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Charles Wolf, Jr.

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Charles Wolf, Jr.*

The RAND Corporation, Santa Monica, California

I

Six years ago, an outgoing president of the Operations Research Society of America raised a question concerning the feasible and desirable role of operations research in connection with the economic development of the less developed countries.[1] Ackoff answered his question by asserting that a large role was both feasible and desirable. He predicted that extremely high returns would result from addressing national planning problems with operations research techniques in these countries. In conclusion he said, "If other underdeveloped countries would use as competent planners as India and if they would supplement them with competent operations researchers, then, in my opinion, the term 'underdeveloped countries' would have to be dropped from our vocabulary in our lifetime."[2]

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This paper was prepared for the Symposium on Possibilities of Operations Research in Developing Countries, organized by the French Society for Operational Research, Paris, June 26-28, 1963.

[1]Russell A. Ackoff, "Operations Research and National Planning," Operations Research, August 1957.

[2]Ibid., underlining added. A somewhat similar view of the bright prospects to be expected from applying operations research to major policy problems at a national level was also expressed

Ackoff's paper brought a strong dissent from a subsequent ORSA president, Charles Hitch (showing, if indeed it needed to be shown, that distinguished practitioners of operations research can be as far apart in their policy prescriptions as, say, nuclear physicists in their views on inspection systems for policing a test ban, or economists in their prescriptions for the proper combination of various fiscal policy measures to combat unemployment). Characterizing OR as "the art of suboptimizing," Hitch urged caution in extending OR to national problems, and particularly urged caution in extending OR to national problems in the less-developed countries.[1] Instead he urged the application of OR at a project and industry level, and stressed the risks of over-selling what OR has to offer the underdeveloped countries at the level of national planning.

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by Ellis A. Johnson, "The Long-Range Future of Operational Research," Operations Research, January-February 1960, pp. 7-8.

"Operational research, Johnson stated,""is badly needed in the U.S. State Department.... I believe that it is in the State Department and in politics that the greatest possible advances in operations research can be made in the future, and that here there can be a tremendous use of symbolic logic and computers to provide for all the interrelations in a way that is presently beyond comprehension of any single human being or of any group of diplomats of reasonable size."

For a more sober view of the opportunities and limitations of operations research in dealing with national security problems, see James R. Schlesinger, "Quantitative Analysis and National Security," World Politics, January 1963, pp. 295-315.

[1]Charles Hitch, "Operations Research and National Planning -- A Dissent," Operations Research, October 1957, p. 718. Since then, Hitch has been a pioneer in adapting OR to national defense problems in the United States as Assistant Secretary of Defense (Comptroller).

A similarly cautionary view has also been expressed by O. M. Solandt[1] and by R. Dorfman.[2] Commenting on the characteristics of problems to which operations research can be most successfully applied, e.g., abundant and reliable data, a well-structured model, and a clear, reduceable objective function, Dorfman concluded that the conditions that are most propitious for the use of operations research tend to occur in "routine and technical problems...at lower and middling levels."[3]

In general it seems to me that the Hitch-Dorfman view had and has much to recommend it. Perhaps its strongest support is provided by some of the more obvious miscarriages that the uncritically optimistic view has led to. Ackoff, for example, inadvertently demonstrates some of the pitfalls that his optimism leads to by his own advocacy of two particular effectiveness measures for OR use in the evaluation of alternative development plans:

$$P/\sigma_p \text{ , and}$$

$$\text{increase in } P/\text{decrease in } \sigma_p \text{ ,}$$

where P is referred to by Ackoff as "average purchasing power," but probably is intended to mean real per capita consumption.

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[1] O. M. Solandt, "Concluding Remarks" in "A Decade of Military Operations Research in Perspective - A Symposium," Operations Research, November-December 1960, p. 857. "Systems research that is not based on a thorough knowledge of the elements that go into the system can become sterile. I think it is particularly dangerous for operations-research workers to deal with continually larger and larger systems until finally they study the political and social systems of the whole world."

[2] Robert Dorfman, "Operations Research," American Economic Review, September 1960.

[3] Ibid., pp. 16-20.

Actually, as Hitch noted, these measures of effectiveness behave so capriciously that they would be highly inappropriate yardsticks for evaluating development programs. They could, for example, lead to the choice of a development program which, if based on the first effectiveness measure, might sacrifice improvements in living standards in order to distribute existing poverty more equally. And the second ratio seems to lead exactly nowhere, since alternative development programs that increased P in varying degrees but left σ_p unchanged would perform equally well!

Perhaps a more serious example of the hazards of letting OR run loose at a national planning level is provided by the influential paper that P. C. Mahalanobis wrote in 1955, "The Approach of Operational Research to Economic Planning in India."[1] By basing his two-sector model on the major and questionable assumption that investment in period t is determined by the domestic production of capital goods in t-1, Mahalanobis "derived" a solution which recommended strong allocative emphasis on the capital-intensive industrial sector, a conclusion that was strongly implicit in the basic underlying assumption of the model.

Actually, this assumption and the model derived from it, ignored such other possibly important constraints on investment as the propensity to save, as Domar noted.[2] And, more important, the Mahalanobis

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[1] Sankhya, December 1955, Vol. XVI.

[2] Evsey Domar, Essays in the Theory of Economic Growth, 1957, pp. 223-230.

model ignored certain important opportunities for raising investment beyond the capacity of domestic industry to produce capital goods; for example, by increasing exports and using the resulting foreign exchange to import capital goods, or by the use of labor-intensive methods for capital construction purposes. When such opportunities are brought into the model, it turns out that Mahalanobis' "optimal" solution is, in fact, dominated by several alternatives, as Komiya has pointed out.[1] Moreover, as noted by Oshima, when consideration is given to the relatively large urban overhead costs that are associated with industrial emphasis, or to the technological possibilities in agriculture, suggested by Griliches' work on the high rates of return on hybrid-corn research expenditures in the United States,[2] it is clear that the analytical and empirical foundations for improvements in the allocation problem must be a good deal more complex and sophisticated than the Mahalanobis model.

These comments are not intended to detract from the notable accomplishments and contributions which Mahalanobis himself has made in numerous other ways to Indian planning and development. They are simply intended to point out the hazards of applying operations research techniques too quickly and broadly. Problems such as national investment allocations over time and space may not be

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[1] R. Komiya, "On Mahalanobis' model of India Economic Planning," Review of Economics and Statistics, February 1959. Somewhat similar criticisms of the Mahalanobis' model have been made in Harry T. Oshima, "A Strategy for Asian Development," Economic Development and Cultural Change, April 1962, pp. 314-315.

[2] Zvi Griliches, "Research Cost and Social Returns," Journal of Political Economy, October 1958.

well-structured and certainly are not adequately reflected by simple two-sector models. When, in addition, reliable data are in short supply, the problem warrants a cautious and qualified approach.

Against this background, it seems to me clear that the dangers of overselling and overdoing operations research on broad national planning problems in developing countries are sufficiently great that the cautionary admonitions of Hitch, Dorfman and others should be kept prominently in mind in a symposium such as this one. Having said this, however, and although I endorse the cautions and reservations which they expressed, I nevertheless want to devote the bulk of this paper to two examples of recent work in which I've been engaged at RAND that I think indicate ways in which operations research can make a distinctly useful, if limited, contribution to important national planning problems in developing countries.

Before doing so, there are two general comments I'd like to make by way of a brief introduction to what must be a similarly brief treatment of these examples. First, I am not particularly concerned with whether it might be more appropriate to apply the labels "econometrics," or "systems analysis," rather than "operations research," to one or both of these examples. Methodological purists may find it preferable to fit the examples into one or the other of these categories, but for my purpose, what we are concerned with is the application of quantitative analytical techniques to decision problems in the underdeveloped countries. From this standpoint, econometrics applied to practical, policy problems is operations research.

The second comment relates to the distinction between military and economic problems in developing countries. I have the strong impression that operations researchers, who have been actively concerned with military as well as industrial problems in the advanced countries, are tending to be predominantly concerned with, or at least displaying an inclination to be predominantly concerned with, the more strictly nonmilitary, economic-development problems in the less-developed countries. On the contrary, I would be inclined to stress the importance of military problems in a number of the principal less-developed countries, particularly those on the Sino-Soviet periphery, and especially to stress the importance of interactions between military and economic considerations in ways that I shall have more to say about later on. Perhaps this general observation is of more relevance to my economist colleagues than to operations researchers from other fields, but it does seem to me that there may be some important uses of operations research methodology in connection with military problems and military-economic interactions in the less-developed countries. In fact, the first example that I will discuss will be principally concerned with a study of this sort.

II

My aim, then, in these examples, is to describe briefly two specific applications of operations research to broad problems relating to the less-developed countries, including in this category problems that concern foreign aid from the more advanced countries to the developing countries.

A. INCREASING THE GROWTH-EFFECTS OF MILITARY PROGRAMS IN LESS-DEVELOPED COUNTRIES

My first example is concerned with a research study conducted several years ago at RAND by Paul Clark and me dealing with the evaluation of military programs in less-developed countries.[1] Basically, this research was concerned with developing a methodology and attempting to apply it, to answer the following question: How can military assistance, and the structure of defense forces and budgets in the underdeveloped countries, be modified so as to yield about equivalent military effectiveness, and yet generate substantially improved economic and political side-effects? Underlying the question as formulated was the notion that comparing and evaluating alternative military programs -- both military aid programs and domestic defense programs in the underdeveloped countries -- requires a multidimensional set of performance measures: economic and political, as well as military. For the military performance measures, we relied on war games, comparing outcomes in terms of area occupied in a stipulated time period, or the time required to occupy or defend a stipulated area, casualties, and materiel and property damage. For the economic performance measures, we compared the effects of alternative military programs on operating costs of the defense establishment, on public capital formation, and on skill formation through technical military training programs. And for the political performance measures, we used more or less informed judgment and conjecture concerning the likely reactions of key political groups and of the public, in the countries under study, to various program alternatives. Here we

[1]The study is described in more detail in Charles Wolf, Jr., "Defense and Development in Less Developed Countries," Operations Research, Vol. X, No. 6, November-December 1962, pp. 828-838.

quite frankly relied on the area "expert" for our primary performance measures -- a by no means riskless procedure.

Focusing on U.S. military assistance programs, the method we developed had five separate steps:

1. We first drew up alternative programs for spending the same hypothetical four-year military aid dollar budget, the amount of the budget being roughly based on recent experience in the particular underdeveloped countries for which the case studies were conducted, Viet-Nam and Iran. The programs were designed to be of equal cost, but they were significantly different in their content. One program, which we might call the 'A' program, generally stressed fairly large, conventionally-armed and trained forces, following rather closely the lines of recent military aid programs and force structures in the major underdeveloped recipient countries. The other program, which we may call 'B,' consisted of smaller, more lightly-armed forces, with the dollar savings resulting from these reductions used hypothetically for expanding internal security forces, increasing ground and air mobility, providing additional ground and airfield installations intended to facilitate effective intervention by free-world forces if this should be necessary and, finally, expanding the technical training of military manpower.

In effect, the same four-year dollar budget was hypothetically expended in different ways, under the 'A' and 'B' programs, for initial equipment (i.e., force improvement); for four-year replacement, operating, and spare-parts costs (i.e., force maintenance); for military construction; and for military training in U.S. technical service schools. Standard cost factors were used for equipment,

maintenance, and training costs, and generous estimates were made for the construction costs of roads, airfields, and other infrastructures in the countries under study where accurate experience factors were not available.

2. The second step consisted of formulating a more or less credible range of threats, covering differing levels of violence, from a major insurrection to invasion by a minor neighbor with only marginal support from one of the large adjacent communist powers and, finally, a larger scale invasion with overt participation by one of the latter powers. The threats were sketched out in game scenarios that gave the game players a set of initial conditions to start from, as well as a plausible sequence of hypothetical events through which these conditions might have evolved.

The scenarios, which were drawn up in 1959, projected events several years into the future in order to allow time for the hypothetical 'A' and 'B' programs to be carried out. While effort was devoted to making these projections sufficiently realistic to motivate the play, detailed 'realism' was not the primary consideration in the design and choice of scenarios. The scenarios were kept at a fairly macroscopic level, and details, to provide a semblance of added realism, were excluded if they were judged to be inessential to the games' purpose. Instead, the primary consideration in formulating the scenarios was their relevance to the games' purpose from the standpoint of spanning the differing levels-of-violence needed to test the military performance of the contrasting aid programs.

3. Next, the research group, consisting of two teams of senior retired military officers, and a CONTROL team, conducted the game operations, using the military resources available to them to try to achieve objectives specified in the game scenarios, which were then played seriatim. Because the free-world, or BLUE team was assumed to have expended military aid dollars in differing ways in the pre-game period, BLUE's order-of-battle and logistic support resources were markedly different under the two programs, and these differences were made known to the RED team. In formulating strategy and carrying out operations, the BLUE team used, in sequence, the two different force-and-facilities packages represented by the 'A' and 'B' programs, while the enemy team used his 'best' strategy against each of the BLUE alternatives.

4. In the fourth step, we evaluated military performance of the alternative packages primarily in terms of the time, area, and casualty measures mentioned before. Occasionally, we also evaluated military performance in terms of the bargaining position of the respective teams when game hostilities were terminated, and the relative probability that a particular contingency (e.g., an insurrection) would have broken out at all, depending on whether 'A' or 'B' had been implemented in the pre-game years. The evaluation technique used standard planning factors and simple quantitative models where they were applicable (e.g., for assessing air-to-air combat, the effects of interdiction attacks, movement of ground forces, etc.), but relied on discussion and experienced judgment where they were not. In comparison with other man-machine simulations, this one

placed relatively heavy reliance on men rather than machines.[1]

In conducting and evaluating the game, play was divided into segments or phases, usually based on convenient blocks of time or space. Each phase was played under both of the program assumptions before either of them was evaluated. The reason for this was to minimize the feedback that would have distorted the results if one program had been played and evaluated before the other was initiated.

It is worth noting that the evaluation was less concerned with the absolute outcomes (i.e., who 'won' or 'lost,' and by how much?), than with comparative outcomes (i.e., how did program 'A' perform compared to program 'B'?). For reasons that should be intuitively clear, one can have more confidence in the comparative outcomes than in the absolute outcomes of an exercise of this sort, because gross estimating errors in evaluating outcomes are likely to be correlated between the two programs.

5. Finally, independent of the war games, we conducted a separate evaluation of the economic and political side-effects of the two different, but equal-costing programs, 'A' and 'B.' The purpose of the economic evaluation was to provide a quantitative indication of differences between the two programs in their effects on economic development in the countries studied. The purpose of the more general political assessment was to get at least a qualitative indication of how the alternative programs would be likely

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[1]For a discussion of gaming methodology, see M. G. Weiner, War Gaming Methodology, The RAND Corporation, RM-2413, July 1959.

to be received by key groups and individuals comprising the leadership of these countries.

What were the results of these comparisons? Let me first consider the general nature of our findings with respect to comparative military performance. First, we found that, between the two fairly sharply contrasting but still technically tenable programs, the differences in military effectiveness were neither large nor uniform. In the three-by-two matrix (i.e., each of the two programs in each of the three differing levels-of-violence) which summarized our military outcomes for Viet Nam and Iran, it turned out that one program produced somewhat better military performance in one contingency at one level-of-violence, while the other program did somewhat better in another contingency. But, more important, the magnitude of these differences did not appear to be very large in any case. In the aggregate, given a reasonably responsible and informed formulation of the contrasting alternatives, factors that were not affected by the program changes we made (e.g., the terrain, the size of the existing road net, the distance of a major road junction from the border, the loyalty of the indigenous population, etc.) seemed to dominate most of the factors that were affected by the program changes (e.g., the size and equipment of forces, and the types of facilities).

It should be emphasized that this latter generalization applies only to the stated assumption that we were comparing alternatives that, though sharply contrasting, still represented responsible and technically tenable changes. This does not imply that changes in forces and facilities do not matter; but rather that, if these

changes are judiciously designed, they seem to trade off against each other at fairly reasonable rates, leaving military performance somewhat better in some contingencies and somewhat worse in others, but not drastically different in any contingency. In this sense, the factors which were not affected by the program changes tended to have a dominant and pervasive effect that made the over-all results more similar than different.

Second, we found that the general technique of trying to design a package of forces and facilities to meet a range of threats, rather than a single, most-likely threat, made considerable sense. The military posture that performed most effectively in one contingency -- for example, in the major invasion contingency -- did not prove to be most effective in the lower violence contingencies.

Third, we found that while sharp improvements in military effectiveness did not seem possible within existing budget levels, there appeared to be opportunities for realizing modest improvements by some specific changes in the force-facilities mix in the under-developed countries situated on the communist periphery. Such specific changes related to internal security forces, mobility, reconnaissance, and at least some of the illustrative "infrastructures."

With this summary of the military performance and evaluation, what can be said about the economic and political side-effects of the program alternatives? Not surprisingly, the so-called 'B' programs (which sacrificed large ground forces in favor of smaller, more mobile, technically trained forces with additional supporting

facilities like roads, airfields, harbor and communication facilities) showed clear dominance over the 'A' program from an economic point of view. Operating costs, and hence budgetary requirements, were lowered, thereby freeing resources for developmental purposes -- at least in principle. Contributions to 'social overhead' capital were enhanced under the 'B' program. And finally, the output of trained manpower was increased because of the additional allowance of military aid funds for this purpose. The significance of these economic findings is clearly enhanced by the fact that the military comparison did not exhibit dominance for either program alternative. In this, as in many other decision-making problems, it seems to make sense to base choice on secondary criteria, when the primary criteria, i.e., in this case, military effectiveness, do not show clear dominance for a particular alternative.

As to the political side-effects, these were both less definite and less dominant than the economic side-effects. In general, it seemed to us that moving in the direction of the 'B' program would be likely to evoke support from some of the principal political elites, and to create a more healthy public image of the role of the national military establishment, as well as of U.S. military assistance programs, than has typically existed in the past.

A few general comments on the method that was developed and used in this work should be added. Probably the first point to note is that many parts of the method were judgmental and imprecise, and the conclusions should be interpreted in this light. This was true not only of the political comparisons, but of some parts of the

military simulation, as well. For example, in comparing the time required under the 'A' and 'B' programs to quell an insurrection of a defined scope, we combined some numbers and facts, on the one hand, with judgment and intuition on the other: numbers and facts concerning differences between the programs in reconnaissance capabilities, in airlift, in ground mobility and in response time; judgment and intuition concerning the effects of these differences on finding and killing guerrillas, shutting off lines of communication, and reducing the number of guerrilla incidents. In a problem as ill-structured as counter-insurgency operations, the game-seminar type of evaluation, which focuses on the known parameters and instrument variables, and makes explicit judgments concerning their effects on the outcome, is useful. Moreover, while the unknown parameters (like population loyalty, the morale of RED and BLUE units, etc.) would turn out to be highly important in the real world, the fact that comparative rather than absolute results are the aim provides an important hedge against mistaken assumptions about these parameters. Under the circumstances, there is a high probability that errors arising from such mistaken assumptions will be positively correlated, and hence the relative differences in the performance of the programs will not be sensitive to these possibly mistaken assumptions. For this reason, it seems to be particularly important in cases of this sort to pursue the analysis in parallel, so to speak, focusing on comparative rather than absolute results.

Nevertheless, the type of judgmental evaluation we applied has serious limitations. The most serious is its susceptibility to

to distortion by human errors. Another is that it is expensive, and 'labor-intensive,' requiring a fairly large number of experienced military and nonmilitary analysts. Consequently, it reduces the sensitivity testing that could be done, using many different assumptions about the unknown parameters, if the problem could be computerized to a greater extent.

Probably the strongest merit of the methodology used in the military assistance study is that it enabled us to join military, political, and economic factors in the analysis rather than focusing on only one of these alone. In the analysis of major public policy questions, it is worth paying some price in imprecision to gain the benefits of such systems-analytical, interdisciplinary research. At the same time, however, in applying the results of such research to the task of formulating policies and programs, we should keep prominently in mind the cautionary observations of Hitch, Dorfman, and others. Specifically, we should avoid claiming more than that the research can help to illuminate the problem, and to suggest some directions of program changes that seem very likely to dominate the direction of previous policies.

B. SAVINGS AND THE MEASUREMENT OF 'SELF-HELP' IN DEVELOPING COUNTRIES

The next example I want to talk about briefly can be put in the context of the Foreign Assistance Act of 1962 which instructs the President of the United States, in providing aid for economic development, to take into account a number of criteria including "the extent to which the recipient country is...demonstrating a

a clear determination to take effective self-help measures." The emphasis that is intended to be placed on this criterion has been made clear by numerous policy statements from the Administration as well as the Congress.

If one accepts the familiar reasons for emphasizing self-help, which I won't repeat here, the question arises how the emphasis can be applied. How can a meaningful, rigorous basis be provided for assessing the performance of recipient countries with respect to this criterion? Although the problem is here set forth in the context of aid from the United States for economic development, it obviously applies as well to aid from other OECD countries which have a similar concern. A research study in which I have been engaged at RAND during the past year has attempted to provide the beginnings of an operationally useful answer to this question.[1]

The problem is, in part, one of defining what is meant by 'self-help.' But once the definitional question is answered, there remains the question of how to provide a yardstick for assessing the extent to which self-help measures are being taken in relation to what a country might be expected to do. Clearly, political, social and cultural conditions within the country will have much to do with the opportunities and constraints affecting the assessment; for this the judgment of specialists familiar with each country is essential. The problem is how to supplement such judgments with a firmer, more 'objective' basis for assessing country performance.

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[1] The study is described in greater length in Charles Wolf, Jr., Savings and the Measurement of 'Self-Help' in Developing Countries, The RAND Corporation, RM-3586-ISA, March 1963, pp. 1-47.

Without such a basis, it may be difficult and perhaps impossible to raise the level of discussion and toughen the inevitable negotiation and bargaining between the United States and recipient countries over aid allocations.

The present study describes a method for dealing with this problem. The method is general, but in this study it is applied concretely to only one possible measure of self-help: gross government and private domestic savings, an important but not necessarily the most important ingredient for sustained economic development. The method consists of deriving standards or 'norms' for individual countries from a multiple regression model that expresses some indicator of performance (in this case, savings) as a function of several indicators of socio-economic structure. The regression is fitted using cross-sectional data from a large number of less-developed countries. The resulting estimating equations can serve as indicators of expected behavior, based on the actual behavior of a large number of countries. Measures to stimulate savings by a particular country can be considered as especially effective to the extent that actual savings are significantly greater than predicted by the regression, or as ineffective to the extent that actual savings are significantly less than predicted by the regression.

For this purpose, several regression models were developed, using gross domestic savings as the principal dependent variable. Gross domestic savings are defined here as gross investment minus the deficit on current account, and minus transfers on current

account.[1] Current transfers are subtracted because they include government-to-government grant aid which in a few countries (such as Korea, Taiwan, India, and Greece) is large enough to bias savings estimates upward. The regression equations then express gross domestic savings, and in some cases average savings defined as the ratio between savings and GNP, in terms of four independent variables: GNP; GNP per capita; urbanization, measured alternatively in terms of urban income,[2] and in terms of percentage of national population living in cities of 20,000 and above; and international trade. In the case of each of these variables the rationale for its inclusion relates to its expected effect on government and/or private savings based on previous empirical work or on received theory. These reasons are discussed in the study, but I will not repeat the discussion here. Several models were tested using gross savings as the dependent variable. These gross savings models are related to two other types of models: an average savings model, using the ratio between savings and GNP as the dependent variable; and a marginal savings model, using the ratio between annual changes in savings and

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[1] According to this definition, countries which undertake to attract private foreign investment in order to finance a larger current account deficit would not be adding to savings. This is just one of the drawbacks of relying on savings as the only or primary measure of self-help.

[2] The urban income estimate assumed that all income originating in the following industrial sectors was concentrated in urban areas: manufacturing; construction; electricity, gas and water; transportation, storage, and communication; banking, insurance, and real estate; public administration and defense; that all income originating in the agricultural sector was rural; and that income originating in housing, mining, trade, and services was divided between urban and rural areas in the same proportion as that between income from the six primarily urban sectors and the latter plus agricultural income.

in GNP as the dependent variable.

Linear relations were generally assumed for each savings function except in the case of gross savings, for which a logarithmic regression was computed as well. The gross savings model is open to the criticism that the requisite assumption of homoscedasticity may be unwarranted, since the cross-sectional data used in the regressions include countries of widely varying size. Using a logarithmic regression makes the assumption of homoscedasticity more plausible, and gives equivalent weight to small and large countries in the fitted equations. Besides the logarithmic regression, there are a number of other ways in which a similar scaling effect can be accomplished. Specifically, we tested an average savings regression, as well as a model using per capita savings as a dependent variable and expressing all the independent variables on a per capita basis, for this reason.

To fit the regressions, the data used were principally derived from the United Nations, Yearbook of National Account Statistics, 1961 (New York, 1962) covering the national accounts variables for 34 less-developed countries for the period from 1955 through 1960, with some supplements to the UN data provided from statistics obtained from the Agency for International Development. Where population figures were needed, we relied on the United Nations, Statistical Yearbook, 1961, New York, 1962, and the United Nations Demographic Yearbook, 1960, New York, 1961. For the time series data for each country, the median value for each country was selected because the medians were considered likely to be a better indicator

of central tendency than the means. For such a short period, the mean would be more subject to distortion by unusual fluctuations over one or two years than the median.

In processing these data, hereafter referred to as the UN/AID data, the procedure followed was to deflate the 1955-1960 time series by a general or wholesale price index based on 1960 prices, and to convert to U.S. dollars using the 1960 exchange rates of the International Monetary Fund. It should be obvious that a number of serious reservations concerning the reliability of these data should be kept prominently in mind, though I will not explore them in detail here.

The 34 less-developed countries for which data were available from the UN/AID sources were organized in the following regional groups:

1. Latin America (10):	Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Panama, and Peru
2. Asia (9):	Burma, Ceylon, Taiwan, Malaya, India, Korea, Pakistan, Philippines, and Thailand
3. Dependencies (during all or most of the 1955-1960 period) (11):	Algeria, Barbados, British Guiana, Congo (Leopoldville), Cyprus, Jamaica, Malta, Mauritius, Nigeria, Puerto Rico, Rhodesia-Nyasaland
4. Latin America, plus Latin American dependencies (14):	All of the Latin American countries in Group 1, plus the following four from the dependencies group: Barbados, Guiana, Jamaica, Puerto Rico
5. "All countries" (UN/AID) (34):	All of the countries in Groups 1, 2, and 3 above, plus the following four: Greece, Israle, Portugal, and Sudan

To give some idea of the results, let me focus on two of the

principal models which were tested. The first is a linear gross savings model of the form:

$$S = a(Y^2/P) + b(Q) + c(U_y) + d(Y) + e \ , \qquad (1)$$

in which:

S = gross savings

Y = GNP

P = population

Q = imports plus exports plus invisible transactions on current account

U_y = urban income as designed in the text above

Except for population, all variables are expressed in 1960 U.S. dollars, converted from local currencies in current prices by the procedure already described. It might be noted that the reason for using Y^2/P is that average savings, S/Y, were presumed to depend on per capita income, Y/P; hence, gross savings depend on income squared per capita. The principal results from this savings model are summarized in Table 1 below.

The logarithmic model corresponding to equation (1) is:

$$\log S = a(\log Y^2/P) + b(\log Q) + c(\log U_y) + d(\log Y) + \log e \qquad (2)$$

The regression results from model (2) are summarized in Table 2 below.

What bearing do the statistical results shown in Tables 1 and 2 have on the original problem of helping to assess the savings of a given country? To answer this question, it is of interest to compare the actual savings data with the savings estimates, or 'norms,'

Table 1

REGRESSION RESULTS FROM SAVINGS MODEL (1) -- UN/AID DATA

Country Grouping[a]	R^2	Significance of F[b]	Regression Coefficients and Standard Errors[c] Variable: Squared Income Per Capita (Y^2/P)	International Trade (Q)	Urban Income (U_y)	GNP (Y)	Intercept
			Coefficient: a	b	c	d	e
1. "All Countries" (n=34)	.9712	< .005	-.00001 (.00001)	.016 (.055)	.161* (.026)	.047* (.010)	-15.0 (34.1)
2. Latin America (n=10)	.9561	< .005	.00004 (.00013)	.139 (.218)	-.126 (.299)	.209[d] (.157)	-70.0 (128.2)
3. Asia (n=9)	.9983	< .005	-.00090* (.00032)	.371* (.095)	.211* (.113)	.055* (.030)	-133.9* (42.8)
4. Dependencies (n=11)	.9133	< .005	-.00001 (.00001)	.251* (.051)	-.168* (.051)	.033* (.023)	6.8 (17.9)
5. Latin America plus Latin American Dependencies (n=14)	.9625	< .005	-.00002 (.00002)	.082 (.141)	-.011 (.143)	.157* (.088)	-27.7 (66.4)

Notes: All variables are in millions of 1960 U.S. dollars.

[a] The countries included in each category are shown on p. 22 above.

[b] In testing the significance of F, the degrees of freedom (d.f.) in the numerator are equal to the number of independent variables, including the intercept. The degrees of freedom in the denominator are the number of countries in the sample minus the degrees of freedom in the numerator; for example, d.f. for the "all-countries" sample is 29.

[c] Standard errors are shown in parentheses. Coefficients marked with an asterisk are significant at a 20 per cent level for a two-tailed test. Where the sign of the regression coefficient is positive, the regression coefficient can be considered significant at a 10 per cent level, as explained in RM-3586, op. cit., p. 27. The significance of the coefficients was tested by the t-distribution, with degrees of freedom equal to the number of countries in the sample minus the number of independent variables (including the intercept); for example, d.f. for the Latin America sample is 5.

[d] This coefficient is just below the borderline of significance.

Table 2

REGRESSION RESULTS FROM LOGARITHMIC SAVINGS MODEL (4) -- UN/AID DATA

Country Grouping[a]	R^2	Significance of F[b]	Regression Coefficients and Standard Errors[c]				
			Variable:	Log Squared Income Per Capita ($\log Y^2/P$)	Log International Trade ($\log Q$)	Log Urban Income ($\log U_y$)	Log GNP ($\log Y$)	Intercept
			Coefficients:	a	b	c	d	e
1. "All Countries" (n=34)	.9296	< .005		-.015 (.093)	.334* (.180)	.420* (.264)	.408* (.221)	-.551
2. Latin America (n=10)	.9617	< .005		-.541 (.414)	.211 (.759)	.005 (1.449)	1.524 (1.253)	-.106
3. Asia (n=9)	.9465	< .01		-.593* (.354)	1.058* (.335)	.663 (.703)	.245 (.672)	-.275
4. Dependencies (n=11)	.9490	< .005		.100 (.097)	.771 (.504)	.124 (.463)	.387 (.326)	-.404
5. Latin America plus Latin American Dependencies (n=14)	.9678	< .005		-.333 (.186)	.482 (.571)	.346 (.651)	.679 (.551)	-.316

Notes: Antilogs of all variables are in millions of 1960 U.S. dollars.

[a] The countries included in each category are shown on p. 22 above.

[b] In testing the significance of F, the degrees of freedom (d.f.) in the numerator are equal to the number of independent variables, including the intercept. The degrees of freedom in the denominator are the number of countries in the sample minus the degrees of freedom in the numerator; for example, d.f. for the "all-countries" sample is 29.

[c] Standard errors are shown in parentheses. Coefficients marked with an asterisk are significant at a 20 per cent level for a two-tailed test. Where the sign of the regression coefficient is positive, the regression coefficient can be considered significant at a 10 per cent level, as explained in RM-3586, op. cit., p. 27. The significance of the coefficients was tested by the t-distribution, with degrees of freedom equal to the number of countries in the sample minus the number of independent variables (including the intercept); for example, d.f. for the Latin America sample is 5.

established by the regression models. In the exploratory work done so far, these comparisons have been made in selected cases, but not for all combinations of models, and country groupings. However, some interesting points stand out from the comparisons that have already been made of the regressions summarized in Tables 1 and 2.

Notwithstanding the fact that the aggregate results for F and R^2 are highly significant for nearly all of the regressions previously discussed, 'predicted' savings for a given country are often quite different, depending on which estimating equation is used. This difficulty sometimes occurs when a particular savings model is applied to different country groupings, and sometimes when different savings models are applied to the same country grouping.

As an example of the first difficulty, for the linear gross savings model (1), Colombia's predicted savings turn out to be less than actual savings by $243 million according to the 'all-countries' regression, but by only $44 million according to the Latin American regression; for the Philippines, predicted savings are $174 million more than actual savings according to the 'all-countries' regression, but only $28 million more according to the Asian regression. In the case of Brazil, predicted savings are $44 million less than actual savings according to the 'all-countries' regression, but are $69 million more than actual savings according to the Latin American regression.

This problem is compounded by the second difficulty: different savings models may yield appreciably different 'norms' when applied to the same country grouping. The difference is illustrated, for

example, by comparing savings as predicted by the linear savings model (1) with the savings predictions of the logarithmic model (2). Table 3 shows this comparison for the 'all-countries' regression. As would be expected, the contrast shows up most strikingly for the large countries; for example, compare the residuals in Columns (C) and (E) for Argentina, Brazil, Mexico, and India.

These difficulties raise a serious problem for the method advanced here. A given country may turn out to be a high or low performer simply depending on which savings model is used.

A possible solution to the problem, however, is suggested by looking not at the absolute amount or sign of the residual, but by comparing each residual with the standard error of the corresponding regression. This is done in the comparison of residuals for the linear and logarithmic regressions of Table 3; country residuals which are significant, in the sense that they are more or less than would be covered by one standard error of the corresponding regression, are marked with an asterisk, as explained in the footnote to the table.

Looking at the significance of residuals in this sense, rather than their absolute amounts, suggests two important points: (a) only a relatively small number of countries turn out to be high or low performers in either regression; most country residuals fall within one standard error; (b) the countries that appear to be significantly high or low performers correspond almost exactly as between the linear and logarithmic models for the 'all-countries' grouping. Countries that appear as significantly high savers in both regressions are Argentina, Colombia, and Peru; the significantly low

Table 3

COMPARISON OF ACTUAL AND PREDICTED SAVINGS, LINEAR AND LOGARITHMIC SAVINGS MODELS -- "ALL-COUNTRIES" REGRESSIONS (UN/AID DATA)

(in millions of 1960 U.S. dollars)

Countries	(A) Actual Savings (1955-60 median)	(B) Savings Predicted by Linear Savings Model (1)	(C) Linear Savings Residual (A-B)	(D) Savings Predicted by Logarithmic Savings Model (4)	(E) Logarithmic Savings Residual (A-D)
1. Latin America					
Argentina	1,696.35	1,471.16	225.19*	1,050.30	646.05*
Brazil	1,607.80	1,563.59	44.21	1,155.10	452.70
Chile	328.51	668.49	-339.98*	492.88	-164.37*
Colombia	643.70	400.34	243.36*	368.72	274.99*
Costa Rica	55.62	31.76	23.86	41.38	14.24
Ecuador	100.28	73.81	26.47	79.76	20.52
Honduras	38.27	20.43	17.84	33.19	50.80
Mexico	1,550.80	1,588.40	-37.60	1,312.20	238.60
Panama	20.56	33.95	-13.39	46.25	-25.70*
Peru	382.27	256.35	125.92*	255.01	127.26*
2. Asia					
Burma	193.49	121.37	72.12	146.07	47.42
Ceylon	118.64	123.20	4.56	156.38	-37.74
India	3,188.00	3,193.43	-5.43	2,843.10	344.90
Korea	70.49	196.51	-126.02*	168.86	-98.37*
Malaya	283.14	173.08	110.07	215.90	67.25
Pakistan	525.36	563.48	-38.12	496.94	28.42
Philippines	267.27	441.35	-174.08*	395.05	-127.78*
Taiwan	139.82	175.09	-35.27	158.03	-18.21
Thailand	300.51	235.42	65.09	250.23	50.28

(continued)

Table 3 (continued)

Countries	(A) Actual Savings (1955-60 median)	(B) Savings Predicted by Linear Savings Model (1)	(C) Linear Savings Residual (A-B)	(D) Savings Predicted by Logarithmic Savings Model (4)	(E) Logarithmic Savings Residual (A-D)
3. Dependencies					
Algeria	151.17	410.79	-259.62*	398.60	-274.43*
Barbados	9.79	-5.45	15.24	9.33	.46
British Guiana	21.31	7.14	14.17	21.14	1.76
Congo (Leopoldville)	180.07	178.85	1.22	232.59	-52.52
Cyprus	40.95	25.28	15.66	37.67	3.28
Jamaica	101.63	89.43	12.20	90.46	11.17
Malta	21.91	3.33	18.58	17.35	4.57
Mauritius	26.12	7.27	18.85	21.01	5.10
Nigeria	230.35	200.43	29.92	224.63	5.72
Puerto Rico	154.69	143.60	11.09	198.01	-43.32
Rhodesia-Nyasaland	299.05	190.02	109.04	231.68	67.38
4. Others					
Greece	320.37	387.79	-67.41	336.96	-16.59
Israel	277.56	344.36	-66.80	256.82	20.74
Portugal	260.23	316.15	-55.92	333.90	-73.67
Sudan	87.54	63.43	24.11	81.24	6.31

Note:

An asterisk indicates that the residual is significant in the sense that it is more or less than would be covered by the standard error of the regression estimate. For the linear regression, the standard error was $119 million. In the logarithmic case, the standard error has a different meaning. It represents the average deviation from the regression of the proportion: actual savings/estimated savings. Significance of the residual does not depend on the absolute amount of the residual, but on the ratio between a country's actual and estimated savings. The antilog of the log standard error for model (4), all countries, was 1.475, which implies that for a residual to be more or less than would be covered by one standard error, the ratio of actual to estimated savings must be above 1.475 or below .678, respectively.

savers in both regressions are Chile, Korea, the Philippines, and Algeria.[1] Panama appears to be a significantly low saver according to the logarithmic model, but not according to the linear model.

Clearly, additional work is needed along these lines. For example, preliminary examination suggests that there may be more variation in the significantly high and low residuals as between different regional groupings for a given model than between the different regression models for the same region; this possibility should be explored further. Moreover, the effect on country residuals of adding new variables or subtracting the apparently insignificant variables from the present models also needs exploration. Reviewing and improving the sorts of data we have used would also be highly desirable. In at least one case of an apparently high saver, Argentina, I suspect that the results may be due more to inadequate allowance in the data for the effects of inflation than to the actual volume of real savings. Besides work to improve the data, it would also be desirable to perform a number of non-parametric tests on the present regressions.

A number of other important caveats should be borne in mind in considering the method we have described. One of these arises from

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[1] The fact that Algeria turns out to be a significantly low saver for the 1955-1960 period, according to both regressio , provides a clear illustration that factors that may have an important influence on savings are left out of the models in particular cases. In the Algerian case, low savings are probably attributable to a major political factor -- intense civil strife.

a previously noted difficulty: the 'norms' which result from this approach may vary appreciably depending on which model and which country grouping is used. A particular country may be a significantly high saver according to one model or one grouping, but not according to another. Unless a consistent pattern emerges, the decisionmaker may be faced with conflicting results. Even if a consistent pattern does emerge, the equations can still only claim statistical reliability, which means that they would make mistakes in individual cases. That these problems may arise with respect to savings, as one indicator of self-help, becomes still more discouraging when we realize that they may also apply to other measures of self-help, as well as to other considerations that enter into aid decisions quite apart from self-help. At the least, however, the exploratory approach we have suggested may provide a way of mobilizing objective, quantitative information to help the decisionmaker take these matters explicitly into account. It can also help in establishing some firmer rules of the foreign aid 'game' than have perhaps typically been applied, rules that can provide an incentive for the developing countries to perform effectively, in contrast to the perverse incentives that have sometimes prevailed in the past.

III

As the examples discussed in Section II suggest, numerous qualifications and reservations usually need to be attached to such efforts to apply OR to the major economic and military-economic problems of the less-developed countries. Moreover, the necessary reservations tend to be more serious the higher the level of

optimization of the problem under examination. This perverse circumstance makes unwarranted the more optimistic claims and expectations that have been advanced in behalf of applying OR to the problems of developing countries.

Nevertheless, granting these limitations, if one considers present decisionmaking practices with respect to these problems, it seems manifestly clear that quantitative analytical techniques can make a number of important contributions to improved decision-making: raising and tightening the level of discussion preceding decisions; uncovering and clarifying the alternative choices that are available; and focusing conscious attention on the policy 'values' or preferences that are implicit in a particular choice by making explicit the foregone benefits associated with the available alternatives.