finite horizon, realistic behavior is forced onto the model solution. Since the objective in this study is to look at the training-education-growth relationship the model is constructed to exhibit the effect on the assumed welfare function of the operation of skill constraints.

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(1) Alan S. Manne, "Key Sectors of the Mexican Economy, 1960-1970." Studies in Process Analysis, Alan S. Manne and Harry M. Markowitz (eds.), John Wiley & Sons (1963), pp. 379-400 and ______, "Key Sectors of the Mexican Economy, 1962-1972," The Theory and Design of Economic Development, Irma Adelman and Erik Thorbecke (eds.), Johns Hopkins Press (1966), pp. 263-286.

(2) Hollis B. Chenery and Kenneth S. Kretschmer, "Resource Allocation for Economic Development," Econometrica, Vol. 24, No. 4, (Oct. 1956), pp. 365-399.

Exports are specified exogenously, but imports are considered endogenously. The model is confined to a single period rather than being fully intertemporal. Strictly, then, consistency is obtained only in the final year results, and nothing is said, in the model, of results for the intervening years. Since the model addresses itself to a single target year, it is necessary to define appropriate stock-flow conversion factors to identify the part of the total increment in capital stock between the beginning and terminal years that would fall in the terminal year itself. This endogenous determination of demand for capital is used to avoid the so-called "edge effects" common in finite horizon models where due to the fact that capital is not desired for itself but only for its contribution to the creation of goods and services for consumption, there is a tendency for these models to "eat up" capital towards the horizon.(3)

A feature of this model that was dictated by the circumstances peculiar to Tanzanian exports is the explicit recognition on non-linearities in export activities. Tanzania can export to its East African neighbors, and can also export to territories overseas. Since there are realistic limits to export potential, the model is constructed to allocate exports, within the limits of those export bounds. This does not appear an unreasonable procedure since Tanzania is a primary produce exporter. A more ambitious endogenous determination was not carried out due to the data requirements on export elasticities.

Skill requirements are operative in the model, but only with respect to high level manpower. Apart from making computations easier the

(3) See Manne, 1963, op. cit.

concentration on high level manpower appears not to violate the condition which is observed in a wide variety of developing countries, namely the abundance of unskilled labor. Unskilled labor is thus not regarded in the model as a scarce resource, and consistent with the duality theorem of mathematical programming, enters the model effectively only with a zero shadow-price.

Of some significance in this model is the structural transformation of the observed economy, since it is this aspect which will most likely make an important demand for skilled manpower and foreign exchange. As is clear from the First Five Year Plan itself, the fastest rates of growth of all sectors for both periods up to the end of the perspective plan are expected from the processing and manufacturing sector.(4) The main thrust of the model accordingly will be in those sub-sectors which comprise the processing and manufacturing sector. In this regard, it is significant that the Plan did not specify the beginning period levels of output or value added for these sectors, while it did indicate both gross outputs and value added for each of the sectors in manufacturing and processing for 1970.

Consumption is maximized subject to the constraints of the model. The use of this type of objective function is meant to reflect the importance to developing countries of the need for raising standards of living.(5) In the Tanzania case, great stress has been placed on the need to increase the average life-span of Tanzanian citizens.

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(4) Tanganyika, Five Year Plan..., Vol. 1, p. 10.

(5) See also Sukhamony Chakravarti, Capital and Development Planning, M.I.T. Press (1969), Chapters 1 and 2.

As already indicated, imports are treated endogenously. Domestic production leads to demand for labor, natural resources and capital. Essentially for each activity in the inter-industry matrix, there are input flows to represent the demand for each productive resource coming from that activity. These therefore comprise direct and indirect resource requirements needed in order to satisfy consumption demand. The export activities also make demands on domestic production but contribute to the accumulation of valuable foreign exchange resources. These foreign exchange resources, which are either borrowed or earned through exports, support the demand for capital goods, as well as the demand for skilled labor which cannot be satisfied by local means competitively.

Significance of the model however is not to be found in any specific optimal program, but in the schedules identifying different levels of some specific goal variables given parametric variation in important policy variables or availability of strategic factors. In this sense it is possible to circumvent the thorny question of the exact nature of the welfare function, and get meaningful policy results nonetheless.

Algebraic Formulation of Model

Notation:-

The model to be presented involves a number of variables and parameters to be defined as follows:

X_i = domestic production of i; $i = 1, 2, \ldots, n + 1$
$i = n + 1$ = high level manpower

M_i = imports of i; $i = 1, 2, \ldots, n + 1$
$i = n + 1$ = high level manpower

E_i = exports of i; $i = 1, 2, \ldots, n$

I_i = in demand for investment for i; $i = 1, 2, \ldots, n$

c_i^p = in private consumption demand for i; i = 1, 2, ..., n

C = $\Sigma_i c_i^p$

N = population increase (absolute)

N* = base period population

F = total foreign funds except export earnings

S = savings

$\overline{E}_i(1)$ = upper limits to exports for i in near market; i = 1, 2, ..., n

$\overline{E}_i(2)$ = upper limits to exports for i in distant market; i = 1, 2, ..., n

$\overline{X}_i$ = exogenous specification of domestically available high level manpower; i = n + 1

LM_{ij} = imports of high level manpower for sector j; i = n + 1

p = relative change in population ($\frac{N}{N^*}$)

a_{ij} = interindustry demand for i per unit of j

b_{ij} = capital input of i per unit of j

l_{ij} = labor input needed per unit of j

$V^e_i(1)$ = export price of commodity i to market (1), assumed equal to unity

$V_i^e(2)$ = export price of commodity i to market (2), assumed equal to unity

V_i^m = import price of commodity i to market, assumed equal to unity

d_i = % of capital of type i to be invested in the target year itself

s = marginal savings rates

mi_i = import investment co-efficient

e_i = expenditure elasticity for i

c_i^* = base period consumption of i

C* = base period total consumption

Equations of the Model:-(6)

The variables of the model all refer to a certain condition expected as of the target year of the plan over the base year values. No account is therefore taken of balances in the intervening years, and the model therefore guarantees consistency strictly only in the target year.

$$(1)\ -X_i + \Sigma_j a_{ij} X_j - M_i + E_i + I_i + C_i^p \leq 0$$
$$i = (1, 2, \ldots, n)$$

Equation (1) states that total commodity availabilities from production and imports must be at least sufficient to satisfy government and private demands, exports and investment demands. No stock demand is included as data on this is entirely non-existent. This could be included however by making stock demand a set proportion of output.

$$(2)\ -LM_i + \Sigma_j l_{ij} X_j \leq \overline{X}_i;\ i = n + 1$$

The demand for high level manpower is constrained to be no greater than the availability of that kind of labor to be generated by production exogenously specified, and imports. Equation (2) identifies the exogenous specification of X_i. This equation, (2) assumes some significance in this model since a pattern of variation of $\overline{X}_i$ will show the importance to the welfare maximum of the availability of skilled labor. This issue is of some importance, not only at the theoretical level, where it is concerned with the availability of skilled labor which could be a bottleneck resource despite large amounts of unskilled labor, but also at the practical level, where questions of the localization of the skilled labor force is a politically important issue.

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(6) The constraints are written so that exogenous variables appear on the RHS of the inequality signs.

(3) $-I_i + \Sigma_j d_i b_{ij} X_j \leq 0$; i = 1, 2, ..., n

Equation (3) states that the availability of capital goods must be at least as great as the sum of total demand for investment purposes.

(4) $-M^i_i + mi_i \Sigma_j d_i b_{ij} X_j = 0$; i = 1, 2, ..., n

Equation (4) specifies imports into investment via the coefficient mi_i, an import-investment parameter.

(5) $I - \Sigma_i I_i = 0$; i = 1, 2, ..., n

Equation (5) is definitional.

The co-efficient, d_i, in (3) and (4) is included to force the model to invest a portion of the total capital investment for the five year period, in the target year itself. Its inclusion follows the lead of Manne(7) and in this regard is made necessary in order to force realistic behavior on finite-horizon models. It serves also to allow the model to generate investment endogenously. As would be expected, the size of the co-efficient, d_i, depends on the length of the horizon, the lag in investment, and the assumed rate of growth. It has been found to be rather stable under realistic changes in the growth rate.(8)

(6) $-C^p_i + e_i c^*_i \frac{C=}{C^*} = c^*_i P (e_i - 1)$

Equation (6) expresses consumption of the i th good in terms of initial consumption of that good, c^*_i, expenditure elasticity for that good, e_i, base period total consumption, C* relative growth in population, P, and total non-governmental consumption. The specification follows in broad

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(7) Alan Manne, op. cit.

(8) Ibid.

outline that of Sandee[9] and also that of Bruno.[10] As Bruno has stated, the population growth parameter on the right-hand side of (6) permits a convenient parametric variation, useful for cases in which immigration is a matter of some signicicance.[11] The model was not run with this version of the consumption equation however, but with the variants shown in Chapter VI.

$$(7) \quad -M_i^c + mc_i C_i^p \geq 0$$

Equation (7) specifies imports into consumption via the consumption import parameter, mc_i.

$$(8) \quad C_i - \sum_i C_i^p = 0$$

$$(9) \quad E_i(1) \lesseqgtr (\overline{E}_i(1), \underline{E}_i\ (1))$$

$$(10) \quad E_i\ (2) \lesseqgtr (\overline{E}_i(2), \underline{E}_i(2))$$

Equations (9) and (10) set upper and lower limits to exports in both markets.

$$(11) \quad M_i^i + M_i^c - M_i = 0 \ (i = 1, 2, \ldots, n)$$

$$(12) \quad -\sum_i mjXj - \pi_i LM_i - \sum_i M_i + M = 0; \ i = 1, 2, \ldots, n + 1$$

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(9) Jan Sandee, A Demonstration Planning Model for India, Asia Publishing House, 1960.

(10) Michael Bruno, "A Programming Model for Israel," The Theory and Design of Economic Development, Adelman and Thorbecke (eds.), Johns Hopkins Press 1966, pp. 327-354.

(11) Ibid., p. 322.

Equations (11) and (12) are the import demand equations, and state that total imports must be at least sufficient to support interindustry, investment, and consumption demands. Equation (12) includes the cost of import of high-level manpower and therefore states the condition of aggregate import demands.

$$(13) \quad E_i - E_i(1) - E_i(2) = 0 \quad (i = 1, 2, \ldots, n)$$

Equation (13) states that total exports is the sum of exports to markets (1) and (2), and is thus definitional.

$$(14) \quad E - \sum_i E_i = 0 \quad (i = 1, 2, \ldots, n)$$

Equation (14) states that total exports is the sum of individual exports of the i commodities.

$$(15) \quad -E + M \leq F$$

Equation (15) states that imports are limited by the availability of foreign funds and earnings generated by exports, a rather usual type foreign exchange constraint.

$$(16) \quad -C + (1 - s)\ Y \leq Y_0\ (1 - s) - C_0^*$$

Equation (16) adds a saving constraint to the model, with the parameter s identifying the marginal savings rate or $s = \frac{S_t - S_{t-1}}{Y_t - Y_{t-1}}$, where S and Y are savings and gross domestic product respectively.

$$(17) \quad -E + M - I + Y - C = 0$$

Equation (17) is definitional.

$$(18) \quad \text{Max} : f(C) = \Sigma_i C_i^p$$

Equation (18) is the maximand, and it is the objective of the model to maximize terminal year consumption, subject to the constraints identified in the preceeding equations and inequalities.

A PLANNING MODEL OF TANZANIA

$$(1)\quad -X_i + \sum_j a_{ij} X_j - M_i + E_i + I_i + C_i^p \quad \leq \quad 0 \ (i = 1 \ldots n)$$

$$(2)\quad \sum_j l_{ij} X_j - LM_i \quad \leq \quad \bar{X}_i \ (i = n + 1)$$

$$(3)\quad \sum_j d_i b_{ij} X_j - I_i \quad \leq \quad 0 \ (i = 1 \ldots n)$$

$$(4)\quad mi_i \sum_j d_i b_{ij} X_j - M_i^i \quad \leq \quad 0 \ (i = 1 \ldots n)$$

$$(5)\quad -\sum_i I_i + I \quad = \quad 0 \ (i = 1 \ldots n)$$

$$(6)\quad -C_i^p + e_i C^*_i \frac{C}{C^*} \quad = \quad C^*_i p \ (e_i - 1) \ (i = 1 \ldots n)$$

$$(7)\quad -M_i^c + mc_i C_i^p \quad \geq \quad 0 \ (i = 1 \ldots n)$$

$$(8)\quad -\sum_i C_i^p + C \quad = \quad 0 \ (i = 1 \ldots n)$$

$$(9)\quad E_i(1) \quad \lesseqgtr \quad \bar{E}_i(1) \ (i = 1 \ldots n)$$

$$(10)\quad E_i(2) \quad \lesseqgtr \quad \bar{E}_i(2) \ (i = 1 \ldots n)$$

$$(11)\quad M_i^i + M_i^c - M_i \quad = \quad 0 \ (i = 1 \ldots n)$$

$$(12)\quad -\sum_j m_j X_j - \pi_i LM_i - \sum_i M_i + M \quad = \quad 0 \ (i = 1 \ldots n + 1)$$

$$(13)\quad E_i - E_i(1) - E_i(2) \quad = \quad 0 \ (i = 1 \ldots n)$$

(14)	$E - \sum_i E_i$	=	$0 \ (i = 1 \ldots n)$
(15)	$-E + M$	$\leq$	F
(16)	$(1 - s)\ Y - C$	$\leq$	$Y_o(1 - s) - C^*$
(17)	$-E + M - I + Y - C$	=	0

(18) Max: $f(C) = \sum_i C_i^p$

Chapter VI

ANALYSIS OF SOLUTIONS TO MODEL

The single period model of the previous chapter was run some sixty-odd times, each run representing a change in some important policy variable, in order to trace out the macro-economic significance of the basic assumptions employed in model construction. In a certain sense, each run can be regarded as representing a different strategem, the whole series allowing for discussion, among policy-makers or between policy-makers and the public concerning the most appropriate among a list of means-goals combinations.

Table 1 shows the pattern of classification. In Group A, as in all groups, the level of skilled labor is varied from .125 million to .220 million at .025 million intervals. Likewise foreign aid (or what is more correct, the deficit on current account to be made up by foreign exchange made available through aid or loans or gifts) ranges from Ŀ25.0 million to Ŀ55.0 million at Ŀ10 million intervals. This is true however only for Groups A through D. Groups AA and AB were run at zero foreign aid levels to test the pattern of solution on less generous assumptions concerning the availability of foreign exchange. This is important since for the single period model, the cost of foreign borrowing is not included, and trade patterns are quite likely very sensitive to the case with which such resources are available. The marginal saving rate is set at 10% in Groups A and C, but 15% in Group B and 20% in Group D.

In some runs of the model, imports of labor was possible. It was also possible for the model to import building materials, mostly cement. The reason for this was the desire to test the differential effects of home production versus imports of an important intermediate good on the

TABLE I

CLASSIFICATION OF VARIOUS RUNS OF MODEL

GROUP	SKILLED LABOR LEVELS (MILL)	FOREIGN AID (£ MILL)	MARGINAL SAVING RATE	OTHER CONSTRAINTS
A	.125; .150; .175; .200	25.0; 35.0; 45.0; 55.0.	10%	Labor imports; Building Mat. Imports.
B	" "	" " "	15%	" "
C	" "	" " "	10%	Building Mat. Imp; No Labor imports
D	" "	" " "	20%	No Labor Imports " Building Mat. Imports

AA	.125; .150; .175; .200	35.0	10%	Bldg. Mat. Imports; LABOR IMPORTS
AB	" "	"	"	Bldg. Material Imports; No LABOR IMPORTS.

Note: The model was run using the MPOR 360 linear programming code. Over 70 runs were made after gaining feasibility, (which itself involved over 50 runs), and each run took approximately 27 seconds.

solutions to model runs.

The results of these various runs of the model are to be found in Appendix B.

It might be worthwhile before launching into the analysis of the solutions to expand on the explanation of the consumption equations used in the model. It will be recalled that the basic consumption equation is written:-

$$-C_i^p + e_i C_i^* \frac{C}{C^*} = C_i^* p\ (e_i - 1) \qquad (1)$$

where C_i^p refers to target year private consumption of product i, e_i is the expenditure elasticity of i, C_i^* is base period consumption (private) of product i, C*, total base period consumption, and C refers to total target year consumption. P, on the right hand side of (1) measures the relative change in population, or P^t/P^o where P^t is target year population and P^o is base period population.

Essentially, the target year consumption pattern is made to reflect the effect of expenditure elasticities. The model was not run with this specification however, as some degree of inflexibility is introduced by having consumption follow an exact Engel curve pattern. Following the work of Sandee and Bruno, guidance is provided by allowing consumption patterns some flexibility around the Engel curve.(1) A variation of 10% was chosen, and thus consumption of each good was allowed a total of 20% (10% above and 10% below variation around the exact Engel pattern.

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(1) Jan Sandee, Demonstration Planning Model for India, Asia Publishing House 1960, and Michael Bruno, "A Programming Model for Israel," Theory and Design of Economic Development, Adelman and Thorbecke (eds.) Johns Hopkins Press (1966), pp. 327-354.

The forms used were:-

$$-C_i + 1.10\,\lambda C \geq 1.10\,\hat{\lambda}\,(e_i - 1) \qquad (2)$$

$$-C_i + .9\,\lambda C \leq .9\,\hat{\lambda}\,*e_i - 1) \qquad (3)$$

where $\lambda = \frac{e_i C_i*}{C*}$; $\hat{\lambda} = C_i*P$

Equation (2) is the equation for the upper limits, and (3) is the lower limit specification.

Some flexibility was also allowed the optimal export pattern as export growth in each case was constrained to be between 1.5% and 3.0% per year.[2]

Diagrams 1 - 5 show the variety of ways in which the consumption maxima are related to the policy variables, skilled labor and foreign aid. In Diagram1(Groups A and B), the resultant consumption pattern in the target years is plotted in the foreign aid/skilled labor space. Skilled labor is not shown however as the maximand did not change as domestic supply of skilled labor was increased when the model could import labor. The reason of course is that since domestic labor was assumed to be as efficient as foreign labor, the model imported labor as long as resources were available to accomplish this, and when exogenous skilled labor was increased, this factor being a free good in the model, importation of skilled labor was reduced, unit for unit with the increase in available domestic supply. If Diagram 1 is compared to Diagram 2, it is immediately obvious that with the possibility to import labor, and given a supply of foreign aid, it is sub-optimal not to import labor. Growth rates reach 12.4% at 10% marginal

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(2) See the Appendix A for explanation of the choice of growth rates.

TABLE 8

CONSUMPTION, WITH BLDG. MAT. & LAB. IMPORTS

	SKILLED LABOR (MILL)	FOR. AID (£MILL) 25.0	35.0	45.0	55.0
Mgl. Saving Rate 10%	.125	365.7	418.24	469.95	521.36
	.150	"	"	"	"
	.175	"	"	"	"
	.200	"	"	"	"
Mgl. Saving Rate 15%	.125	306.10	361.10	—	471.11
	.150	"	"	—	"
	.175	"	"	—	"
	.200	"	"	—	"

CONSUMPTION, WITH BLDG. MAT. IMPORTS, WITHOUT LAB. IMP.

	SKILLED LABOR (MILL)	25.0	35.0	45.0	55.0
Mgl. Saving Rate 10%	.125	193.76	193.76	193.76	193.76
	.150	251.22	251.22	251.22	251.22
	.175	304.99	—	308.69	308.69
	.200	346.96	—	361.44	366.15

TABLE 3

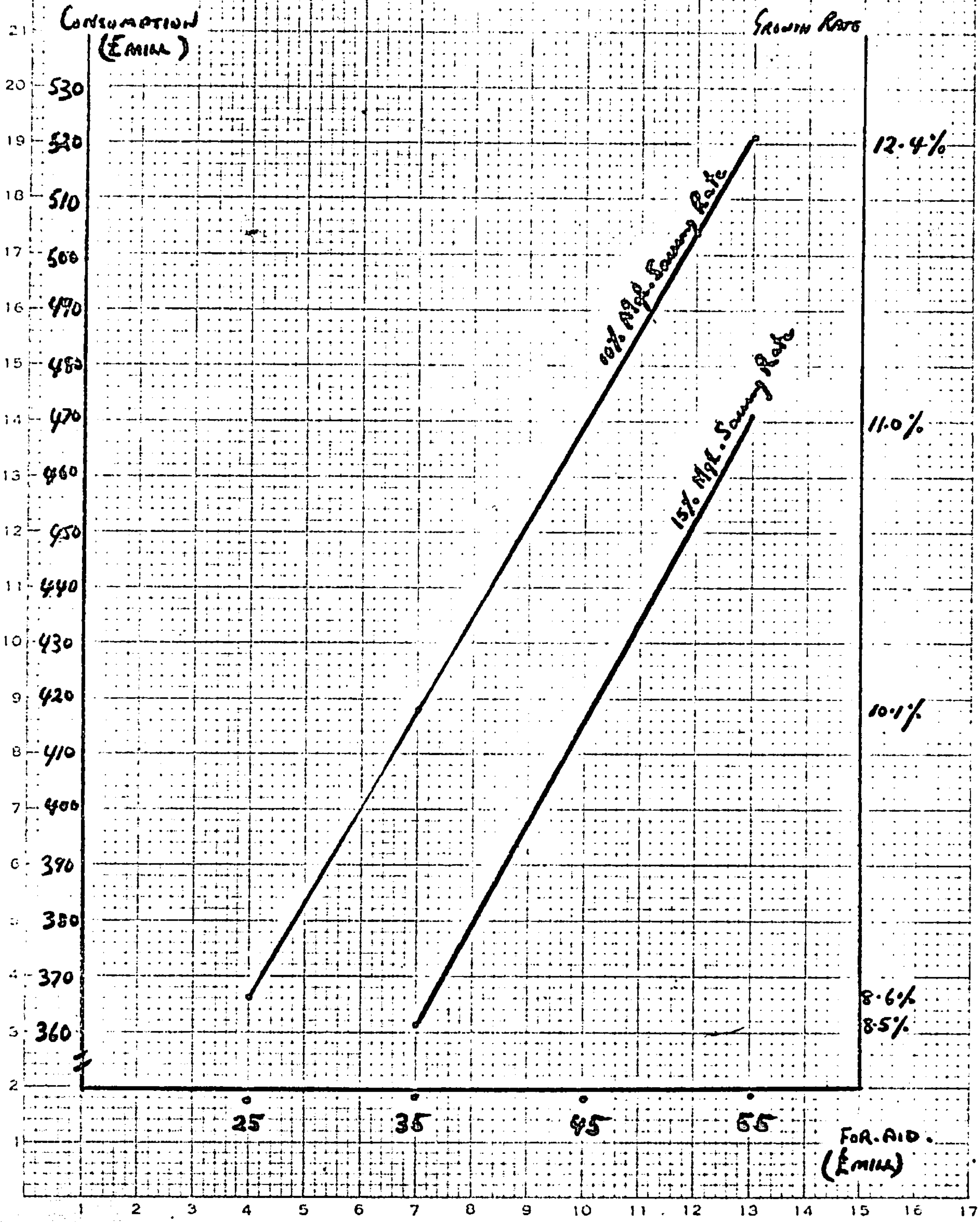
CONSUMPTION, WITHOUT LABOR OR BLDG MAT. IMPORTS

	SKILLED LABOR (MILL)	FOR. AID (£MILL)			
		25.0	35.0	45.0	55.0
Marginal Savings Rate 20%	.125	188.45	188.45	188.45	18845
	.150	212.23	245.84	245.84	245.84
	.175	212.23	286.97	303.23	303.23
	.200	212.23	286.97	358.45	360.62
Marginal Saving Rate 10%	.125				188.45
	.150				245.84
	.175				303.23
	.200				360.62

DIAGRAM 1

CONSUMPTION (WITH LABOR IMPORTS)

ALL LEVELS OF EXOG. SPECIFIED SKILLED LABOR



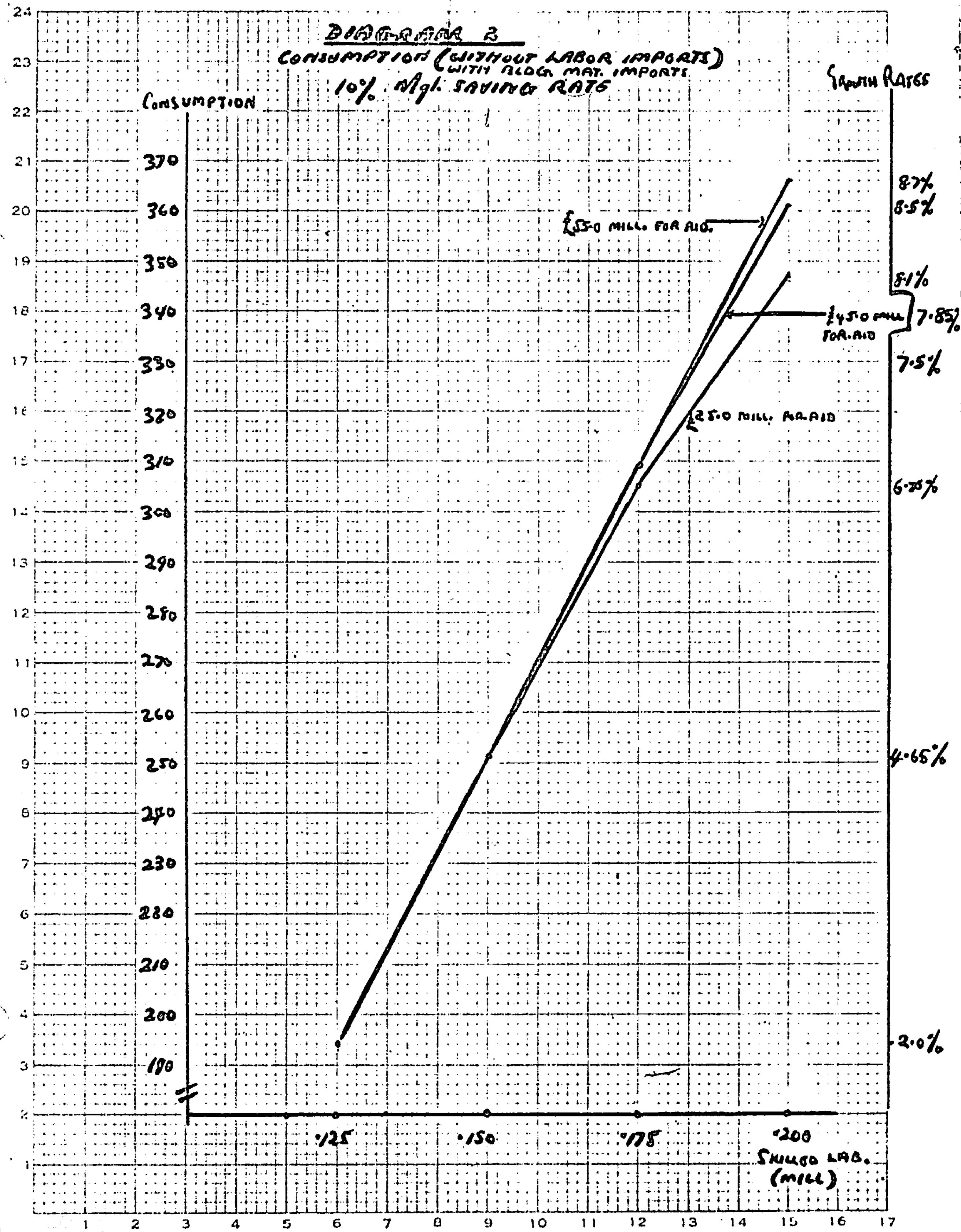


DIAGRAM 2
CONSUMPTION (WITHOUT LABOR IMPORTS) WITH BLDG. MAT. IMPORTS
10% Mgl. SAVING RATE
CONSUMPTION
GROWTH RATES
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
8.7%
8.5%
8.1%
7.85%
7.5%
6.75%
4.65%
2.0%
55.0 MILL. FOR AID.
45.0 MILL FOR. AID
25.0 MILL. FOR. AID
.125
.150
.175
.200
SKILLED LAB. (MILL)

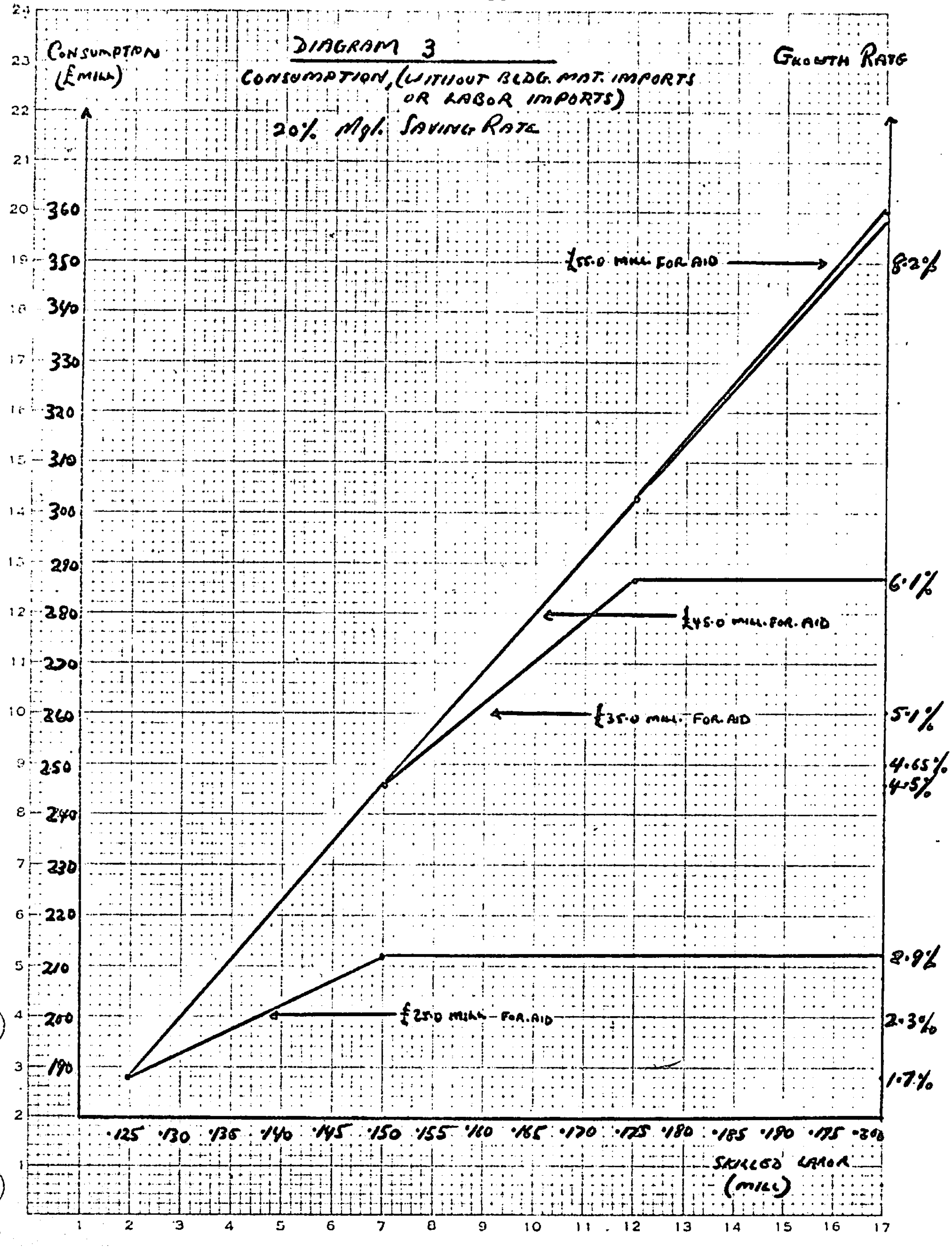
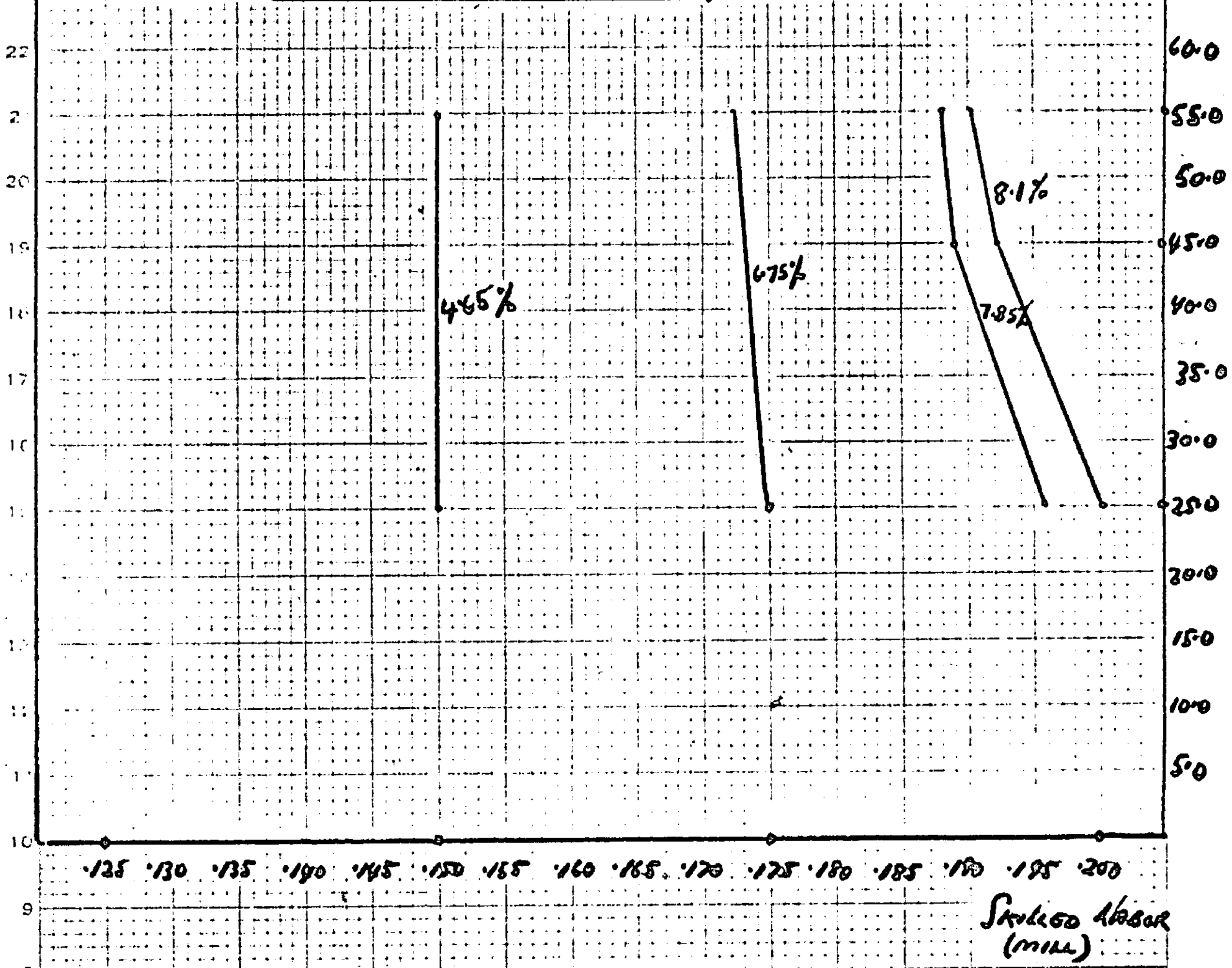


DIAGRAM 3
CONSUMPTION, (WITHOUT BLDG. MAT. IMPORTS OR LABOR IMPORTS)
20% Mgl. SAVING RATE
CONSUMPTION (£MILL)
GROWTH RATE
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
£55.0 MILL FOR AID
£45.0 MILL. FOR. AID
£35.0 MILL. FOR AID
£25.0 MILL. FOR. AID
8.2%
6.1%
5.1%
4.65%
4.5%
2.9%
2.3%
1.7%
·125
·130
·135
·140
·145
·150
·155
·160
·165
·170
·175
·180
·185
·190
·195
·200
SKILLED LABOR (MILL)

DIAGRAM 4

ISO-CONSUMPTION CURVES; 10% MGL. SAVING RATE



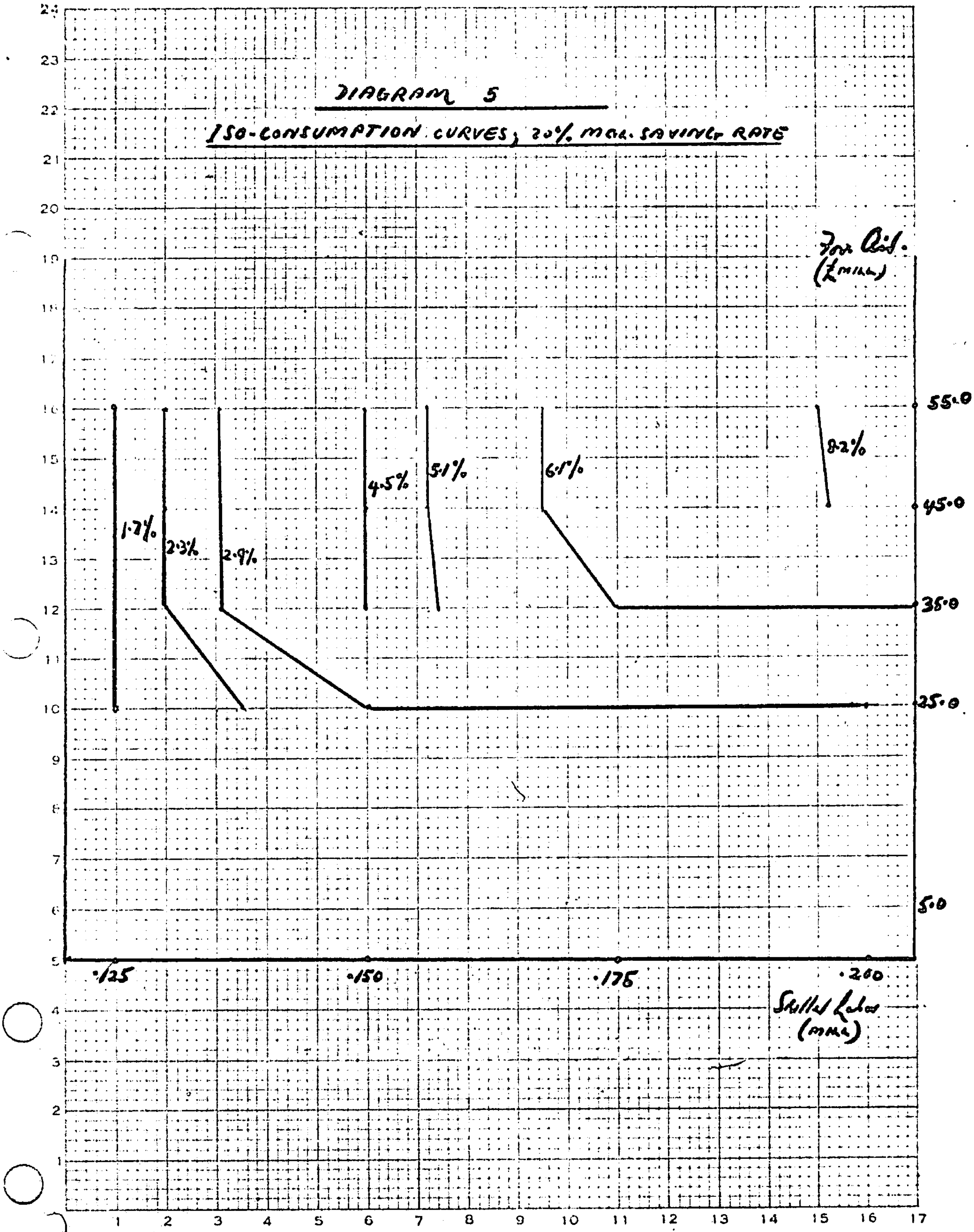


DIAGRAM 5
ISO-CONSUMPTION CURVES; 20% MGL. SAVING RATE
For. Aid. (£mill.)
1.7%
2.3%
2.9%
4.5%
5.1%
6.1%
8.2%
55.0
45.0
35.0
25.0
5.0
·125
·150
·175
·200
Skilled Labor (mill.)

savings rates with labor imports compared to just under 9.0% without labor imports. The same thing can be said in another way: full "Tanzanization" of the work force in terms of high level manpower may very well be a sub-optimal decision, given the availability of co-operant factors. One of the central pillars of development policy for Tanzania is full localization of the high level manpower by 1980. Such a policy is not consistent however with the conditions of allocative efficiency, given the reality of certain options available to the economy.

This conclusion is not warranted however, if the assumptions made in the model, namely equal efficiency and ample foreign exchange turn out to be unrealistic. It can be argued that the use of domestic skilled labor of equal efficiency will lower the total labor cost compared to a situation in which skilled labor is expatriate. If this is true, then the conclusions reached above do not hold. It might be difficult to encourage foreign labor to go to some areas where they are needed, particularly if these areas are located some distance from urban centers. When this is true, there are realistic cost differences between foreign and local labor, the advantage being with the latter where there is no efficiency differential between the two.

It should however be remembered that the model does not include costs of supply for domestic skilled labor. Should these costs be made endogenous to the model, the benefit-cost choice mechanism would determine the most economical manner of production, and it cannot be said a priori in which direction this choice would be made.(3)

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(3) Some additional runs of the model are now being made in an attempt to make some of the costs endogenous.

The force of the conclusion reached above concerning importation of labor is further weakened if the goal of full localization of high-level manpower is regarded as essentially non-economic. In other words, the typical programming model will evaluate all options using the same marginality criterion. However, to the extent that certain non-economic goals which must be satisfied are identified, then these specifications reflect non-efficiency kinds of decisions and allocative efficiency should rightly operate within the bounds identified by these higher level goals.[4] What I am asserting is that the goal of full localization might very well be such a priority as to weaken any criticism of it derived from a model which does not treat it as such. I will, however, not assume that it is such a priority, and therefore will let the conclusions derived from operating the model stand.

In Diagrams 2 and 3, the effects of raising the level of skilled labor on the pattern of consumption have been traced. The curves really represent transformation surfaces between skilled labor and the associated optimal consumption levels. Per level of foreign aid, as the level of skilled labor increases, consumption increases but these consumption increases, quite sharp at first, get less steep as the level of skilled labor is increased. The reasoning is this, that as more skilled labor is added, consumption is allowed to increase since co-operant factors are released from other activities and thus used to increment total consumption. However, since these resources can only be released with greater and greater difficulty, the shape of the transformation surface is of the usual

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(4) Thomas Vietorisz, "Quantized Preferences and Planning by Priorities," The American Economic Review, (May 1970), pp. 65-69.

concave-to-the-origin type.

These transformation surfaces were used in addition to derive families of iso-consumption curves in the skilled-labor/foreign exchange space. This was done by deriving the growth rates for the transformation surfaces at discrete points and then tracing out those combinations of foreign aid and skill availability which permit a constant rate of growth in consumption. These iso-consumption curves are found in Diagrams 4 and 5. First, they have the correct shape, being convex to the origin identifying the diminishing rate of substitution of one factor for the other as we move down each curve. Second, the curves get less steep as we move out in growth rates. This is an important result. It means that as desirable growth rates increase, a unit fall in foreign aid must be compensated for by larger and larger increments in skilled labor. This reflects the fact that as consumption growth increases, and given export limits, the foreign exchange constraint becomes tighter with respect to skilled labor. This is an important conclusion for an economy like Tanzania which is faced, like other underdeveloped economies at her level of development with both foreign exchange and skilled labor constraints. It means that fast rates of growth may prove unrealistic. Tanzania recorded a growth rate of 4.5% compounded in GDP between 1954 and 1961, but has targeted a 6.7% rate of growth for the two periods 1960/1962-1970 and 1970-1980.(5) Our results indicate that whereas these growth rates are clearly attainable, they are only so to the extent that at least 175,000

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(5) Tanganyika Five Year Plan, 1964-1969, Vol. I, p. 10.

TABLE 4

G.D.P. PATTERNS IN OPTIMAL SOLUTIONS OF MODEL RUNS

Foreign Aid (£mill.)	£25.0 mill.				£35.6 mill.			
Group / Skilled Lab (mill.)	·125	·150	·175	·200	·125	·150	·175	·200
A	471·1	471·1	471·1	471·1	529·5	529·5	529·5	529·5
B	391·4	391·4	391·4	391·4	452·6	452·6	452·6	452·6
C	280·1	339·2	391·9	447·0				
D	247·0	273·4	273·4	273·4	247·0	310·7	356·4	356·4
AA*	194·9	194·9	194·9	194·9				
AB*	"	"	"	"				

Foreign Aid (£mill.)	£45.0 mill.				£55.0 mill.			
Group / Skilled Lab (mill.)	·125	·150	·175	·200	·125	·150	·175	·200
A	587·0	587·0	587·0	587·0	644·1	644·1	644·1	644·1
B					574·8	574·8	574·8	574·8
C	280·1	339·2	389·4	441·5	280·1	339·2	389·4	431·5
D	247·0	310·7	374·5	435·8	247·0	310·7	374·5	438·2
AA*								
AB*								

NOTE: * EVALUATED AT ZERO FOREIGN AID.

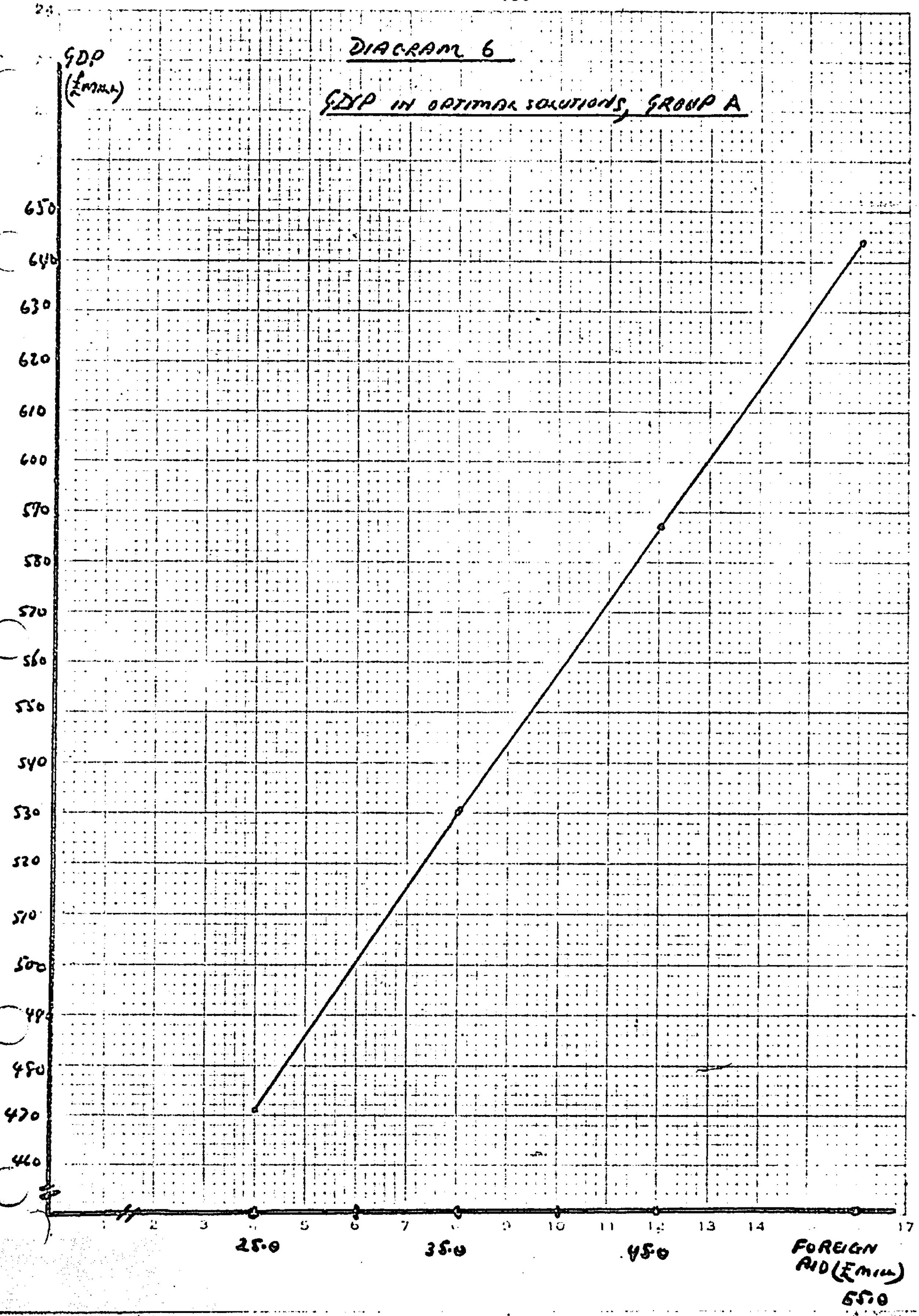


DIAGRAM 6
GDP IN OPTIMAL SOLUTIONS, GROUP A
GDP (£mill)
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
25.0
35.0
45.0
FOREIGN AID (£mill)
55.0

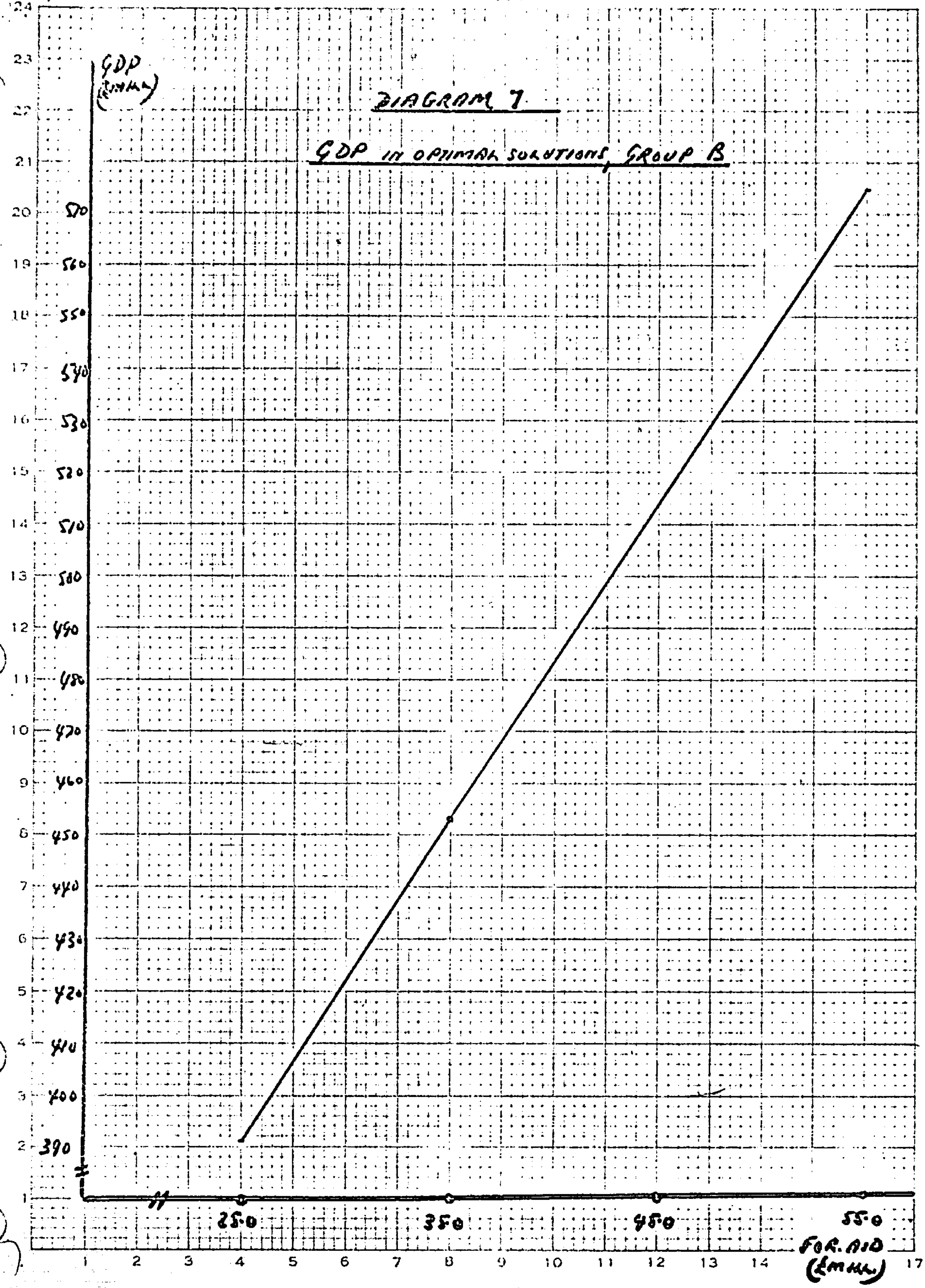


DIAGRAM 7
GDP IN OPTIMAL SOLUTIONS, GROUP B
GDP (£mill.)
570
560
550
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400
390
25.0
35.0
45.0
55.0
FOR. AID (£mill.)

DIAGRAM 8

GDP IN OPTIMAL SOLUTIONS, GROUP C

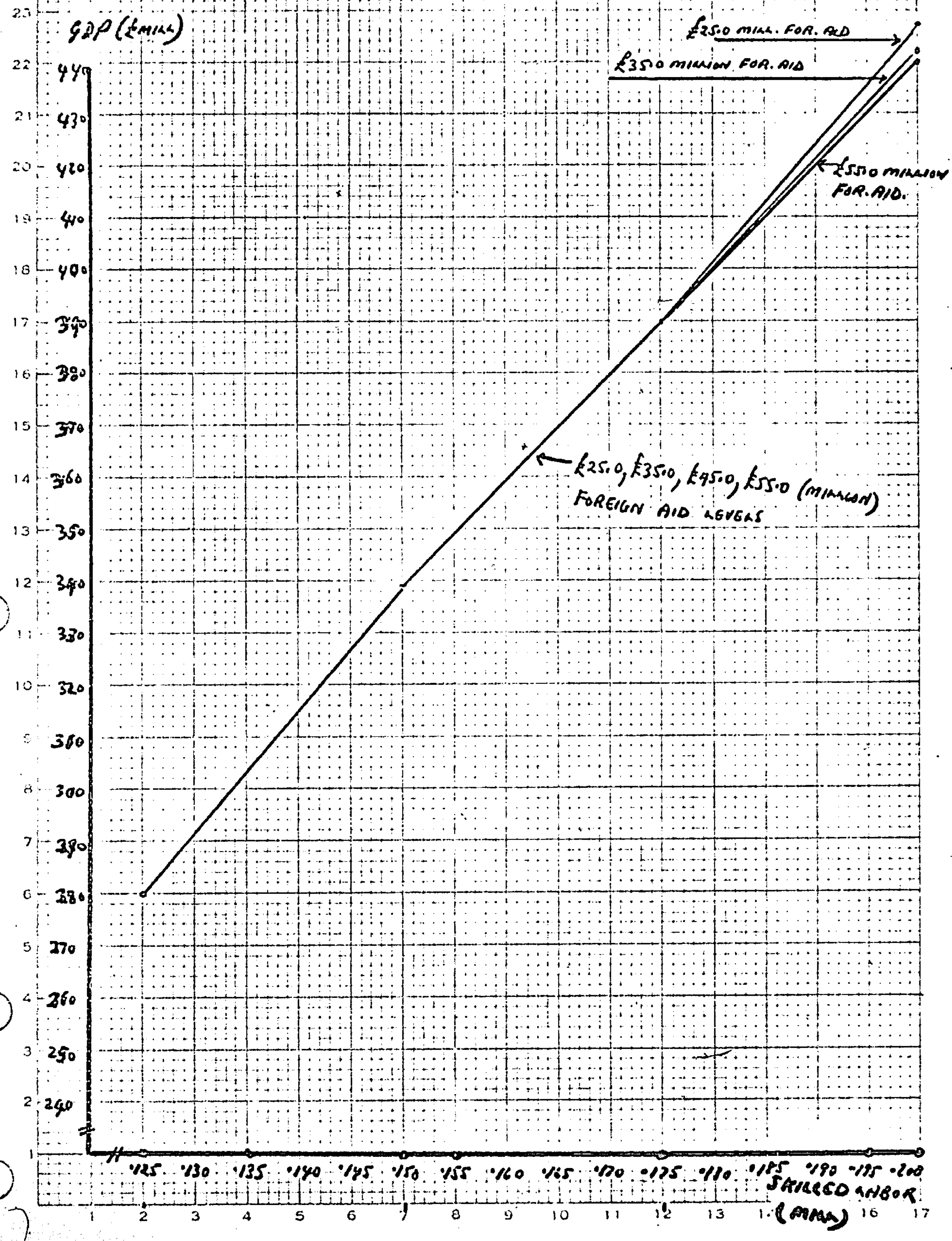
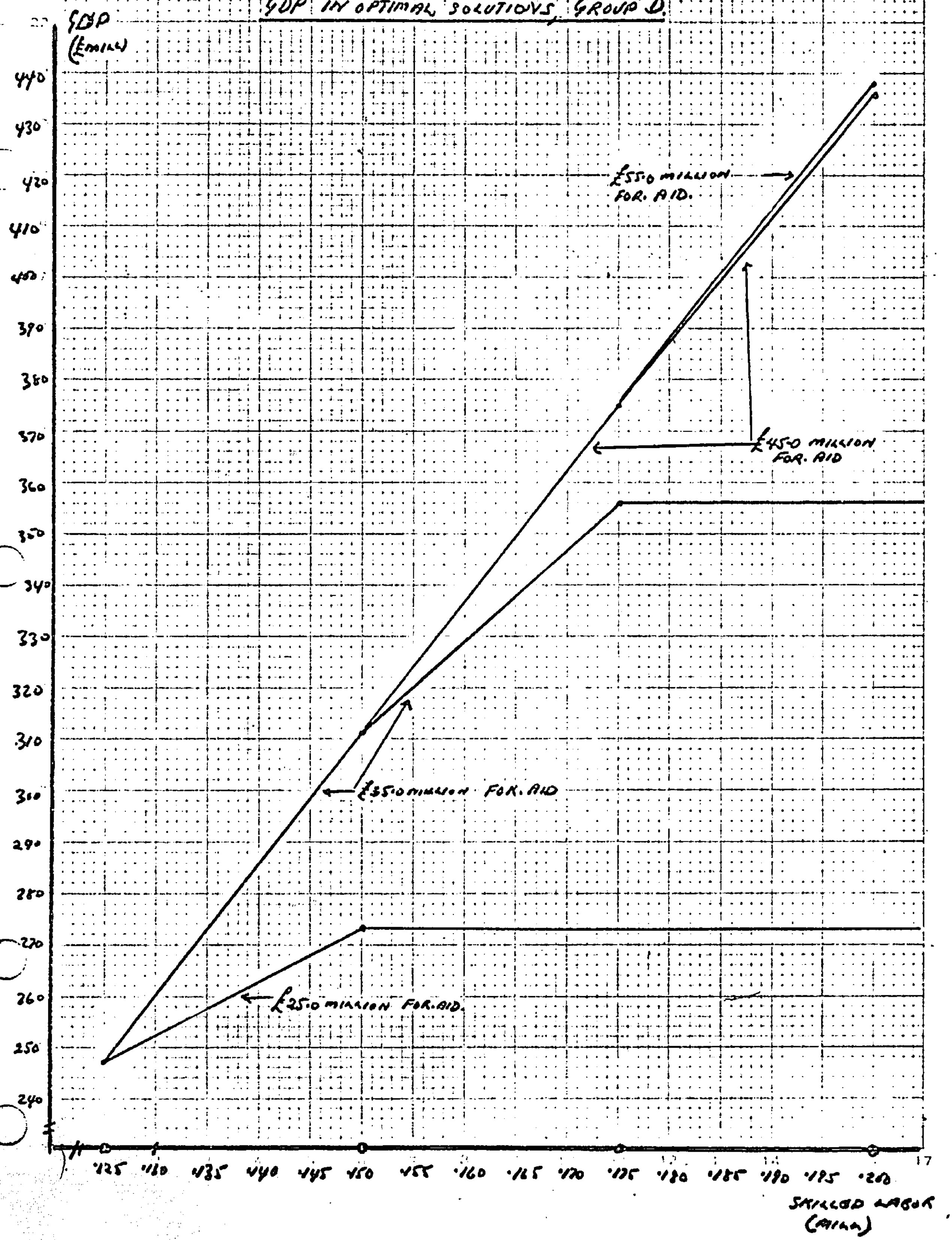


DIAGRAM 9

GDP IN OPTIMAL SOLUTIONS, GROUP D.



high level workers are available, even if available foreign aid in the target year is of the highest magnitude considered in the model. The manpower plan related to the Second Five Year Plan shows a demand for high-level manpower in 1973/1974 over 1969/1970 of 37,341. These include 3,849 in Class A occupations (requiring a university degree), 12,333 in Class B occupation (requiring from one to three years formal post-secondary education), and 13,109 in Class C occupations (requiring a secondary school education for standard performance). A safety factor of 8,050 to provide for wastage from Form 4 through graduation from the university and from Category B. There were 44,096 in all categories in 1968/1969 which means a total of 81,437 in Categories A, B, and C in 1973/1974. This figure is about half of the 175,000 high-level workers identified in the model. However, the difference can be explained by the differing definitions used, and by the fact that the skilled labor figures, on industry lines, were estimated from Uganda data, while the categories used by the Plan are establishment figures.[6] In any event, if the objective of this exercise is to demonstrate the importance of the skilled labor restraint, the actual data used in the model and the specific model results assume somewhat less significance, while greater importance gets attached to the macro-economic trade-offs that are generated.

Examination of Table 2 and Diagrams 1, 2 and 3 show the results of varying foreign aid on total consumption and the rate of growth of consumption. When skilled labor is imported, per level of domestically

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(6) Survey of the High and Middle Level Manpower Requirements and Resources for the Second Five Year Development Plan: 1969/1970 to 1973/1974. Ministry of Economic Affairs and Development Planning, Republic of Tanzania, (March 1969).

supplied labor, the effect of variation of foreign aid is quite marked. When the marginal saving rate of 10% and labor can be imported total consumption in the target year reaches a level of Ł531 million at foreign aid level of Ł55.0 million and, Ł366 million at foreign aid level of Ł25.0 million. These compare with a base year level of Ł159 million. When labor cannot be imported, the levels of consumption in the target year are not much changed from base year figures except when domestic levels of skills reach 200,000. The results thus support the argument made earlier that not to import labor, if indeed resources are available to do so, is not an efficient macro-economic decision, since consumption growth rates are increased by 50% again with labor imports compared to the cases in which labor is not imported.

The same argument can be made from the dual results as shown in Table 5. The shadow price of foreign exchange is the partial derivative of the maximand with respect to foreign aid. In symbols, this is $\frac{\delta C}{\delta F}$. This can be expected to fall as more foreign aid is provided. In Table 5, when foreign aid is zero, the shadow price of foreign exchange is 8.16 for all levels of domestically supplied skills. This falls to 5.50 when foreign aid is set at Ł25.0 million, and further to 5.17 and 5.12 at Ł45.0 million and Ł55.0 million foreign aid levels respectively. However, shadow prices of foreign exchange do move higher as the levels of the co-operant factor(s) in this case, labor, gets larger and larger. This is shown in Table 5 by the increase in shadow price of foreign exchange, per level of skilled labor, as we move from a situation of non-importation to one of importation of skilled labor. It is also evident from the results derived entirely without imports of labor, but with increases in the level

TABLE 5

SHADOW PRICES OF SKILLS AND OF FOREIGN EXCHANGE

DOMESTIC SUPPLY OF LABOR (MILL)	NO LABOR IMPORTS OR TOTAL SUPPLY OF LAB. FIXED: FOREIGN AID (£MILL)			WITH LABOR IMPORTS OR TOTAL SUPPLY OF LAB. NOT FIXED: FOREIGN AID (£MILL)		
	25.0	45.0	55.0	25.0	45.0	55.0
.125	0.0 2298.53	0.0 2298.53	0.0 2298.33	5.50 .005329	5.171 .007421	5.12 .007740
.150	0.0 2298.53	0.0 2298.53	0.0 2298.53	5.50 .005329	5.171 .007421	5.12 .00774
.175	.724 1678.74	0.0 2298.53	0.0 2298.53	5.50 .005329	5.171 .007421	5.12 .00774
.200	.724 1678.74	.724 1678.74	0.0 2298.53	5.50 .005329	5.171 .007421	5.12 .00774

Note: Top number in each box refers to shadow price of foreign exchange; bottom number refers to shadow price of skilled labor.

	FOREIGN AID	£0.0 MILLION			
	SKILLED LABOR (MILL)	.125	.150	.175	.200
SHADOW PRICE	FOR. EXCHGE	8.16	8.16	8.16	8.16
	SKILLED LABOR	0.0	0.0	0.0	0.0

of domestically supplied skills.

It might be worthwhile to point out at this juncture that the observed sharp divergences between the shadow prices of labor when no importation of this factor is available as an option, reflect more on the formulation of the model than on the optimal price structure of the competitive situation. One obvious possibility is the simplicity of the model in that only one variety of labor input is specified. This, however, was determined by the absence of breakdowns of labor by classes used by the manpower planners, namely Classes A, B, C, and D, by industries. What is suggested therefore is the development of labor-use statistics on an industry by industry basis in the various classificatory types used in the Tanzanian manpower plan.

Other possibilities which might explain the behavior of relative prices in the model are (a) the absence of finance in the model, and (b) the level of aggregation used. All these factors have necessarily to be weighed when evaluation of the dual results is being made.

One striking feature of the various solutions of the model which should be identified is the inflexibility of the optimal basis with varying final demand levels. Metal products production never is profitable and the production of building materials is never profitable if it is possible to import these necessary intermediate goods. Since the cases in which building material imports could be made were separated from those in which these imports were not possible, the results really say that for each group of cases, the optimal basis was invariant with respect to varying levels of final demand, consumption in this case. This type of behavior of the optimal basis in activity analysis models is a reflection of the simplicity of the model structure in terms of scarce resources. As shown by Samuelson, Koopmans, Arrow and Georgescu-Roegen,(7) in an open Leontieff model where there is a single scarce resource, the optimal basis will not change when the level of final demand changes. This is due to the fact that once the optimal basis is found, since the included activities face only one scarce factor, only the levels of these activities will be adjusted to satisfy the levels of final demand, the basis remaining the same since the pattern of relative prices does not change when there is a single scarce resource. For all practical purposes only one scarce resourse is operative in the model at a time, and thus there is no reason for the optimal basis to change with higher levels of consumption. These results do indicate that the model is consistent with the non-substitution theorem of activity analysis, and reflects the simultaneous solution of the primal and dual programs in a linear programming problem.(8)

Metal production, to include machinery, was never profitable in any run of the model. This means that, at least during the time span of the model, it is better for Tanzania to import its requirements for metal machinery, given the assumed structure of production. Building material production entered the optimal solution only when it was not permitted to generate a supply through imports. It means again that given the production structure, Tanzania should rather continue to import its cement requirements

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(7) Tjalling C. Koopmans, (ed.), Activity Analysis of Production and Allocation, Cowles Commission Monograph, No. 13, New York (1951), Chapters VII to X.

(8) For a proof based on linear programming, see Kelvin Lancaster, Mathematical Economics, The Macmillan Press, (1968), pp. 91-94.

rather than build cement producing capacity.

In summary, the results of the experiments have demonstrated that:- (a) full Tanzanianization of the labor force in skilled categories may not be a justifiable policy goal; (b) if foreign aid is available, it is better to import labor than not to do so; (c) manpower planning for countries like Tanzania need to include, in more specific ways the effect of the availability of foreign exchange; (d) as growth rates increase and as foreign aid gets more difficult to acquire, the skill restraint becomes even more critical if certain patterns of consumption have to be maintained.

The conclusions derived from the over seventy runs of the model appear exceedingly reasonable, and suggest that countries facing rather much the same kind of developmental problems might opt for the use of such a model to identify policy alternatives that are appropriate. Should the precise questions addressed in the model be those that concern ministers of government charged with growth and developmental responsibilities, then the use of such a model is strongly encouraged. However, we hasten to add that a veritable host of non-pure economic questions have not been brought into the analysis, and to the extent that they loom large, their non-inclusion will make results from the model somewhat misleading. Among these "missing links" are questions of urbanization and the emergence of new elites, questions of race and the importance of race in allocation decisions, differential incentives appropriate to a system opting for both academic and vocational education, and education and technological transfer, to name a few. In addition, we have said nothing concerning the question of income distribution. While these equity concerns are most important, their inclusion in planning models of the type constructed creates several difficulties. In the first place realistic inclusion of income distributional concerns in the model would immediately dictate a change in focus from single period to multi-period; and secondly, it would most certainly require the endogenous treatment of skilled labor supply. What is being said therefore, is, that while efficiency considerations can be handled with reasonable success by models of the type constructed for Tanzania, such models cannot in their present state address either important non-economic considerations like the ones just mentioned, or the equally important considerations linked with the whole question of income distribution, and subsumed under the general term, equity.

APPENDIX A

DATA FOR THE TANZANIAN PLANNING MODEL

TABLE- A 1

Sector Breakdown of Model

	Sector	Sectors from Segal's model
(1)	Agriculture and Forestry	Agriculture
(2)	Mining	Stone quarrying, Salt
(3)	Metal Products	Metal goods
(4)	Food, Beverage, Tobacco	Sugar, Dairy products, Grain mill products, Bakery products, Miscell. foods, Beverages, Tobacco.
(5)	Textiles, Clothing Shoes	Textiles, Ginning, Footwear, Tailoring
(6)	Building Materials and glass prod.	Brick, Block and Tile
(7)	Chemicals	Rubber products, Oil milling and soap
(8)	Wood and Paper	Sawmilling, Woodworking
(9)	Electricity and Water	Electricity
(10)	Construction	
(11)	Transportation	Transportation
(12)	Services	Engineering and Repair, Electrical and Motor Vehicle and Repair.

TABLE A-2

Gross Domestic Product (at factor cost), Current Prices, in T.shillings (million). Selected Years.

Sector	1961	1962	1963	1964	1965	1966
Agr.	2282	2485	2787	2805	2651	2905
Mining	109	103	88	121	121	141
Mfg.	139	154	156	194	234	283
Constr.	117	122	124	154	151	172
Transp.	172	188	188	197	216	247
Pub.Util	27	30	32	35	37	48
Commerce	445	484	517	600	658	766
Rent	167	175	187	222	246	267
Other Services	412	448	468	509	580	615
TOTAL	3870	4189	4547	4837	4894	5444

Source: Tanzania, Background to the Budget: An Economic Survey (annual).

TABLE A-3

Net Imports in T.pounds(million)

<u>1964</u>

Sector	Net Imports
(1)	-
(2)	-
(3)	19.17 (a),(f)
(4)	3.38 (d),(f)
(5)	11.40 (e),(f)
(6)	1.27 (b),(f)
(7)	6.67 (c),(f)
(8)	1.64 (f)
(9)	-
(10)	-
(11)	-
(12)	-

Source: <u>Statistical Abstract for Tanzania,</u> 1965, p.43.

(a) IncludesMachine and Transport equipment and various metal mfrs.

(b) Cement

(c) Min. fuels, lubricants, Chemicals and fertilizers, other non-met. mineral mfrs.

(d) Food, Bev., Tobacco, Animal and Veg. Oils and fats

(e) Textiles, leather and rubber goods and 50% of miscellaneous mfrs., mainly clothing and shoes.

(f) A total of 6 million pounds of miscell. mfrs. was distributed tosectors 3 to 8. 50% of miscell. mfrs. is in the 6 mill. pounds.

TABLE A-4

TANZANIA - DOMESTIC EXPORTS, IN T. POUNDS (MILL).

1960-1964

SECTOR	1960	1961	1962	1963	1964
AGRICULTURE	47.75	40.69	43.61	56.24	63.1
MINING	7.05	8.01	7.59	7.36	9.19

Source: Tanganyika, Statistical Abstract, Budget Survey (several years)

Note: "Other" exports constitute a small portion of the total. This was distributed to the other two sectors in pretty much the proportion of each to total exports. Diamond and gold exports constitute about 10% of the total, hence 10% of "other" exports distributed to Mining sector, the rest to Agriculture(Domestic exports go to countries outside East Africa).

TABLE A-5

Tanzania Exports to East Africa

T.Shillings(mill)

SECTOR	1962	1964
(1)	3.0	1.5
(2)	3.0	6.0
(3)	3.0	13.6
(4)	37.0	50.0
(5)	8.6	22.1
(6)	3.0	6.0
(7)	8.8	6.5
(8)	3.0	1.5
(9)	—	—
(10)	—	—
(11)	—	—
(12)	—	—
OTHER MFG. & MISCELL. ARTICLES	24.4	45.2

Source: Tanzania, The Annual Economic Survey, 1968.

Note: Entries in Other Mfg. and Miscell. category were distributed to what were considered international trading sectors, 1 through 8. 3 million shillings were added to each sector in 1962 and 6 million shillings were added in 1964.

TABLE A-6

Growth of Non-agricultural High-level Manpower in Plan Categories.

CATEGORY	1964-1965	1968-1969	1973-1974	DEMAND 1969-1970 TO 1973-1974.
A	2,801	4076	11 950	3 849
B	5778	10 943	27 301	12 333
C	20 910	29 077	42 186	13108
				8050*
TOTAL	29 489	44096	81 437	37341

Source: Tanzania, Ministry of Economic Affairs and Development Planning, "Survey of High and Middle Level Manpower Requirements and Resources for the Second Five Year Develppment Plan, 1968-70 to 1973-74.

Note: Category A jobs, are those which normally require a University degree; category B jobs normally require from one to three years formal post-secondary(Form 4) education; category C jobs normally require a secondary school educationfor standard performance and includes skilled office workers and the skilled manual workers in the "modern crafts".

* Wastage.

TABLE A-7

High-level Manpower for Tanzania. 1964

SECTOR	LABOR/OUTPUT RATIO
(1)	.00008
(2)	.00025
(3)	.00098
(4)	.00023
(5)	.00024
(6)	.00518
(7)	.00084
(8)	.00164
(9)	.00060
(10)	.00098
(11)	.00018
(13)	.00031

Sources: Tanzania, Background to the Budget, An Economic Survey; Tanzania, Statistical Abstract, 1965, p.142.

Notes: Figures were estimated from results for Uganda, found in OECD, Statistics of the Occupational and Educational Structure of the Labor Force in 53 countries, OECD, (Paris), 1969, p.255.

TABLE A-8

Matrix of Interindustry Co-efficients for Tanzania, 1964.

SECTOR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	.2000	.0024	.0019	.5885	–	.0373	.2335	.1193	.1210	–	–	–
(2)	–	.0018	–	–	–	.3457	–	–	–	–	–	–
(3)	.0003	–	.0315	.0409	.0019	–	.0222	.0115	–	.4049	–	–
(4)	–	.1388	–	.0048	–	–	–	–	–	–	–	–
(5)	.0184	–	–	–	.0006	–	.3400	.0014	–	–	–	–
(6)	.0003	–	–	–	–	–	–	.0014	–	.1925	–	–
(7)	.0003	–	–	.0001	–	–	.0724	.0014	.0280	.1050	.0335	–
(8)	.0003	–	–	–	–	–	–	.0969	–	.0250	–	–
(9)	–	.0012	.0086	.0088	.0016	.0186	.0089	.0065	–	–	.0021	.0076
(10)	–	–	–	–	–	–	–	–	–	–	–	–
(11)	–	.0233	.0376	.0037	.0054	.1775	.0356	.0289	.1180	–	.096	.0021
(12)	.0066	–	–	–	–	–	–	–	–	.1300	–	–

Source: Aggregated from the Matrix of Interindustry Flows for the Tanganyika Economy, 1961, in David Segal, East African Common Market Inequities of the 1960's: An Arbitration Scheme, (1969), (Unpublished Ph.D. Dissertation at Yale University), p. 35.

Notes: The Transportation and Metal Goods, Machinery and Transport Equipment columns were estimated from the Kenya tables in Segal, Ibid.

TABLE A-9

Derivation of base period Consumption -1964 (T.pounds-mill)

Sector	C_i	X_i	$a_{i1}X_1$	$a_{i2}X_2$	$a_{i3}X_3$	$a_{i4}X_4$	$a_{i5}X_5$	$a_{i6}X_6$	$a_{i7}X_7$	$a_{i8}X_8$	$a_{i9}X_9$	$a_{i10}X_{10}$	$a_{i11}X_{11}$	$a_{i12}X_{12}$	$\sum_j a_{ij}X_j$	M_i	E_i	I_i
(1)	46.69	140.2	28.04	.0145	.0009	2.5658	—	.0035	.1809	.8697	.2117	—	—	—	31.09	.75	62.17	
(2)	—	6.05	.2523	—	—	—	1.1736	—	—	—	—	—	—	—	1.42	.75	5.38	
(3)	—	.485	.042	—	.0152	.1785	.0064	—	.0172	.0067	—	.8077	—	—	1.017	21.1	.680	19.9
(4)	11.2	4.365	—	.8397	—	.0209	—	—	—	—	—	—	—	—	.8606	10.2	2.50	
(5)	14.89	3.395	2.579	—	—	—	.0020	—	.2635	.0008	—	—	—	—	2.8453	15.45	1.10	
(6)	—	.095	.042	—	—	—	—	—	—	.0008	—	1.8820	—	—	1.524	1.729	.30	
(7)	10.11	.775	.042	—	—	.0004	—	—	.0561	.0008	.049	.8085	.3299	—	1.2867	10.95	.325	
(8)	2.37	.585	.042	—	—	—	—	—	—	.0566	—	.1925	—	—	.2911	2.15	.075	
(9)	1.157	1.75	—	.0072	.0044	.0384	.0054	.0017	.0068	.0038	—	—	.0206	.505	.5930			
(10)	—	7.7	—	—	—	—	—	—	—	—	—	—	—	—	—			7.7
(11)	8.30	9.85	—	.1403	.0182	.0161	.0183	.0168	.0275	.0169	.2065	—	.9456	.1315	1.5457			
(12)	64.52	66.45	.925	—	—	—	—	—	—	—	—	1.801	—	—	1.926			

$\Sigma = 159.2$

Note: $C_i = X_i + M_i - \sum_j a_{ij}X_j - E_i - I_i$

TABLE A-10

Capital/Output Ratios (b_{ij})

Sector Producing \ Sector Consuming	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(3)	.20	1.80	1.20	.55	.60	.40	.80	.60	2.90	.10	2.20	.50
(10)	1.30	1.20	2.00	.25	.60	1.00	.60	.60	2.60	.70	.80	1.00
TOTAL	1.50	3.00	3.20	.80	1.20	1.40	1.40	1.20	5.50	.80	3.00	1.50

Note: These coefficients are assumed, using a variety of countries. Importance therefore cannot be attached to the results using these ratios as guides for specific policy proposals.

TABLE A-11

Import/Investment Matrix $(mi_i b_{ij})$

To Sector / From Sector	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(3)	.16	1.44	.96	.44	.48	.32	.64	.48	2.30	.08	1.76	.40

Note: A constant percent of import into investment was assumed. That figure is 80%.

TABLE A-12

Import/investment matrix for Target year
($mi_i d_i b_{ij}$)

TO / FROM	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(3)	.0240	.2160	.1440	.0660	.0720	.0480	.0960	.0720	.0345	.0120	.2690	.0600

Note: d_i represents the stock/flow conversion factor, assumed to be 15%, which relates the flow of investment in the target year to the stock of investment for the period as a whole.

TABLE A-13

Intermediate Import Coefficient Vector(m_1)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
.0033	.0075	.0235	.013	.0150	.0555	.1150	.1325	—	—	—	—

Source: Calculated from intermediate import coefficients for several countries. In some cases the estimates were guessed at since other country data did not correspond closely enough to the required sector classification.

TABLE A-14

Import-Consumption Coefficient Vector

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
—	—	—	.60	.60	—	.50	.53	—	—	—	—

Source: Estimated from Tanzania data in imports by main classes, using as a guide, the product breakdowns. See for example, Tanzania, Annual Economic Survey, 1968, pp. 18 & 19.

TABLE A-15

Matrix of Intermediate current and capital Coefficients($m_i a_{ij} + mi_i d_i b_{ij}$)

From \ To	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	.0006	—	—	.0019	.0025	.0001	.0007	.0003	.0063	—	—	—
(2)	—	—	—	—	—	.0025	—	—	—	—	—	—
(3)	.024	.216	.144	.0669	.072	.0480	.0965	.0722	.0348	.0148	.2640	.0600
(4)	—	.0076	—	.0002	—	—	—	—	—	—	—	—
(5)	.0013	—	—	—	—	—	.0256	.0001	—	—	—	—
(6)	—	—	—	—	—	—	—	—	—	—	—	—
(7)	—	—	—	—	—	—	.0135	.0002	.0052	.0195	.0374	—
(8)	—	—	—	—	—	—	—	.0128	—	.0033	—	—
(9)	—	—	—	—	—	—	—	—	—	—	—	—
(10)	—	—	—	—	—	—	—	—	—	—	—	—
(11)	—	—	—	—	—	—	—	—	—	—	—	—
(12)	—	—	—	—	—	—	—	—	—	—	—	—

Source: Tables A-9 to A-13.

TABLE A-16

Table of Base year figures and Export Limits in Model (T.pounds in mill).

	GDP_0	M_0	$E(1)_0$	$E(2)_0$	$\overline{E(1)}$ 3%	$\overline{E(2)}$ 3%	$\underline{E(1)}$ 1.5%	$\underline{E(2)}$ 1.5%	C_0
(1)	140.25	.75	.075	63.10	.1005	84.75	.087	73.196	46.68
(2)	6.05	.75	.30	5.08	.4025	7.11	.348	5.8928	–
(3)	.485	21.10	.68	–	.9100	–	.788	–	–
(4)	4.365	10.20	2.50	–	3.35	–	2.90	–	11.20
(5)	3.395	15.45	1.105	–	1.48	–	1.28	–	14.89
(6)	.095	1.728	.30	–	.4025	–	.348	–	–
(7)	.775	10.95	.325	–	.4366	–	.377	–	10.11
(8)	.585	2.15	.075	–	.1005	–	.087	–	2.368
(9)	1.75	–	–	–	–	–	–	–	1.157
(10)	7.70	–	–	–	–	–	–	–	–
(11)	9.85	–	–	–	–	–	–	–	8.304
(12)	66.45	–	–	–	–	–	–	–	64.52

Source: Tables A-2 to A-5, and A-9.

Note: The lower limit of 1.5% is arbitrary, but the 3.0% figure for the upper limit was derived from the yearly growth rate calculated for Tanzania exports by Maizels in Exports and Economic Growth of Developing Countries, Oxford U. Press (1968), Chap. 6. The 3.0% figure is an average of low and high figures for constant world trade proportions.

TABLE A-17

Sectoral Expenditure Elasticities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.8	–	–	1.3	1.5	1.5	2.0	1.4	1.4	–	1.1	1.0

Note: To derive expenditure elasticities, several sources were used. However, it was necessary to make guesses in some cases as the model categories did not correspond at all times to the available statistics. I also used other country data. See Benton Massell and Judith Heyer, "Household Expenditure in Nairobi: A Statistical Analysis of Consumer Behaviour," Economic Development and Cultural Change, (Jan.1969),pp.212-234.

TABLE A-18

Data for Consumption Equation

	$e_i C_i^*$	e_i	C_i^*	C^*	$e_i C_i^* / C^* = \lambda$	$C_i^* \rho$	$(e_i - 1)$	$C_i^* \rho (e_i - 1)$	$1.10\, C_i^* \rho (e_i - 1)$	$.9\, C_i^* \rho (e_i - 1)$	1.10λ	$.9 \lambda$
(1)	62.0	0.8	46.69	159.2	.2346	56.96	−0.2	−11.39	−12.52	−10.25	.258	.2111
(2)	–	–	–	"	–	–	–	–	–	–	–	–
(3)	–	–	–	"	–	–	–	–	–	–	–	–
(4)	18.915	1.3	11.20	"	.0914	13.66	0.3	4.098	4.507	3.688	.1005	.0822
(5)	26.625	1.5	14.89	"	.1402	18.16	0.5	9.08	9.98	8.172	.1542	.1261
(6)	2.10	1.5	–	"	–	–	–	–	–	–	–	–
(7)	22.85	2.0	10.11	"	.427	12.33	1.0	12.33	13.56	11.097	.1397	.1143
(8)	3.745	1.4	2.37	"	.0208	2.89	0.4	1.156	1.271	1.04	.0228	.0187
(9)	2.45	1.4	1.15	"	.0101	1.403	0.4	.5612	.6173	.505	.0111	.009
(10)	–	–	–	"	–	–	–	–	–	–	–	–
(11)	10.835	1.1	8.30	"	.0573	10.126	0.1	1.0126	1.1138	.911	.063	.0515
(12)	64.52	1.0	64.52	"	.4173	81.06	0.0	0.0	0.0	0.0	.459	.3755

Note: ρ = 1.22 (or the multiplier appropriate to a 2% rate of growth per year for ten years). The coefficients 1.10 and 0.9 in columns 9 through 12 are used to get the 10% variation around the Engel curve for the consumption equation.

TABLE A-19-1

Foreign Exchange Availabilities

(T.pounds,mill)

25.0	35.0	45.0	55.0

Note: These figures were selected on the basis of first Five Year Plan estimate that approximately 130 million would be financed out of foreign funds. A low figure of 25 million was used as final year foreign exchange needs.

TABLE A-19-2
Marginal Saving Rate

10.0%	15.0%	20.0%

TABLE A-19-3

Domestic Availibilities of High-level Manpower

(million)

.125	.150	.175	.200

APPENDIX B

SOLUTIONS TO THE SINGLE PERIOD MODEL OF TANZANIAN ECONOMY

TABLE B-1

PRODUCTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

PROD. \ FOR. EXCH.	£25.0 MILL.	£35.0 MILL.	£45.0 MILL.	£55.0 MILL.	£0.0 MILL.
AGRP	221.997382	242.6	265.8	285.4	148.56
MINP	6.252254	6.2	6.2	6.2	6.25
METP	0.0	0.0	0.0	0.0	0.0
FOOP	14.386612	16.1	17.8	19.5	7.19
TEXP	51.194794	60.5	68.9	77.2	8.00
BLDP	0.0	0.0	0.0	0.0	0.0
CHMP	27.394623	31.8	36.2	40.6	8.41
WOOP	6.277140	6.4	7.2	12.3	2.33
ELEP	4.549685	5.2	5.9	6.6	1.35
CONP	90.264740	100.8	111.3	121.6	48.49
TRAP	21.346649	24.5	27.6	30.9	6.92
SERP	160.227371	181.8	201.9	221.8	66.58

TABLE B-2

IMPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

FOR. AID / IMPORTS	£25.0 MILL	£35.0 MILL	£45.0 MILL.	£55.0 MILL	£0.0 MILL
MFTM	51.83	58.43	64.91	71.70	60.00
FOOM	15.82	18.41	20.96	23.50	5.09
TEXM	0.80	0.0	0.0	0.0	5.96
BLDM	18.05	20.16	22.27	24.32	9.70
CHMM	15.35	18.35	21.30	24.24	2.24
WOOM	3.74	3.59	4.10	0.62	0.89

TABLE B-3

EXPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

FOR. AID / EXPORTS TO TWO MARKETS	£25.0 mill	£35.0 mill	£45.0 mill	£55.0 mill.	£0.0 mill
AGFA	0.08	0.08	0.08	0.10	0.09
MIEA	0.34	0.34	0.34	0.34	0.35
MEEA	0.78	0.78	0.78	0.78	0.78
FOEA	2.90	2.90	2.90	2.90	2.90
TEEA	1.48	1.48	1.48	1.48	1.28
BLEA	0.40	0.40	0.40	0.40	0.40
CHEA	0.37	0.37	0.37	0.37	0.37
WOEA	0.08	0.08	0.08	0.08	0.08
AGEB	73.19	77.22	82.60	84.74	73.19
MIEB	5.89	5.89	5.89	5.89	5.89

TABLE B-4

CONSUMPTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

CONSUMPTION \ FOR. AID	£25.0 MILL	£35.0 MILL.	£45.0 MILL	£55.0 MILL.	£0.0 MILL
AGPC	87.41	98.50	109.41	120.25	38.91
FOPC	26.37	30.69	34.94	39.16	8.48
TFPC	46.41	54.51	62.48	70.41	9.94
CHPC	30.70	36.70	42.61	48.49	4.49
WOPC	7.06	6.78	7.74	8.70	1.67
ELPC	2.78	3.25	3.72	4.18	0.66
TRPC	17.92	20.62	23.29	25.93	5.74
SEPC	147.03	167.16	185.73	204.19	59.30

TABLE B-5

PRODUCTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

15% Marginal Saving Rate

FOR. AID. / PRODUCTION	£25.0 mill	£35.0 mill	£45.0 mill	£55.0 mill
AGRP	202.14	219.57		254.44
MINP	6.25	6.25		6.25
METP	0.0	0.0		0.0
FOOP	12.41	14.23		17.86
TEXP	21.72	37.15		68.01
BLCP	0.0	0.0		0.0
CHMP	22.27	26.85		36.01
WOOP	5.22	6.16		8.02
ELEP	3.71	4.46		5.96
CONP	77.76	88.03		108.59
TRAP	17.58	20.97		27.76
SERP	137.31	158.28		200.24

TABLE B-6

IMPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

15% Marginal Saving Rate

IMPORTS \ FOR. AID	£25.0 mill.	£35.0 mill.	£45.0 mill.	£55.0 mill.
METM	42.69	49.82		-64.09
FCOM	12.88	15.59		21.02
TEXM	20.51	13.90		0.86
BLDM	15.55	17.60		-21.71
CHMM	11.94	15.08		21.37
WOOM	3.02	3.68		5.01

TABLE B-7

EXPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

15% Marginal Saving Rate

FOR. AID / EXPORTS TO TWO MARKETS	£25.0 mill	£35.0 mill	£45.0 mill	£55.0 mill
AGEA	0.087	0.087		0.087
MIEA	0.348	0.348		0.348
MEEA	0.788	0.788		0.788
FCEA	2.900	2.900		2.900
TEEA	1.280	1.280		1.480
BLEA	0.402	0.402		0.402
CHEA	0.377	0.377		0.377
WCEA	0.087	0.087		0.087
AGEB	73.195	73.195		73.195
MIEB	5.893	5.893		5.892

TABLE B-8

CONSUMPTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

15% Marginal Saving Rate

FOR. AID / CONSUMPTION	£25.0 mill	£35.0 mill	£45.0 mill	£55.0 mill
AGPC	74.83	86.44		109.65
FOPC	21.47	25.99		35.03
TEPC	37.22	45.70		62.66
CHPC	23.89	30.17		42.75
WOPC	5.70	6.96		9.47
ELPC	2.24	2.74		3.73
TRPC	14.85	17.68		23.35
SEPC	125.86	145.39		184.44

TABLE B-9

PRODUCTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

NO LABOR IMPORTS

FOR. AID / SKILLED LAB. (MILL) / PRODUCTION	£25.0 mill.				£45.0 mill.				£55.0 mill.				
	·125	·450	·175	·200	·125	·150	·175	·200	·125	·150	·075	·200	
AGRP	178.71	193.8	216.7	279.1	178.7	193.8	208.9	233.3	178.7	193.8	208.9	224.0	
MINP	6.25	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	
METP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
FOOP	9.80	12.1	12.3	13.7	9.8	12.1	14.4	14.2	9.8	12.1	14.4	16.7	
TEXP	12.52	16.3	20.8	41.4	12.5	16.3	20.1	25.0	12.5	16.3	20.1	24.0	
BLDP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
CHMP	13.26	17.8	22.3	25.9	13.2	17.8	22.4	26.8	13.2	17.8	22.4	27.0	
WOOP	3.12	3.9	4.7	5.3	3.1	3.9	4.7	5.5	3.1	3.9	4.7	5.5	
ELEP	2.13	2.9	3.6	4.2	2.1	2.9	3.6	4.3	2.1	2.9	3.6	4.4	
CONP	59.87	68.9	78.8	87.6	59.8	68.9	77.9	88.1	59.8	68.9	77.9	87.0	
TRAP	12.88	V7.0	17.4	20.1	12.8	17.0	21.1	20.8	12.8	17.0	21.1	25.3	
SERP	81.72	104.5	126.2	143.1	81.7	104.5	127.4	148.7	81.7	104.5	127.4	150.2	

TABLE B-10

IMPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

NO LABOR IMPORTS

FOR. AID / SKILLED LAB (MILL) / IMPORTS	£25.0 MILL				£45.0 MILL				£55.0 MILL				
	.125	.150	.175	.200	.125	.150	.175	.200	.125	.150	.175	.200	
METM	39.7	37.1	42.2	48.6	39.7	37.1	43.4	48.2	39.7	37.1	43.4	49.7	
FOOM	8.9	12.4	12.8	14.8	8.9	12.4	15.9	15.6	8.9	17.4	15.9	19.3	
TEXM	11.9	17.2	21.5	7.6	11.9	17.2	22.5	26.3	11.9	17.2	22.5	27.8	
BLDM	11.9	13.7	15.7	17.5	11.9	13.7	15.5	17.6	11.9	13.7	15.5	17.4	
CHMM	5.5	8.8	11.8	14.2	5.5	8.8	12.0	15.1	5.5	8.8	12.0	15.3	
WOOM	1.3	1.9	2.4	2.8	1.3	1.9	2.5	3.0	1.3	1.9	2.5	3.0	

TABLE B-11

EXPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

NO LABOR IMPORTS

FOR. AID / SKILLED LAB (MILL) / EXPORTS TO TWO MARKETS	£25.0 mill				£45.0 mill				£55.0 mill.			
	.125	.150	.175	.200	.125	.150	.175	.200	.125	.150	.175	.200
AGEA	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
MIEA	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348	0.348
MFFA	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788
FOFA	2.900	2.900	2.900	2.900	2.900	2.900	2.900	2.900	2.900	2.900	2.900	2.900
TFEA	1.280	1.280	1.280	1.280	1.280	1.280	1.280	1.280	1.280	1.280	1.280	1.280
BLEA	0.348	0.348	0.402	0.402	0.348	0.348	0.348	0.402	0.348	0.348	0.348	0.348
CHEA	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377	0.377
WOEA	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
AGFB	73.195	73.195	73.195	73.195	73.195	73.195	73.195	73.195	73.195	73.195	73.195	73.19
MIEB	5.892	5.893	5.892	5.892	5.892	5.893	5.893	5.893	5.892	5.893	5.893	5.89

TABLE B-12

CONSUMPTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

10% Marginal Saving Rate

NO LABOR IMPORTS

FOR. AID / SKILLED LAB. (MILL) / CONSUMPTION	£25.0 MILL				£45.0 MILL				£55.0 MILL			
	.125	.150	.175	.200	.125	.150	.175	.200	.125	.150	.175	.200
AGPC	60.17	69.64	86.57	94.73	60.17	69.64	79.11	97.55	60.17	69.64	79.11	88.58
FOPC	14.96	20.74	21.38	24.83	14.96	20.74	26.51	26.02	14.96	20.74	26.51	32.29
TFPC	19.89	28.75	37.04	43.52	19.89	28.75	37.62	45.75	19.89	28.75	37.62	46.48
CHPC	11.05	17.61	23.76	28.56	11.05	17.61	24.18	30.21	11.05	17.61	24.18	30.75
WOPC	2.58	3.65	4.66	5.44	2.58	3.65	4.73	5.71	2.58	3.65	4.73	5.80
ELPC	1.23	1.75	2.23	2.61	1.23	1.75	2.27	2.74	1.23	1.75	2.27	2.79
TRPC	11.09	14.71	14.79	16.95	11.09	14.71	18.33	17.70	11.09	14.71	18.33	21.95
SEPC	72.75	94.33	114.52	130.28	72.75	94.33	115.91	135.72	72.75	94.33	115.91	137.49

TABLE- B-13

PRODUCTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

20.0% Marginal Saving Rate

NO LABOR OR BLDG.MAT. IMPORTS

FOR. AID / SKILLED LAB (MILL) / PRODUCTION	£25.0 mill.			£35.0 mill			£55.0 mill			
	.125	.150	.200	.125	.150	.200	.125	.150	.200	
AGRP	177.35	173.85	173.85	177.35	192.46	198.17	177.35	192.46	222.66	
MINP	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39	
MLTP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
FOOP	9.60	10.56	10.56	9.60	11.92	13.58	9.60	11.92	16.56	
TEXP	12.18	13.59	13.59	12.18	16.00	18.65	12.18	16.00	23.65	
BLDP	0.40	0.40	0.40	0.40	0.41	0.41	0.40	0.41	0.42	
CHMP	12.85	16.20	16.20	12.85	17.44	23.23	12.85	17.44	26.62	
WOOP	3.05	3.68	3.68	3.05	3.85	4.89	3.05	3.85	5.46	
ELEP	2.07	2.45	2.45	2.07	2.84	3.43	2.07	2.84	4.39	
CONP	59.16	61.77	61.77	59.16	68.19	73.75	59.16	68.19	86.26	
TRAP	12.58	12.04	12.04	12.58	16.73	16.58	12.58	16.73	25.02	
SERP	79.62	95.72	95.72	79.62	102.45	120.71	79.62	102.45	148.09	

TABLE B-14

IMPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

20.0% Marginal Saving Rate

NO LABOR OR BLDG. MAT. IMPORTS

FOR. AID / SKILLED LAB (MILL) / IMPORTS	£25.0 mill			£25.0 mill			£85.0 mill		
	.125	.150	.200	.125	.150	.200	.125	.150	.200
METM	79.67	73.91	73.91	79.67	74.11	65.28	62.99	79.67	74.11
FOOM	8.65	10.09	10.09	8.65	12.12	14.60	19.04	8.65	12.12
TEXM	11.44	13.64	13.64	11.44	16.75	20.56	27.37	11.44	16.75
BLDM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHMM	5.22	8.04	8.04	5.22	8.50	13.26	15.06	5.22	8.50
WOOM	1.31	1.89	1.89	1.31	1.88	2.79	3.02	1.31	1.88

TABLE B-15

EXPORTS AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

20.0% Marginal Saving Rate

NO LABOR OR BLDG. MAT. IMPORTS

For. Aid / Skilled Lab. (mill) / Exports tie mats.	£25.0 mill			£35.0 mill			£55.0 mill		
	.125	.150	.200	.125	.150	.200	.125	.150	.200
AGEA	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
MIEA	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
MEEA	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
FOEA	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
TEEA	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
BLEA	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
CHEA	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
WOEA	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
AGEB	73.19	73.19	73.19	73.19	73.19	73.19	73.19	73.19	73.19
MIEB	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89

TABLE B-16

CONSUMPTION AT VARYING LEVELS OF SKILLED LABOR AND FOR. EXCHANGE

20.0% Marginal Saving Rate

NO LABOR OR BLDG. MAT. IMPORTS

For. Aid / Skilled Lab. (mill.) / Consumption	£25.0 mill			£35.0 mill			£45.0 mill			£55.0 mill		
	.125	.150	.200	.125	.150	.200	.125	.150	.200	.125	.150	.200
AGPC	59.30	55.03	55.03	59.30	68.75	70.80	59.30	68.75	86.89	59.30	68.75	87.67
FOPC	14.43	16.82	16.82	14.43	20.20	24.33	14.43	20.20	31.51	14.43	20.20	31.73
TEPC	19.08	22.74	22.74	19.08	27.92	34.27	19.08	27.92	45.29	19.08	27.92	45.62
CHPC	10.44	16.08	16.08	10.44	17.00	26.53	10.44	17.00	34.21	10.44	17.00	30.12
WOPC	2.48	3.56	3.56	2.48	3.55	5.27	2.48	3.55	5.66	2.48	3.55	5.70
ELPC	1.19	1.40	1.40	1.19	1.70	2.07	1.19	1.70	2.72	1.19	1.70	2.74
TRPC	10.75	10.01	10.01	10.75	14.37	13.86	10.75	14.37	17.54	10.75	14.37	21.60
SEPC	70.76	86.55	86.55	70.76	92.31	109.82	70.76	92.31	134.66	70.76	92.31	135.41

TABLE B-17

CONSUMPTION AT VARYING LEVELS OF SKILLED LABOR; AND FOR. EXCHANGE = £55.0 mill.

10.0% Marginal Saving Rate

NO LABOR OR BLDG. MAT. IMPORTS

FOR. AID / SKILLED LAB. (mill.) / CONSUMPTION	£55.0 mill.			
	·125	·150	·175	·200
AGPC	59.30	68.75	78.21	87.67
FOPC	14.43	20.20	25.96	31.73
TEPC	19.08	27.92	36.77	45.62
CHPC	10.44	17.00	23.56	30.12
WOPC	2.48	3.55	4.63	5.70
ELPC	1.19	1.70	2.22	2.74
TRPC	10.75	14.37	17.99	21.60
SEPC	70.76	92.31	113.86	135.41

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