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Preface

The *Population Bulletin of the United Nations* presents brief articles relating to population which, by their nature, do not require separate publication. Material for the *Bulletin* is selected in the light of the interests and needs of Governments, international organizations, research institutions and individuals engaged in social and economic research, as well as the public interested in population.

The first seven issues of the *Population Bulletin* were prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat between 1951 and 1963. The *Bulletin* has now been reinstated as a United Nations publication in accordance with the endorsement and recommendation of the Population Commission at its eighteenth session, and, as in the past, it will be prepared by the Population Division.

It is expected that most of the articles to be published in future issues of the *Bulletin* will be prepared by the United Nations Secretariat in pursuance of the programme of work recommended by the Economic and Social Council and the Population Commission. Studies by consultants and reports of meetings organized by the United Nations, or excerpts from such studies and reports, may also be included. In addition, contributions will be solicited from the specialized agencies of the United Nations, the secretariats of the regional commissions and scholars.

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EXPLANATORY NOTES

The following symbols have been used in the tables throughout the report:

Three dots (. . .) indicate that data are not available or are not separately reported

A dash (—) indicates that the amount is nil or negligible

A blank in a table indicates that the item is not applicable

A minus sign (–) indicates a deficit or decrease, except as indicated

A full stop (.) is used to indicate decimals

A slash (/) indicates a crop year or financial year, e.g., 1970/71

Use of a hyphen (-) between dates representing years, e.g., 1971-1973, signifies the full period involved, including the beginning and end years.

Reference to "tons" indicates metric tons, and to "dollars" ($) United States dollars unless otherwise stated.

Details and percentages in tables do not necessarily add to totals, because of rounding.

THE RELATIONSHIP BETWEEN DEMOGRAPHIC AND SOCIO-ECONOMIC FACTORS IN THE CONTEXT OF DEVELOPMENT

*Marcel Y. Fabri**

Part One

INTRODUCTION

The following is a report of a quantitative study of the relationship between population and socio-economic factors which aims to identify and characterize this relationship in the context of development.

During the past decade, this issue has become one of the major preoccupations of those who are responsible for devising programmes to raise economic levels and improve social conditions in developing countries. It is thus not surprising that governmental and non-governmental bodies have repeatedly expressed concern regarding the need for a better understanding of these interrelationships. The importance of the problem was further emphasized at the World Population Conference, at Bucharest, where the debate on issues of population policies emerged between countries at different stages of development. It may be suggested that the controversy mainly arose from gaps in scientific knowledge concerning the reciprocal effects of population factors and development and that it principally affects countries undergoing a process of development.

At the level of development policy, an improved understanding of the phenomenon should help to mitigate the classical opposition between development strategies oriented to population limitation and those oriented to the growth of socio-economic factors. In general, a sound understanding of the mechanisms of the interplay of population and development is a necessary prerequisite to intervention.

However, research in the area has thus far been rather disappointing. In the past decade, a considerable number of reliable demographic development studies have attempted to infer the existence of such a relationship. In general, though, the investigations have led to contradictory conclusions or to no conclusions at all.[1] Most cross-sectional studies showed little evidence of a sustained relationship between population growth and growth of *per capita* product. Whether negative or positive, the correlations tend to be very weak.

It is of interest to assess briefly how these studies resemble or differ from one another methodologically. In this way, it will be possible to formulate a new approach to the problem, which benefits from past attempts and perhaps reconciles previous divergent results.

One possible cause for difference in conclusions is the diversity of sources from which data were selected. However, it is highly unlikely that sources in discordance could be held responsible for contradictory results. Differences observed between data sources tend to be of orders of magnitude; on the whole, they preserve internal consistency, and allow comparison between distributions from various sources.

A common feature of the investigations is their dependence on a comparison of population with some form of *per capita* product. The latter is taken as the indicator of development, despite the limitations of any single index in depicting the whole of economic development. Besides, one may question the validity of results drawn from comparisons between a very limited number of factors, taken out of their context. As Easterlin himself has observed, "the true relationship may be obscured in a simple two-variable comparison".[2]

Moreover, the comparison is usually between rates of growth of population and measures of economic development which might mask the real impact of the factors on each other. Because of their complexity, the use of growth rates compounds the problem of analysing their contingent relationship.

Another common feature of research in this area is the broad difference between samples of countries included in the analysis. This is clearly what Easterlin suggested in commenting that "indeed, it may well be that no single generalization is appropriate for countries differing as widely in growth rates, densities and income levels as do those areas".[3] The sampling composition may very well be

* Population Division of the Department of Economic and Social Affairs, United Nations Secretariat.

[1] Cf. Richard Easterlin, "Effects of population growth in the economic development of developing countries", *Annals of the American Academy of Political and Social Science*, vol. 369 (January 1967) pp. 98–108; Simon Kuznets, "Demographic aspects of modern economic grwoth". United Nations World Population Conference, September 1965; "Population and economic growth", *Proceedings of the American Philosophical Society*, vol. 111, No. 3 (1967), pp. 170–193; Anthony P. Thirwall, "A cross section study of population growth and the growth of output and per capita income in a production function framework", *Manchester School*, vol. 40 (December 1972), pp. 339–356; M. Stockwell, "Some observations on the relationship between population growth and economic development during the 1960's", *Rural Sociology*, vol. 37 (December 1972), pp. 628–632; J. C. Chesnais et A. Sauvy, "Progrès économique et accroissement de la population, une expérience commentée", *Population*, vol. 28 (juillet–octobre 1973), pp. 843–857.

[2] R. Easterlin, *op.cit.*, p. 98.

[3] R. Easterlin, *op.cit.*, p. 107.

one of the major reasons why so many studies have yielded contradictory results.

One should also add that these studies were not designed as a direct contribution to the field of operation but mainly with the purpose of clarifying a theoretical point. Possible applications were thus a remote by-product, mostly foreign to the initial purpose of this endeavour.

There are alternative ways in which the relationship of population to social and economic development can be analysed; one that appears quite effective is presented here in some detail.

An important innovation is that policy relevance has been a major and explicit concern in the research design. If some action guideline is to be derived for either planning or for project implementation, it must rely on a better understanding of how demography and development are linked, of what are the significant relationships between them, and of which are the key variables involved in the process. For example, one may wish to influence demographic factors in order to improve the socio-economic conditions of populations. However, any such policy is justifiable only to the extent that, through a direct link, a given input will produce the expected output. When, on the contrary, results become erratic and induce unanticipated events, there is a serious risk of loss of time and financial resources. Here, the assumption is that demographic and socio-economic factors do not interact in isolation but instead as part of a network of relations. In such an approach, the basic concept of structure can be viewed as the pattern of factors in their mutual relationship. This approach requires consideration of a much larger number of variables than was typical of previous studies. In general, it appears to better fit the experience of a country in the process of development.

Another departure from previous practice concerns the way in which growth is treated here. This study is based on observations of various structural states at points in time. Proceedings through a series of static assessments provides a better estimation of global change than would analysis of growth rates. The latter approach tends to focus mostly on the evolution of individual factors. As a ratio involving only the initial and final terms of a time interval, the growth rate imparts a spurious dynamism to the analysis in the sense that it suggests implict projections into the future. Finally, examination of complex growth rates does not readily lend itself to the detection of relationships.[4]

[4] A more realistic approach would be to assume that relationships between variables are not instantaneous but instead take place after a certain delay. This time span would also vary according to interrelating factors. However, any methodology based on this hypothesis requires, first of all, a theoretical model of the lag distribution among variables involved and such a model is not available given the present state of knowledge. In the absence of any such model, lags would have to be determined arbitrarily and that would provide no advantage over the assumption of simultaneously interacting variables. These remarks do not however preclude the possibility of building such a model, if reliable time series were available. It is likely that a stochastic model could be derived from the analysis of cross-lagged correlations between paired variables, in conjunction with a tentative model based on simultaneous relations.

Finally, a basic and not unreasonable hypothesis is that, with respect to a diversity of contexts, countries are at various stages of development, without inferring the existence of a unilateral process from one stage to the next. There may be alterations of structures, according to time and place, so that there is no unique pattern to be found for all countries or periods. If this is so, it would be justifiable, first, to attempt to group countries in accordance with their structural affinities and, secondly, to investigate within these more homogeneous sets of countries the specific networks of relationship between factors, relative to a given period of time. To the extent that these structural differences can be discovered, interventions into any aspect of the relationship between population and development can be made more specific and therefore more effective.

The report on this research is divided into two parts: the first, which appears in this issue of the Population Bulletin, consists of an identification, through an objective classification, of groups of countries with structural affinities. The classification is based on a summary measure of the demographic and socio-economic structure of a country, constructed from a set of specific variables. In addition, countries have been ranked according to particular demographic, economic and "modernization" substructures.

The second part, which will be presented in a subsequent issue of the Population Bulletin, focuses on the identification and analysis within the groups of countries of the structure and direction of the relationships between demographic and socio-economic factors.

Methodology

The methodology employed consists of two distinct parts. One delineates a framework for the study and the other adapts procedures of analysis to the objectives of the research in consistency with the defined framework.

Framework of the study

An explicit conceptual framework is necessary for an effective analysis; this in turn calls for a full set of definitions. In this case, a basic conceptualization is given to socio-economic development. Other definitions and interpretations will follow by implication.

Considering its formal aspect, Sheldon White remarks that "[development] arises wherever and whenever we find an organization that retains its integrity as an organization—that is called by the same name and persists in the same function—even as it undergoes modification".[5] At this level of conceptualization, development is viewed as a continuous process of structural change which involves some essential permanency even while it is taking place through time.

When taken through its successive alterations, the structure is identified as a system. A system is thus an

[5] Sheldon H. White, "Developmental psychology and Vico's concept of universal history", *Social Research*, vol. 43, No. 4 (1976), p. 663.

entity, while development is the process of its internal transformation. When the process of structural change is disrupted in such a way that a new system emerges, this break in development is viewed as a "mutation". Change in a structure takes place when there are quantitative or qualitative variations in its components which modify the pattern of their relationships.

This definition obtains for all types of evolving structures, including socio-economic structures.

There is, however, no general agreement about this definition with regard to the specific case of economic development. Most economists, for whom the final objective is the creation of wealth and its distribution disregard the distinction between economic development and economic growth.[6] The concept of generalized growth of socio-economic factors, as opposed to structural change, has tended to prevail in United Nations strategies for development, despite an emerging new orientation which emphasizes social well-being.

This study centres upon structures and the evolution of structures. As an additional feature, socio-economic development, whether directed or not, is regarded as a process of structural improvement. The socio-economic development is therefore characterized by its consequences.

A formal definition of development is necessary for the selection of analytic procedures; it is also necessary in order to identify the essential set of variables and their appropriate indices.

A condition of international comparison is that it be based on a universal category. It may be that socio-economic development is characteristic of any culture in space and time. However, socio-economic development is postulated here to be essentially an occidental phenomenon, which has no intrinsic equivalent in past and present civilizations outside of the Western world. Since each culture creates its own categories, it follows that socio-economic factors were originally specific to the group of industrialized countries. In the course of historical experience socio-economic categories have been grafted, with various degrees of local recognition, on to diversified cultural backgrounds. They have thus come to represent what various cultures have in common with the West. Elements of the socio-economic system that typifies the developed countries have come to permeate the developing countries as well. In the developing countries they coexist with elements of a traditional system (or an already transitional version of it). Whatever the nature of the society, these elements are assumed to perform the same function in terms of development as in their original context. Of course, it may be expected that some of these structures will be poorly articulated, depending on the place and time. Nevertheless, from a broad international perspective the socio-economic system of the developed countries represents a single category which is assumed to have world-wide validity and to follow the same patterns as in industrialized countries. Therefore, the performance of the socio-economic system is seen as an indication of how various countries are coping with development.

Countries may be compared with reference to their differences or similarities. Emphasis on comparative differences leads to a qualitative analysis; a quantitative approach requires that the terms of a comparison be the same. In the case of the research discussed here, the need for objective procedures within the defined framework justifies the choice of a quantitative approach. It will become evident that the use of a single category of variables satisfies the conditions set for both a comparative and a quantitative approach.

A basic working hypothesis is that a set of demographic factors, having a common structural basis all over the world, may be similarly related to socio-economic development.

This hypothesis justifies and helps identify appropriate variables for the analysis. For practical reasons, chiefly time constraints, many of the indicators chosen are similar to those used in other research in this area. It is commonly acknowledged that inaccurate data necessarily lead to indecisive results, whatever the level of statistical sophistication. Nevertheless, although there is undeniable lack of accuracy in most of the available data, this should not undermine the over-all validity of the results. Use of indicators, instead of direct measures, denotes a different approach to the formulation of the problem. The indicator should be taken literally as a quantified indication about a phenomenon, the order of magnitude of which is of little meaning when considered in isolation. However, it can provide valuable information when considered in the context of a system of many variables, which together characterize a society as a whole. In addition, this study, like most of those based on indicators, is primarily concerned with relations and therefore with relative orders of magnitude for comparison rather than with the assessment of levels as such. Furthermore, by increasing both the number of countries and the number of indicators, the risk arising from use of one country or a few deficient data is reduced.

Finally, instead of selecting a sample from the universe of countries, the procedure has been reversed: countries

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[6] Economists generally regard economic development and/or economic growth, either explicitly or implicitly, as a rise in product *per capita.* Cf. Easterlin, "Population growth and economic development" in *The Annals* (January 1967), who considers economic development as a part of the general phenomenon of "modernization"; Kuznets, "Demographic aspects of modern economic growth", *loc.cit.;* and *Modern Economic Growth* (New Haven, Yale University Press, 1966), for whom "the high rate of aggregate growth was accompanied by marked and rapid structural shifts" (p. 6). The structure referred to is of an institutional nature, related to the concept of development formulated by Schumpeter in *The Theory of Economic Development* (New York, Oxford University Press, 1934), who defines it as "the carrying out of new combinations—new goods, new methods of production, opening of new markets, . . . carrying of new organization" (p. 66). Others draw a distinction between underdeveloped "economies of development" and "economies of growth". The difference, however, appears to be one of setting and not of process. See, for example, O. Hirshman, *The Strategy of Economic Development* (New Haven, Yale University Press, 1958); "Obstacle to development: a classification and a quasi-vanishing act", *Economic Development and Cultural Change* (July 1965); and Joan Robinson, *Freedom and Necessity* (London, Allen and Unwin, 1970).

Even C. Furtado, in *Development and Underdevelopment* (Berkeley and Los Angeles, University of California Press, 1964), who refers explicitly to development as a structural process, tends to rejoin Schumpeter and Kuznets' view in noting (p. 61) what "the development process involves either new combinations of existing factors at a given technical level or the introduction of technical innovations".

were eliminated from this universe according to various criteria. This step was necessitated by some practical considerations. One was the need to base the analysis on countries for which measures for all indices were available. Another major consideration was the wish to avoid introducing anomalies arising from countries with highly atypical conditions. Under the circumstances, criteria used to delete countries are: (*a*) circumstances which prevent any kind of assessment; (*b*) large windfall profits or losses, which have affected a country's economic performance but which cannot be related in a meaningful way to its economic development infrastructure (e.g., windfall profits of oil countries); and (*c*) markedly atypical development, as in Puerto Rico. The total number of countries which could be considered by the study is 99, of which 74 are usually considered developing and 25 developed countries.[7] All 99 are market economies. The dichotomy is maintained throughout for analytical purposes and is confirmed by the results.

A set of 43 variables is used. They are grouped in three broad categories: 17 refer to demographic characteristics; 13 to economic ones; and 13 others to what may be labelled the socio-modernization substructure. Three years have been selected for examination, 1960, 1965 and 1970, so that change can be investigated over an entire decade.[8]

Operational methods

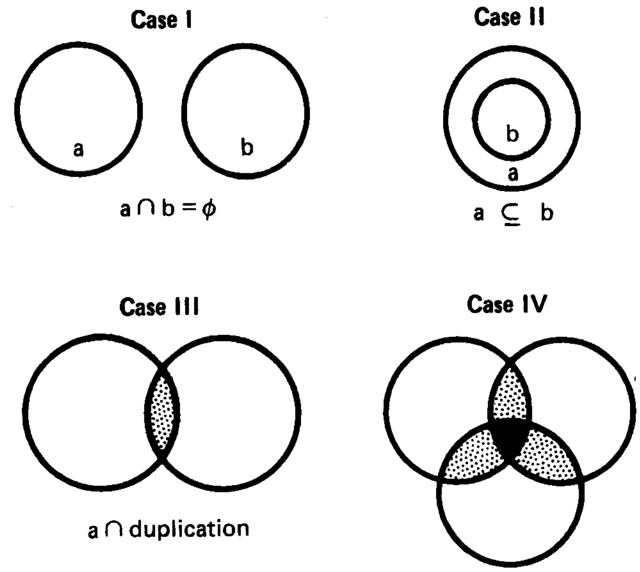
(*a*) The I-distance method, developed by B. Ivanovic for the United Nations Conference on Trade and Development[9], has been selected as the most adequate among the various taxonomic schemes available. Its application permits classification of countries according to their structure as measured by the set of indicators.

In practice, the distances are viewed as the difference between the respective indicators relative to each country and their minimal value, taken as the origin of the classification. In order to render their dispersion uniform, the differences are standardized. The sum of these differences is taken as the discrimination effect between countries and, given a corrective procedure to eliminate redundant information, synthesizes a structure of indicators which denotes level of development. Formal notation for a given country is the following:

$$D_I = \sum_{i=1}^{43} \frac{x_i - x_i^*}{\sigma_i} \prod_{j=1}^{i-1} (1 - r_{ji}, 12 \dots j-1)$$

The first term on the right shows the difference for a given variable (X_i) in a given country (I) from the minimum value for the variable observed in any country (X_i^*). The sum is over-all 43 indicators ($i = 1, 2, \dots 43$).

The second term shows the procedure for the elimination of redundant information. The concept may be demonstrated in the following diagrams in which the



amount of information in a variable is presented by an area.

Whenever indicators are added in a sequential process, the following cases relative to two variables may arise:

Case I: The two variables are completely independent and each one accounts for its original information input.

Case II: Instead, one may find that the information provided by a new variable is already strictly included in the contribution made by the first one. In other words, the two variables are so closely correlated that by knowing just one of them it is possible to completely determine the other. This means that the new variable does not bring any new information and is, therefore, redundant.

Case III: The more general case, however, is one of partial co-determination of the variables, where only part of the information supplied by the new indicator is already contained in the first one. Under the circumstances, there is genuine new information in the second variable.

Duplication of information is denoted through the simple correlation between two variables, so that if only the genuine contribution is to be retained, the new indicator has to be multiplied by the complement of the correlation, i.e. $(1 - r)$.

When more than two indicators are introduced sequentially in the system, one must take into account the operations already performed. Any new indicator could be related with the net amount of information already obtained (Case IV). In this case, partial correlation coefficients account for the multiple inclusion of information by denoting the association between two variables, given that which has already been taken into consideration.[10] The process follows its course until any

[7] The partition is arbitrary but generally agreed upon.

[8] For the list of countries, see table 1. The list of variables is given as annex I.

[9] Problème de l'identification des pays les moins avancés parmi les pays en voie de développement", United Nations Conference on Trade and Development, Research Division, Research memorandum No. 41, (Geneva, November 1970).

[10] The second term of the relation comes as

$$\prod_{j=1}^{i-1} (1 - r_{ji, 12 \dots j-1}) = (1 - r_{1i})(1 - r_{2i \cdot 1}) \dots (1 - r_{i-1, i \cdot 12 \dots i-2})$$

All the indicators were given the same direction, so that the partial correlation coefficients cannot be negative:

$$(r_{ji \cdot 12 \dots j-1}) \geqq 0.$$

new variable fails to contribute additional information to the system. The system being described by the variables it includes is then considered to be a "closed" system. It follows that the structure may be fully described with only a few variables, which condense the information of the whole set of variables. This is so in the investigation presented here, for example, in the case of the demographic structure in which all the information of the 16 indicators is entirely included in eight variables.

The procedure implies an order of intake of the variables. It is determined through an iterative process of trial and error, on the base of the highest degree of dependency between a variable and the level of development, as figured by the I-distance itself. The procedure starts with any sort of order to compute a tentative I-distance. Variables are then reordered following the level of their correlation with the provisional index. This is then recomputed accordingly. It is therefore through successive approximations that the final order is obtained.

The final product is a single indicator for each country, accounting for its level of development, through the synthesis of a set of indicators. This allows, therefore, a simple classification of the countries along a single dimension.

Through the application of the I-distance method, it is possible to generate a method to measure clustering. Instead of considering the distance from each country to a minimal value of origin, the procedure introduces sequentially a shift in origin, so that each country becomes alternately the origin. It is then possible to compute the distances between countries, which measures their mutual affinity, on an interval scale. Clusters can be built up by stages by widening the range in which countries are associated with each other, either one by one, or by having single countries uniting with previously formed groups or by merger of groups. The whole process can then be viewed as a progressive clustering of countries, along widening distances, which can be visually expressed as a tree-diagram. This is illustrated in figure I, where the distance hierarchy is shown along a scale at the top of the graph, and the corresponding distances between countries or groups of countries are represented by thick lines, joining two or more countries.

Results

The results presented here concern the classification and partition of countries obtained through the application of the I-distance method. The study on causal analysis is currently under progress.

The classification

Tables 1 and 2 present the classification of developing and developed countries respectively. For each reference year (1960, 1965 and 1970) the tables consist of country lists which have been ranked according to four types of structures: demographic structure (B), economic structure (C), "modernization" structure (D) and finally the structure that is based on all three sets of specific factors (A). (See annex I for the definition of variables.)

These classifications require substantial qualification. They rely on observed distances between factors, with no possibility of identifying all the causes which underlie the ranking. Actually, different causes may produce similar effects and lead to misinterpretation. For example, Chad and Ivory Coast occupy neighbouring positions in the ranking based on demographic factors. This will seem surprising to those who know that Ivory Coast has developed at a more rapid pace than did Chad during the 1960s. In this instance it seems that fertility factors have determined the respective ranks assigned to these countries. Ivory Coast's gross reproduction rate is 3.05, which is similar to most tropical African countries. In contrast, the reported level of fertility in Chad is the lowest in black Africa (GRR = 2.60) and is more akin to countries at more advanced levels of development. This, however, does not appear to reflect the incidence of family planning programmes or any upsurge in economic development which might both have influenced fertility trends. Fertility is relatively low in Chad because poor morbidity conditions limit the number of live births. Thus, what superficially appears as progress in terms of relative ranking is in fact an additional obstacle to development.

Similarly, mortality must be considered cautiously, so that ambiguous conclusions are avoided. For instance, no general conclusion about socio-economic attainment could be derived from the observation that mortality levels are low. A mortality decline by no means suffices to reflect the general development of a country, because it often results from external factors, rather than from improved socio-economic conditions. For many developing countries, much of the early decline of mortality has been due to intensive and unilateral interventions of public health services, particularly to anti-malarial campaigns.

When examining classifications according to specific criteria, namely demographic (B), economic (C) and modernization (D), one would expect to find a similar ranking pattern in all three hierarchies. A position taken by a given country in the general classification (A) should correspond to equivalent rankings in the particular classifications, if there exists a strong association between the three groups of factors. However, this is not the case. An internal discrepancy between structural rankings relative to single countries is emphatically illustrated by Sri Lanka, which in 1960 takes the fourth position with respect to demographic factors but ranks thirty-seventh for economic structure. This pattern is broadly sustained from one year to another. Similar discrepancies are also shared by Algeria, Mexico and Burma.

Single observations, however, may be thought to reflect exceptional conditions, which on the whole would not affect a general pattern of association between the three substructures envisaged here. This is actually not the case, as is evident when possible interstructural connections are investigated across all countries, using Kendall's rank correlation between classification B and C, B and D or C and D. The resulting coefficients for 1960 and 1970 are presented in table 3.

TABLE 1. DEVELOPING COUNTRIES: CLASSIFICATION BY RANK, 1960, 1965 AND 1970

(A—All factors, B—Demographic factors, C—Economic factors, D—Modernization factors)

	1960				*1965*				*1970*			
Countries	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
Jamaica	1	1	2	6	1	1	1	1	5	6	2	13
Panama	2	2	3	2	2	2	2	9	2	4	1	7
Chile	3	5	4	4	3	6	4	5	1	1	9	4
Guyana	4	3	6	20	5	7	7	14	9	9	6	25
Sri Lanka	5	4	37	21	8	3	39	19	11	5	45	24
Brazil	6	8	9	1	7	8	16	2	8	10	11	1
Lebanon	7	9	1	3	9	10	3	3	7	11	3	2
Costa Rica	8	7	7	14	4	4	6	13	6	7	5	9
Mauritius	9	6	13	15	6	5	9	21	3	2	20	17
Mexico	10	10	5	5	10	9	5	4	12	14	4	3
Colombia	11	12	12	9	11	11	15	15	13	13	18	15
Paraguay	12	11	32	16	13	13	30	8	15	15	38	5
Republic of Korea	13	13	36	17	12	12	35	10	4	3	12	10
Philippines	14	14	33	22	20	20	28	6	25	31	35	6
Turkey	15	16	27	8	17	18	26	12	18	19	29	12
Malaysia	16	17	20	19	16	15	18	18	17	16	17	21
Ecuador	17	15	29	31	14	14	29	27	23	20	27	20
Egypt	18	19	34	7	18	19	32	7	14	12	33	8
Dominican Republic	19	18	10	35	19	17	20	22	26	33	19	23
Syrian Arab Republic	20	20	17	11	21	21	24	17	21	23	22	14
Peru	21	22	25	10	15	16	11	11	16	17	23	11
Tunisia	22	21	23	28	24	24	21	36	19	18	14	33
Nicaragua	23	23	18	30	29	32	8	20	34	41	15	18
Algeria	24	31	8	13	28	26	23	45	30	37	10	38
Jordan	25	29	14	12	26	29	13	16	24	26	24	16
Gabon	26	24	19	55	33	35	14	30	10	8	7	26
El Salvador	27	25	22	12	22	22	12	24	28	28	31	31
Iraq	28	28	15	23	23	23	19	23	20	22	16	27
Guatemala	29	26	11	40	25	25	10	35	29	29	28	41
Bolivia	30	27	29	47	31	30	37	26	27	27	37	19
Iran	31	33	16	29	27	27	17	28	22	25	8	22
Morocco	32	34	30	18	30	28	34	33	36	36	36	37
Thailand	33	30	46	34	32	31	42	31	38	39	40	28
Haiti	34	32	48	61	37	33	49	63	32	21	62	69
Congo	35	38	21	52	36	39	25	46	31	32	26	39
Indonesia	36	35	63	51	39	37	66	49	42	35	68	50
India	37	37	52	27	35	38	51	25	35	30	60	35
Senegal	38	39	24	26	51	56	33	43	51	53	42	45
Burma	39	36	59	59	38	36	61	37	33	24	63	46
Honduras	40	42	28	48	34	34	27	40	41	45	21	36
Uganda	41	40	60	37	43	41	56	44	44	44	54	40
Sudan	42	41	50	46	42	40	52	56	50	46	58	53
United Republic of Cameroon	43	43	40	44	46	47	41	47	39	38	41	48
Liberia	44	45	35	39	44	45	38	50	37	34	25	51
Zambia	45	47	26	24	40	43	22	29	44	50	13	32
Mauritania	46	44	43	60	45	44	47	65	40	40	32	60
Kenya	47	46	45	25	41	42	45	32	55	62	43	29
Gambia	48	49	47	43	56	57	46	42	43	42	39	30
Somalia	49	48	54	68	48	46	50	69	54	54	46	68
Zaire	50	50	42	65	47	48	43	64	46	47	34	62
Sierra Leone	51	52	41	57	50	50	40	53	49	48	48	56
Afghanistan	52	51	62	56	49	49	44	61	53	51	64	65
Madagascar	53	54	44	45	54	52	48	48	57	57	55	43
Chad	54	53	66	38	57	51	63	55	47	43	50	54
Ivory Coast	55	56	38	36	52	59	31	41	48	52	30	42
Pakistan	56	55	56	41	55	53	53	34	62	63	59	44
Central African Empire	57	60	49	58	61	62	55	57	52	49	57	57
Ghana	58	63	31	50	53	58	36	38	56	61	44	34
Nigeria	59	61	57	33	59	60	58	39	58	60	52	47
Burundi	60	57	65	69	63	63	65	66	60	55	69	59
Ethiopia	61	59	70	63	62	61	69	68	63	58	67	67
United Republic of Tanzania	62	58	68	70	60	55	67	70	66	64	53	70
Malawi	63	62	67	67	65	65	60	52	65	66	49	49
Niger	64	64	58	42	58	54	62	58	61	59	61	63
Guinea	65	65	51	66	66	66	54	62	59	56	56	64
Togo	66	66	53	53	64	64	57	51	64	65	47	52
Benin	67	67	61	54	67	67	59	54	69	70	51	58
Mali	68	68	64	49	68	69	64	60	70	69	66	61
Upper Volta	69	69	69	64	70	70	68	67	67	67	65	66
Ruanda	70	70	55	62	69	68	70	59	68	68	70	55

TABLE 2. DEVELOPED COUNTRIES: CLASSIFICATION BY RANK, 1960 AND 1970

A—All factors, B—Demographic factors, C—Economic factors, D—Modernization factors)

Countries	1960				1970			
	A	B	C	D	A	B	C	D
United States of America	1	9	1	1	1	2	1	1
United Kingdom	2	1	3	10	4	3	12	13
Sweden	3	8	4	2	2	4	3	2
Canada	4	18	2	3	3	15	2	3
Switzerland	5	7	6	5	7	11	9	5
Denmark	6	4	13	6	9	14	11	6
Germany, Federal Republic of	7	5	5	14	5	7	4	10
Australia	8	12	7	7	6	8	10	7
Norway	9	6	14	9	12	17	8	14
Belgium	10	14	9	11	14	20	6	16
New Zealand	11	23	12	4	10	19	13	4
France	12	10	11	16	11	10	5	18
Netherlands	13	3	15	15	8	6	14	12
Iceland	14	26	8	8	20	25	17	8
Austria	15	13	17	17	22	22	18	19
Luxembourg	16	25	10	13	18	27	7	11
Hong Kong	17	2	19	29	13	1	22	25
Italy	18	11	21	21	19	9	19	21
Israel	19	16	18	19	15	13	15	17
Finland	20	24	16	12	21	24	16	15
Uruguay	21	17	23	22	27	26	28	26
Argentina	22	19	24	23	24	21	23	22
Singapore	23	22	20	24	17	5	21	23
Japan	24	20	26	18	16	12	20	9
Greece	25	15	27	25	25	16	27	24
Spain	26	21	28	27	26	18	25	27
Ireland	27	27	22	20	23	23	24	20
Cyprus	28	29	25	26	28	28	29	29
Portugal	29	28	29	28	29	29	26	28

TABLE 3. CROSS RANK CORRELATION BETWEEN CLASSIFICATIONS RELATIVE TO SPECIFIC SUBSTRUCTURES, 1960–1970

1960	BC	.5867	BD	.5743	CD	.5536
1970	BC	.5346	BD	.5776	CD	.5495

These correlations are high enough to be significant, according to a null hypothesis test. However, their level is unexpectedly low, considering that a national structure is the result of the three component structures. This indicates a high degree of internal variation among the various groups of factors in a single country structure. Moreover, the partial rank correlation coefficient, resulting from the association between classification B and C, when D is held constant, is notably lower than the corresponding rank correlations provided in table 3. The coefficients, which thus account for the elimination of variation effects by D upon the relation between B and C, are found to be equal to 0.3942 in 1960 and to 0.3185 in 1970. Unfortunately, the sampling distribution of the partial correlation is not yet known and therefore no test of significance is now possible. In any event, the low value of these indices casts serious doubts on the existence of a definite relationship between population and economic factors under a structural purview.

The various classifications do not rely on the whole set of 43 indicators but only on the 26 indicators which proved to be sufficient to close the system. This minimum set of indicators remains identical for each reference year and for both developing and developed countries, and thereby demonstrates a qualitative stability of the structures through the decade. Table 4 shows the variables of the respective systems, according to the importance of the information they contribute to the same system.

While the qualitative content of structures is kept unchanged, the internal hierarchy of factors is not preserved throughout the period. Mortality indicators are dominant discriminatory variables for any year and both groups of countries, with the exception of the developing countries in 1970. By 1970 natality factors become more closely correlated than any others with the composite I-distance. This information conforms to what is known about the sharp decline in mortality during the 1950s and part of the 1960s. By 1970, however, while gains on mortality were slowing down, a downtrend in fertility levels began to appear. A few rates started to decline and some others stabilized; fertility patterns became more peculiar to a country. Natality emerged as the main discriminatory factor among countries.

The partition

Partitions are derived from the classification process, following the procedure outlined previously.

TABLE 4. MINIMUM SET OF INDICATORS USED FOR THE CLASSIFICATION OF COUNTRIES

	Order of intake: Developing countries 1960	1965	1970	Developed countries 1960	1970
Demographic factors					
Life expectancy at birth	2	2	4	1	1
Crude death rate	1	1	3	2	2
Proportion of urban population	3	3	5	3	5
Crude birth rate	4	4	1	4	4
Average at marriage	5	6	7	5	3
Gross reproduction rate	6	5	2	6	6
Age structure	8	8	6	7	7
Activity rate	7	7	8	8	8
Economic factors					
Private consumption/capital formation	1	1	3	1	2
GDP labour force	2	3	2	2	1
Capital formation/labour force	6	2	1	4	3
Energy consumption/capital formation	4	4	4	5	4
Government expenditures	3	5	5	3	5
Agricultural production	5	6	6	6	6
Industrial production	7	7	7	8	7
Import (part GDP)	8	8	8	7	8
Export per labour force	9	9	9	9	9
Social policy and modernization factors					
Telephones *per capita*	1	3	3	1	1
Newsprints *per capita*	2	2	2	2	2
School enrolment, primary	7	7	8	3	4
Physicians per inhabitant	3	1	1	4	3
Radio *per capita*	4	4	7	5	7
Calories *per capita*	5	6	6	6	6
School enrolment, secondary	6	5	4	8	9
Protein *per capita*	9	9	9	7	8
Professionals in labour force	8	8	5	9	5

Figure I is constructed as a tree-shaped diagram to show in detail the progressive clustering of countries by structural affinity. How close one country is to another depends on their interdistance, as measured against the interval scale. This scale ranges from a theoretical 0 distance between countries to an upper limit where the largest distances observed between countries or groups of countries fall within the interval. This largest distance includes all other distances and all the countries are therefore viewed as one single group.

This scale reflects a progressive clustering through declining homogeneity among the groups of countries. At the lower range, when two countries exhibit a short distance between them, they tend to be very similar. As we move along the interval, larger distances between countries are admitted and more countries are allowed to cluster, leading to groups which are less and less homogeneous.

Thus, countries which are not distant from each other by more than a given limit of the scale are to be considered as one or several clusters, depending on their position in the ranking. Actually, distances are expressed as a percentage of the interval. Any transversal cut determines, at a given distance level, a partition of countries.

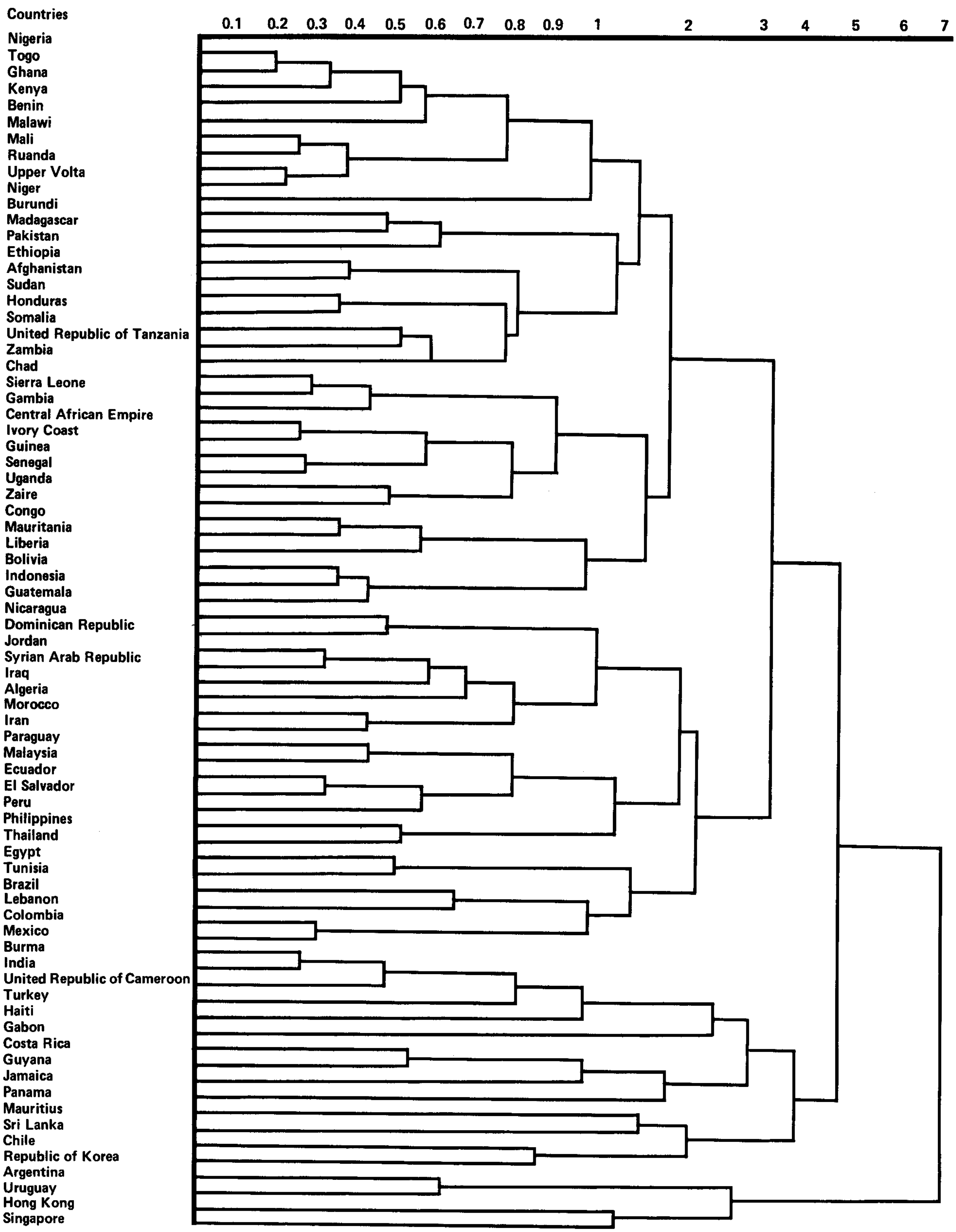
The partitioning process has been applied only to developing countries on the demographic, economic and modernisation dimensions, in addition to the over-all structure, for each year of reference. Twelve chart diagrams are generated but only one is presented here for illustration.

Discussion is restricted to a few selected features that are reflected mostly in comparisons between partitions within each substructure and in time. Attention will be focused first on distances as expressed in absolute value. One reason for doing so is that the total interval represented by the scale varies from one group of factors to the other and from one period to the other. This can be observed in table 5, which shows the extent to which the

TABLE 5. DISTANCE INTERVALS BETWEEN LOWER AND UPPER LIMITS OF MERGER, FOR EACH TYPE OF STRUCTURE, IN 1960 AND 1970.

Structure	*Period*	*Lower limit*	*Upper limit*	*Interval*	*Trend*
Demographic	1960	0.136	7.944	7.808	
	1970	0.190	7.849	7.659	–
Economic	1960	0.124	9.372	9.248	
	1970	0.162	8.186	8.024	–
Modernization	1960	0.135	11.080	10.945	
	1970	0.247	12.279	12.032	+
Over-all	1960	0.192	9.717	9.525	
	1970	0.386	9.984	9.958	–

Figure I. Partition according to demographic structure, 1970



lower and upper limits of the total interval depend on the structure and time considered.

A general observation drawn from the tree-shaped graphs is that the necessary distance for two countries to cluster tends to increase from 1960 to 1970. In other words, the more developed the countries, the larger their interdistance. This suggests that development, as it takes place, makes these countries more singular. It emphasizes their peculiarities through a more intricate interrelationship of their elements. Countries like Argentina and Uruguay, though they are closer to each other than to any other country, nevertheless cluster at a high distance level. This association is maintained throughout the decade, although distance between increases. At the lower distance level, where most of the African countries are found, clustering thresholds are also higher in 1970 than in 1960. But, while the affinities of countries in the upper range of the scale are rather stable, associations in the lower one are more changeable. There are numerous shifts among pairs of African countries between 1960 and 1970.

As may be seen, the lower limit assumes increasing value between 1960 and 1970, while the upper limit declines for the demographic and economic structures but not for the modernization structure. As a result, interval contraction appears from one year to the next for two structures, while the range becomes larger for modernization. The increase of the lower limit from 1960 to 1970 emphasizes the growing singularity of the least developed countries, while the reduction of the interval denotes that the clustering process is also achieved at lower levels, which implies a larger concentration among countries.

This trend towards concentration of the grouping, i.e., towards a higher homogeneity of countries, requires additional and more direct confirmation. To this end, both the distance levels and the number of corresponding groups are expressed in relative value. The concentration of the various clusters is then investigated. This is done for 1960 and 1970 at various given distance levels up to 0.50. (For at higher levels, groups are increasingly large and their homogeneity decreases rapidly.) The "entropy" that is used here to characterize and compare the intensity of concentration among groups of countries is a common measure of disorder within a distribution (see annex II). It ranges from the value 0, for complete concentration of countries in one single group, to 1, when all the countries are equally distributed among strata. Though this index will be referred to as a "concentration index", it actually measures the degree of equipartition of countries between strata, i.e., the reverse of concentration.

Table 6 shows that at any distance level in 1960, and at most of them in 1970, the countries are more evenly distributed among groups according to demographic characteristics than according to other types of structures. In 1970 the group distributions undergo a process of higher concentration. This in turn implies that the size of some of the groups has become larger. In general, though, groups of countries depending on demographic structures are smaller and more numerous but, given the smaller interval, slightly closer to each other than groups based on other types of structures.

Since the concentration process has to take place within a given range, starting from a theoretically possible complete dispersion of individual countries to a theoretically possible clustering into one group only, the problem becomes one of identifying the level or the area of levels where higher concentration occurs. In slightly different terms the answer concerns the pace of the concentration process. Because population factors induce a more scattered distribution of clusters than do other factors, concentration takes place at a later stage in the grouping process. The least developed countries are more differentiated according to demographic criteria than to others. By contrast, concentration resting with economic structure tends to occur at an earlier stage, a tendency which is even more notable by the end of the period. As a consequence, there is a clear and early partition through countries which are not very different from one another, and an increasing minority of more developed countries cluster beyond the level 0.50 in 1970.

When the concentration indices are averaged, it is observed that their mean practically corresponds at level 0.25, for all types of structures. This level has therefore been chosen as a reference level to study how various distributions of countries among groups would eventually match with a geo-cultural partition of the same countries. Table 7 shows the distribution of countries among groups at level 0.25, in 1960 and 1970, for each type of structure.

While the group composition changes by varying degrees among structures and over time, it is clear that the concentration process, which takes place between 1960

TABLE 6. EQUIPARTITION OF COUNTRIES AT VARIOUS DISTANCE LEVELS, FOR EACH TYPE OF STRUCTURE, IN 1960 AND 1970

	1960				*1970*			
Distance level	*Over-all structure*	*Demographic structure*	*Economic structure*	*Modernization structure*	*Over-all structure*	*Demographic structure*	*Economic structure*	*Modernization structure*
0.05	0.997	0.983	0.969	0.963	0.990	0.980	0.953	0.964
0.10	0.934	0.947	0.894	0.899	0.936	0.928	0.884	0.836
0.15	0.889	0.932	0.794	0.751	0.854	0.905	0.734	0.814
0.20	0.855	0.902	0.803	0.713	0.819	0.845	0.716	0.776
0.25	0.807	0.832	0.750	0.552	0.741	0.725	0.699	0.667
0.30	0.729	0.827	0.614	0.627	0.702	0.715	0.777	0.563
0.35	0.552	0.520	0.452	0.396	0.605	0.622	0.567	0.304
Mean	0.823	0.849	0.753	0.700	0.806	0.817	0.761	0.703

TABLE 7. DISTRIBUTION OF COUNTRIES AMONG GROUPS AT LEVEL 0.25 IN 1960 AND 1970 FOR EACH TYPE OF STRUCTURE

Number of the group	1960				1970			
	A	B	C	D	A	B	C	D
1	8	24	25	37	31	35	41	47
2	8	14	15	20	4	5	8	18
3	16	14	21	6	10	15	9	2
4	7	7	8	4	12	2	8	2
5	5	3	2	5	2	2	2	3
6	5	7			2	6	3	
7	3	2			4	4		
8		2			3	2		
9					2	2		
Number of countries	72	72	71	72	70	73	71	72

and 1970, results in an increase in the number of least developed countries, even if, as a whole, they have progressed slightly during the interval.

It may be that if there is a weak connexion between population and economic structures, this would be reflected by a closed correspondence between the demographic structures and some regions defined in terms of geo-cultural affinities. In accordance, the map of the developing countries of the world has been divided into the conventional five major regions that are thought of as being geographical or cultural entities.[11]

In order to compare simultaneously the grouping relative to each structure to this geo-cultural pattern an index has been designed. When there is complete coincidence between group and region, the index value is 0 and when there is no paired correspondence between group and region, the value of this index reaches a maximum of 1 (see annex II).

There are clear indications that the distribution based on demographic structure corresponds more closely to a geo-cultural partition of the countries than does either the economic or the modernization structure. This coincidence is emphasized throughout the decade, as changes in concentration correspond to geo-cultural regions. The economic distribution of countries departs to a greater degree from the geo-cultural model over the decade.

The two processes diverge in time. These results are, however, not surprising, since the demographic process appears to depend to a greater extent than the economy or modernization on geo-cultural factors. On the contrary, higher values of the dissociation index suggest that socio-economic development, instead of being regionally geared, would be more subordinated to national conditions, possibly to national political orientations.

CONCLUSIONS

Taken at face value, the most significant proposition to emerge from the preceding analysis have been the indications of a weak relationship between demographic and economic structures, a tendency for the demographic structure to coincide with a geo-cultural partition and also an increasing downward concentration of countries within the least developing group.

TABLE 8. INDEX OF DISSOCIATION BETWEEN DISTRIBUTION AND A GIVEN PARTITION

Over-all structure	1960	0.483	1970	0.426
Demographic structure	1960	0.486	1970	0.469
Economic structure	1960	0.591	1970	0.602
Modernization structure	1960	0.521	1970	0.539

Results in table 8 must, however, be qualified. When faced with a decreasing value of the dissociation index during the decade, one comes to view this evolution as resulting more from the growing concentration of the least developed countries than from any general trend of dependency on geo-cultural factors. In other words, what is being reflected here could be a prevalence of these factors but at a lower level of development. Similarly, the lower correspondence shown between economic distributions and the geo-cultural partition of countries would then express the weight of the heaviest group. In line with this hypothesis, the influence of socio-economic factors in least developed countries would be very weak. In sum, these qualifications suggest a unique pattern for this latter group of countries, which should be considered and studied for their own characteristics. In an extended perspective, this view underlines the necessity of investigating relationships between factors within groups of countries that are homogeneous.

Annex I

INDICATOR LISTINGS

A. *Demographic indicators*

Population size
Age structure index
Sex ratio for the complete population
Average household size
Life expectancy at birth
Crude birth rate
Crude death rate
Gross reproduction rate
Average age at first marriage (female population)
Unmarried population over age 45
Population density
Net migration ratio
Urban population 100 000 + per total population
Number of towns 100 000 + per 100 000 km^2 estimated area
Urban growth less rural growth
Global activity rate

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[11] Geo-cultural partition of the countries into five regions:

First region. All African countries, with the exception of the Maghrebian countries and Egypt, but including Mauritius and Madagascar, in all 32 countries.

Second region. Most of the Islamic countries gathered into one continuous region, including Morocco, Algeria, Tunisia, Egypt, Jordan, Syria, Arab Republic, Lebanon, Iraq, Iran and Turkey, i.e., 10 countries.

Third region. South America, including Colombia, Ecuador, Peru, Bolivia, Paraguay, Chile, Argentina, Uruguay, Brazil, Guyana, i.e., also 10 countries.

Fourth region. Central America and a few Caribbean countries, including Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala, plus Mexico.

Fifth region. The rest of Asia, with 12 countries.

B. *Economic indicators*

Gross domestic product per labour force, in producer's value, at constant price
Government final consumption expenditures *per capita*
Private final consumption expenditures *per capita*
Gross fixed capital formation per consumption unit
Gross fixed capital formation per consumption unit
Export-import ratio
Export per gross fixed capital formation
Import per labour force
Proportion of imports in gross domestic product
Agricultural production in gross domestic product
Food export per unit of total export
Food import per unit of total import
Industrial production in gross domestic product
Energy consumption, kg of coal equivalent, *per capita*

C. *Modernization indicators*

Number of physicians per 10 000 inhabitants
Number of nurses per physician
Calorie consumption, *per capita*, per day
Protein consumption, *per capita*, per day
Proportion of education expenditures within the government total expenditures
Proportion of health expenditures within the government total expenditures
Total motor vehicles in use per 1 000 inhabitants
Number of radio receivers per 1 000 inhabitants
Newsprint consumption *per capita*
Number of telephones in use *per capita*
School enrolment ratio at first level
School enrolment ratio at second level
Number of third level graduates per labour force

Annex II

NOTE ON THE INDICES OF CONCENTRATION

1. Whenever there are two independent sets of events, X and Y, with respectively n and m issues, it can be said that the indetermination of the two events occurring simultaneously (XY) depends on n and m. Thus, their indetermination is a function (f) of nm:

$$f(nm) = f(n) + f(m)$$

The type of function which fulfils the general conditions set by this kind of problem is the logarithmic function, i.e.:

(*a*) $f(nm) = f(n) + f(m)$
(*b*) $f(1) = 0$
(*c*) $f(n) > f(m)$ if $n > m$

hence:

$$log(nm) = log(n) + log(m)$$

When the occurrence of the event is certain, there is no indetermination and

$$p(X_i) = p_i = 1$$

On the other hand, when any occurrence of $X_i (i = 1, \ldots, m)$ is equally probable, then $p(X_i) = p_i = \frac{1}{m}$ and the degree of indetermination is maximum.
The expected information of a distribution, generally referred to as the entropy, can therefore be regarded as an adequate measure of disorder. The entropy will be set equal to the sum of the product of each indetermination relative to the probabilities and their weights. It stands then as a weighted average of the information content:

$$H(Y_i) = \sum_{i=1}^{m} y_i lg \frac{1}{y_i}$$

The objective is to measure the concentration of partition groups at various distance levels. The arguments presented above suggest that the entropy is an appropriate inverse concentration measure: the higher the entropy, the lower the degree of concentration.

When the concentration is maximum, there is a complete certainty; $y_i = p_i = 1$ and $H(Y_i) = 0$. Since there is a minimum certainty when all m probabilities are even and equal to $\frac{1}{m}$, the maximum value of $H(Y_i)$ is lgm. If it is wished that the index vary between 0 and 1, it suffices to express it relative to its maximum value by dividing the entropy by lgm.

2. The other objective is to test a repartition of countries into several distributions for its degree of concentration as against a given distribution of the same countries. The problem relates to conditional distributions.

More specifically, the problem of appraising how far the computed groups' distribution is from a geo-cultural repartition of the countries comes to one of measuring the actual concentration of the partition groups within each stratum of the given distribution.

By contrast with the general case exposed in the previous paragraph, the problem will be stated in terms of a two-dimensional distribution. Thus, given n geo-cultural groups $(X_1, \ldots, X_n)$ to which are compared m partition groups $(Y_1, \ldots, X_m)$, f_{ij} is the probability that a country belongs simultaneously to X_j and to Y_i, f_i that it belongs to Y_i, and $f_{\cdot j}$ to X_j.
The three sets of values add up to 1 and are non-negative:

$$\sum_{i=1}^{m} f_{i\cdot} = \sum_{j=1}^{n} f_{\cdot j} = \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij} = 1 \qquad \begin{matrix} i = 1, 2, \ldots, m \\ j = 1, 2, \ldots, n \end{matrix}$$

The adequate measure results in a joint entropy, which combines the information on the concentration of a set of m partition groups distributed with n geo-cultural groups. It is written as follows:

$$H(YX) = \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij} lg \frac{f_{i\cdot} f_{\cdot j}}{(f_{ij})^2} \qquad (1)$$

On expanding the index:

$$H(YX) = \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij} lg \frac{f_{i\cdot}}{f_{ij}} + \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij} lg \frac{f_{\cdot j}}{f_{ij}} \qquad (2)$$

$$= \sum_{i=1}^{m} f_{1\cdot} lg \frac{f_{i\cdot}}{f_{ij}} + \sum_{j=1}^{n} f_{\cdot j} lg \frac{f_{\cdot j}}{f_{ij}} \qquad (3)$$

Each term is the expected information value of $f_{i\cdot}$ given f_{ij} and $f_{\cdot j}$ given f_{ij}, showing how far the f_{ij} are, respectively, either from $f_{i\cdot}$ or $f_{\cdot j}$.

Another way of splitting the index is as follows: when each term of (2) has been respectively multiplied and divided by $f_{i\cdot}$ and $f_{\cdot j}$:

$$H(YX) = \sum_{i=1}^{m} f_{i\cdot} \sum_{j=1}^{n} \frac{f_{ij}}{f_{i\cdot}} lg \frac{f_{i\cdot}}{f_{ij}} + \sum_{j=1}^{n} f_{\cdot j} \sum_{i=1}^{m} \frac{f_{ij}}{f_{\cdot j}} lg \frac{f_{\cdot j}}{f_{ij}} \qquad (4)$$

Then, the ratio $f_{ij}/f_{i\cdot}$ is the conditional probability of a country to be part of X_j when it is given that it belongs to Y_1 with the probability $f_{i\cdot}$. The definition is the same for $f_{ij}/f_{\cdot j}$ with the groups reverted.

For a fixed X_j and Y_i varying from 1 to m, the entropy of the resulting distribution is:

$$\sum_{i=1}^{m} \frac{f_{ij}}{f_{\cdot j}} lg \frac{f_{\cdot j}}{f_{ij}} \qquad j = 1, \ldots, n$$

This is the conditional entropy of the partition groups for a given geo-cultural group. When weighted by the $f_{\cdot j}$ it comes to the second term of the expression (4).

Terms are symmetrical to one another.

It is easy to see that the first term of (4) is equal to 0 when there is only one element in each line, i.e., in each partition group. Concentration in Y_i is then maximum. By contrast, it yields a maximum equal to $lg\, n$, when

$$f_{ij} = \frac{1}{n} \times f_{i\cdot}$$

The same holds for the second term, with one element in each column and a maximum for $f_{ij} = \frac{1}{m} \times f_{\cdot j}$.

When $f_{ij} = f_{i\cdot} * f_{\cdot j}$, which is the case of stochastic independence between both distributions, the expression (4) reduces to:

$$H(YX) = \sum_{i=1}^{m} f_{i\cdot} \sum_{j=1}^{n} f_{\cdot j} lg \frac{1}{f_{\cdot j}} + \sum_{j=1}^{n} f_{\cdot j} \sum_{i=1}^{m} f_{i\cdot} lg \frac{1}{f_{i\cdot}}$$

or

$$= \sum_{j=1}^{n} f_{\cdot j} lg \frac{1}{f_{\cdot j}} + \sum_{i=1}^{m} f_{i\cdot} lg \frac{1}{f_{i\cdot}}$$

The index then comes to the sum of the respective entropies of each marginal distribution.

CHOICE OF POLICY MEASURES TO AFFECT FERTILITY: A COMPUTER MICRO-SIMULATION STUDY

*Shunichi Inoue**

PURPOSE AND METHOD OF THE STUDY

According to the United Nations "Third Population Inquiry among Governments on Population Policies in the Context of Development", conducted in 1976, 40 countries had policies designed to reduce the rate of natural increase.[1] The total population of those countries is estimated at around 2.2 billion in 1977, which is 56 per cent of the world total population and 78 per cent of the total population of the less developed regions. Since none of these countries intends to increase mortality rates to achieve such a goal, the aim of their policies can safely be interpreted as a reduction of fertility rates. In other words, the majority of the people in the less developed regions, whose fertility still remains very high, appear to be living under government policies to reduce fertility levels in some manner. The percentage is clearly large enough to affect significantly the world prospects of future fertility and population growth, if those policies should be carried out effectively.

Under these circumstances, it would be inappropriate to underestimate or ignore the possible impacts of Governments' policies upon future fertility trends, especially when preparing comprehensive demographic projections for the countries of the world at the United Nations Secretariat. A quantitative evaluation of the impact of population policies on fertility is admittedly a very difficult task and requires assumptions about the extent and tempo of population policy implementation. Nevertheless, such an exercise may help provide not only an improved assessment of future population prospects for individual countries but also an opportunity to reappraise the goals of population policies and the ways and means by which policies could be implemented.

To date, studies on this subject have been primarily limited to the evaluation of family planning programmes sponsored by Governments and other public institutions.[2] Such studies usually try to estimate the number of programme acceptors and their continuation rate to assess the extent of fertility reduction attributable to the programme. Although these studies have their own aims and merits, they tend to limit their attention to relatively narrow technical fields in comparison with a full range of possible population policies. Their limitation is clear since contraception may be practised outside the government programmes, especially when some traditional and indigenous contraceptive methods are widely used. More importantly, however, the determinants of fertility change and concomitantly the choice of policy measures extend beyond the customary coverage of family planning. Theoretically, it may be argued that a comprehensive fertility policy must be formulated considering all aspects of fertility determining processes. There are many difficulties in such broad policy formulation not only because of the large number of factors that must be taken into consideration but also because of the complexity of the interrelationships among these factors, as well as between them and the resulting fertility changes. Conceptually, however, it seems possible and even promising to sift out some major elements which are operating as a set of conduits to channel the consequences of both socio-economic changes and governmental programmes and activities on to fertility. These intermediate elements or intermediate variables may include age at marriage, desired family size, contraceptive practice rate, use-effectiveness of the contraceptive methods, induced abortion, infant mortality rate etc.[3] In a sense these elements may be regarded as the measures to implement population policies because policies can only be effectuated by working through these conduits.

A stratification can be made among variables affecting fertility. In the first tier is the process in which non-demographic factors, such as social and economic changes as well as government policies affect the intermediate

* Population Division of the Department of Economic and Social Affairs, United Nations Secretariat. This article is an interim report on an ongoing project.

[1] "Concise report of monitoring of population policies, report of the Secretary-General" (E/CN.9/324, 19 October 1976), paper presented to the Population Commission at its nineteenth session, 10–21 January 1977.

[2] C. Chandrasekaran, D. V. R. Murty and K. Srinivasan, "Some problems in determining the number of acceptors needed in a family planning programme to achieve a specific reduction in the birth rate", *Population Studies*, vol. 25, No. 2 (July 1971), pp. 303–308; Robert G. Potter and S. L. N. Rao, "Future family planning impact: method and data requirements". *Economic Bulletin for Asia and the Far East*, vol. 24, No. 1 (June 1973), pp. 74–82; John A. Ross, "Acceptor targets", in C. Chandrasekaran and Albert I. Hermalin, *eds., Measuring the Effect of Family Planning Programs on Fertility* (Dolhain, Belgium, 1975), pp. 55–91; C. Chandrasekaran, "Acceptor data", in *ibid.* pp. 17–53; Economic and Social Commission for Asia and the Pacific. *Report of the Multinational Study in Methodologies for Setting Family Planning Targets in the ESCAP region*, Asian Population Studies Series No. 31 (NST/ESCAP/14, 1976).

[3] Intermediate variables are meant here to cover a wider dimension than the one originally defined by Davis and Blake. See Kingsley Davis and Judith Blake, "Social structure and fertility: an analytic framework", *Economic Development and Cultural Change*, vol. 4, No. 3 (1956), pp. 211–238.

variables in one way or another; in the second, is the process in which these intermediate variables determine fertility rates in accordance with well-structured bio-demographic processes. The second stage of fertility determination is relatively better known to the researcher yet complicated enough to require intensive treatment. Simulation studies, like the one presented in this paper, are quite suitable to elucidate questions related to this second stage. It is hoped that an understanding of this second stage of fertility determination will eventually help clarify the studies about its first stage and will make it easier to draft a set of comprehensive population policies that are properly aimed at a certain policy goal.

This study thus intends to construct and use a simulation model of human reproduction in order to examine various possibilities for fertility changes in developing countries under several assumptions regarding the choice of population policy measures. As will be discussed in the next section, the type of model that has been adopted in this study is a micro-simulation model of fertility with bio-demographic components. The input variables to the model represent the "intermediate" variables mentioned above and thus can be regarded as population policy measures. The same model can also be used in searching for a set or a package of policy measures which are practicable and yet would warrant the achievement of the policy goal. In addition, the model could provide fertility assumptions for population projections by assuming future trends of those input variables with, or without, Governments' interventions.

In a micro simulation of this type, a large number of women's reproductive life histories will be simulated under given assumptions and then various fertility indices will be computed from the results. In this procedure, there are two contradictory demands regarding the data requirements. On the one hand, the model requires a large number of biological and demographic variables as input data. On the other hand, the input variables must be simple and obtainable with relative ease in order to apply the model to developing countries where such data are scarce in most cases. The solution for this dilemma that has been adopted here is to prepare alternative sets of estimates for various probability distributions of demographic and biological events, from which suitable estimates can be derived by simplified input variables. In addition, the model needs a dynamic feature, that is, the capacity to simulate fertility rates over a certain period of time allowing for changes in the assumptions about the input variables. This dynamic feature will make it possible to illustrate more realistically the effects of population policies on fertility rates for a specified time interval.

In order to accomplish the purpose of the study stated above, the following objectives have been set forth:

1. To construct a computer simulation model of fertility with bio-demographic components which is suitable for policy evaluation and fertility projections.

2. To prepare estimates of probability distributions concerning age at marriage, permanent sterility by age, infant deaths by months of age, use-effectiveness of contraceptive methods and foetal mortality rates by age of a woman in order to facilitate the use of the model under a variety of conditions, especially in cases of insufficient data.

3. To test the validity and robustness of the model by applying it to a non-contraceptive population, i.e., one exhibiting natural fertility. The Hutterites have been chosen for this purpose.

4. To test the validity and robustness of the model by applying it to a contraceptive population, in particular, Japan.

5. To study the population policy in a selected developing country (Pakistan) and estimate the relevant input variables. Based on this assessment and using the model, to simulate fertility rates of the same country with existing population policies in a concrete time dimension.

6. To simulate fertility changes in a concrete time dimension with alternative sets of the input variables which may be viewed as alternative assumptions on policy measures for the same country.

7. To incorporate the simulation results with population projections for the developing country selected.

This paper is a preliminary report of a simulation study, the purpose and characteristics of which are described above. This introductory section will be followed by a brief description of the features of the model, and also by the results of the validity test for simulations with reference to the Hutterite and Japanese fertility rates. The major application of the model is made for Pakistan and will consist of four topics: (*a*) a simulation at the current age-specific fertility rates, (*b*) an assessment of the effects of various assumptions for each of the policy measures or the input variables, (*c*) time-specific simulations for future fertility trends with plausible alternative sets of assumptions on the policy measures. The last section of the paper will present the results of population projections for Pakistan, including several simulation results which may be useful for formulating projections for the developing countries. A technical description of the model used and other related matters will be presented in the appendices to the paper.

Main features of the model used

The model which has been developed for this study is a micro-simulation model of fertility with bio-demographic components. The model is designed to produce age-specific fertility rates and other fertility indices, such as a parity distribution of women and the length of birth intervals, which are to be utilized for many purposes including the United Nations population projections. The input variables to the model are simplified so that an application of the model to developing countries becomes feasible. The input variables, or more properly the intermediate variables between fertility and socio-economic and cultural determinants, can also be seen as the population policy measures so that the model may be used for the evaluation of effects on fertility of those policy measures. An additional feature of the present model is its power to make a dynamic simulation. This feature can produce fertility trends over a period of 35 years with changing assumptions and is expected to be useful for projection purposes and also to clarify the time dimension of the policy effects.

The model is called a *micro model* because it generates a large number of individual women's reproductive life histories in a computer on a stochastic basis. In this particular model, a maximum of 1 000 women's reproductive histories can be simulated and the results will be summarized in various fertility measures. The model is also called *bio-demographic* because it contains in its framework both biometric elements, such as fecundability, intra-uterine mortality and sterility, as well as demographic elements, such as age, marital status, parity, desired number of children, contraception and sterilization.[4]

More specifically, the present model regards a reproductive life of a woman as follows: the reproductive life span, which may be defined as the married, fecund period within the limit of time span from 15 to 20 years of age, is composed of one or more reproductive cycles. Each reproductive cycle is further composed of three periods: a period of contraception delay, a period of gestation and a period of post-partum infecundity. The last reproductive cycle of a woman is usually interrupted by the termination of her reproductive life span at some point in the period of conception delay or the period of post-partum infecundity.

In the present model, the period of conception delay is determined by a monthly probability of conception which is assumed to vary with a woman's age. In the absence of contraception, the probability would be equal to fecundability; with the contraceptive practice, the probability becomes residual fecundability. The period of gestation that follows a conception is considerably different depending on the result of the conception: a live birth, a foetal death (including still birth) or an induced abortion. The period of post-partum infecundity or the idle period depends not only on the results of the conception but also, in the case of a live birth, on the length of survival of the child and the custom of breast-feeding. After this idle period, the next reproductive cycle will begin with the resumption of susceptibility. The reproductive cycles will be repeated until the woman reaches the end of her reproductive life span as defined in the above paragraph.

Family planning practice will be introduced into the model when a couple wants to limit the family size or to keep a proper interval between child births. The readiness for family planning for stopping purposes will occur only after the number of surviving children reaches the desired number, the difference between the two being called here the number of excess children. Given the readiness for stopping or spacing, however, a woman may or may not practice contraception, depending on the given contraceptive practice rate. When contraception is practiced, fecundability will be reduced to residual fecundability to the extent to be derived from the extended use-effectiveness of the method chosen. If a conception takes place too soon relative to the desired spacing or in spite of the stopping preference, the conception could be ended by an induced abortion, depending on the given induced abortion rate (see fig. I).

Since the micro-simulation model is a numerical model, it does not require extensive mathematical treatments of the subject but instead uses extensively a technique of stochastic random determination by a computer, such as the Monte Carlo method. In other words, the occurrence and timing of many events in the simulation will be regulated by computer-generated random numbers in accordance with given probability schedules. For example, the timing of a conception will be determined in the model by a monthly probability of conception as follows: in the first month after the first marriage or the resumption of susceptibility, a random number R_1 ($0 < R_1 < 1$) will be generated by a computer and compared with the probability of conception, say 0.2, and if R_1 is equal or less than 0.2, it is decided that a conception takes place in the first month but if R_1 is greater than 0.2, the conception delay goes to the second month. For the second month, a newly generated random number R_2 will be compared with 0.2, if the probability remains the same, and the process continues until $R_n \leq 0.2$ is found in the n^{th} month. Obviously, n could be different for each conception and for each woman but if aggregated, the frequency distribution of the conception delay will have a mean value of five months, and a standard deviation of about 4.4 months. On the contrary, if a model is deterministic instead of stochastic, the conception delay would be constant at five months for all women in the above instance.

In spite of the apparent complexity, the micro-simulation model with bio-demographic components has some advantages for a study such as this due to its potential capacity to manipulate as many input variables and as much complexity of the model structure as are necessary without producing disturbing interactions among the variables and without requiring excessive computer capacity.[5] Some of the macro-simulation models of fertility reportedly have a limit of precision due to the computer capacity.[6] On the other hand, the micro-simulation models with only demographic components, such as POPSIM,[7] seem to have problems with input

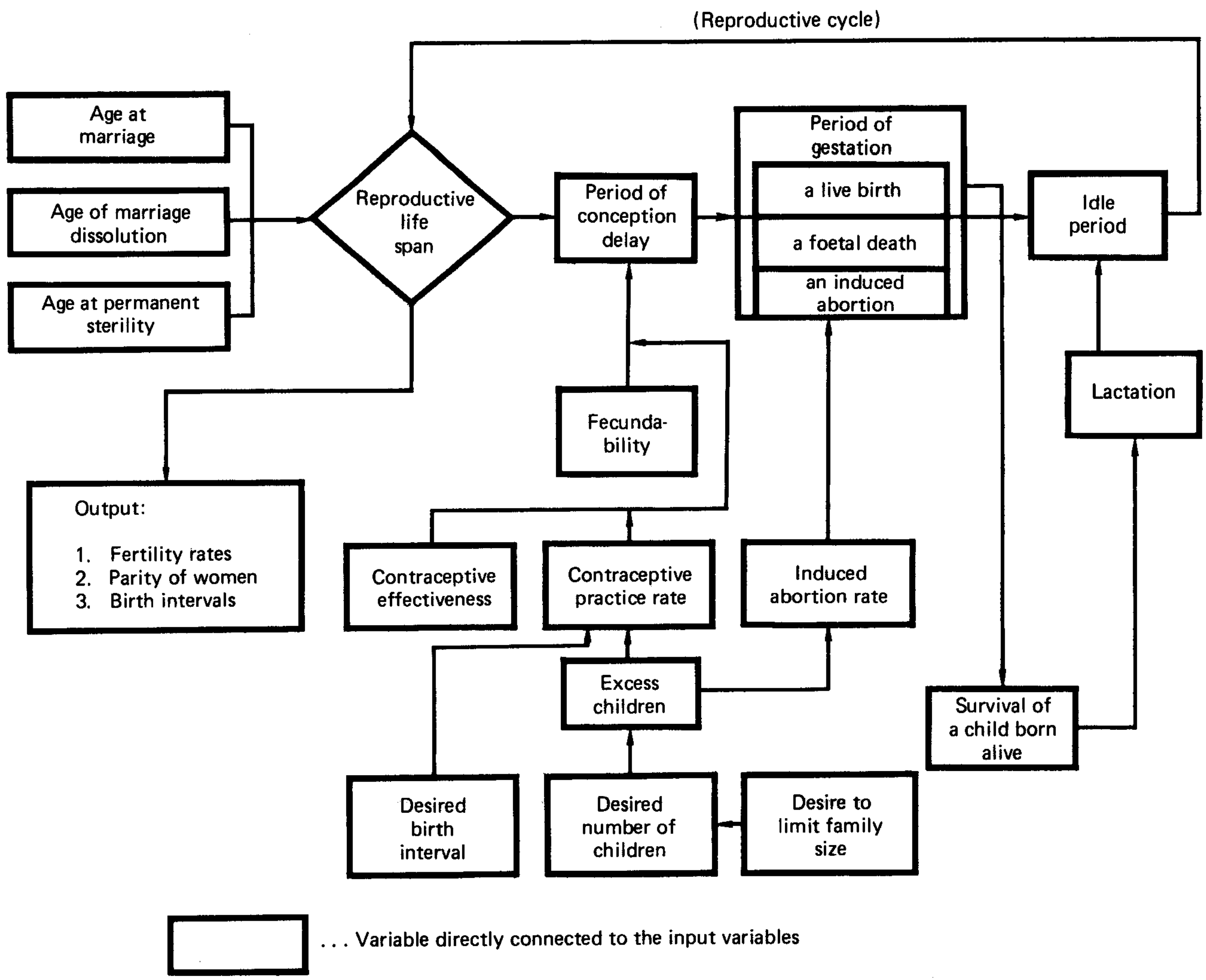
[4] See Menken's classification of simulation models. Jane Menken, "Simulation studies", in C. Chandrasekaran and Albert I. Hermalin, *eds., Measuring the Effect of Family Planning Programmes on Fertility* (Liège, 1975), pp. 351–379.

[5] Albert Jacuard, "La Reproduction humaine en règime malthusien", *Population*, Vol. 22 (septembre–octobre 1967), pp. 897–920; K. Venkatacharya, "Some implications of susceptibility and its application in fertility evaluation models", *Sankhya*, Series B, vol. 31 (June 1970), pp. 41–54; Ingvar Holmberg, "*Fecundity, Fertility and Family Planning, Application of Demographic Micromodels*", Demographic Institute Report 10 (Göteborg, University of Göteborg, 1970); Mindel C. Sheps and Jane Menken, "A model for studying birth rates given time dependent changes in reproductive parameters", *Biometrics*, vol. 27, No. 2 (June 1971), pp. 325–343.

[6] Robert G. Potter and James M. Sakoda, "A computer model of family building based on expected values", *Demography*, vol. 3, No. 2 (1966), pp. 450–461.

[7] D. G. Horvitz, F. G. Giesbrecht, B. V. Shah and P. A. Lachenbruch, "POPSIM, a demographic microsimulation model", *Carolina Population Center Monograph 12* (Chapel Hill, University of North Carolina, 1971), pp. 45–63. Also, United States of America, National Center for Health Statistics, *User's manual for POPSIM*, United States of America, Department of Health, Education and Welfare, Publication No. (HSM) 73–1216 (Rockville, Maryland, 1973).

Figure I. . Block diagram on the scheme of the simulation model



variables. The latter model depends on a specific fertility rate, such as age-marital status-parity-contraception fertility rates, to determine the age of pregnancy for an individual woman in the simulation. But it is another big project by itself to estimate such specific fertility rates.

In order to simulate a reproductive history of a woman by the present model, the following 14 input variables have been selected with a criterion that they can be obtained relatively easily for most developing countries. As mentioned previously, these variables are in a sense the intermediate variables linking the purely demographic reproductive processes to the social, economic and other external factors which would ultimately affect fertility. As such, the input variables to the model can also be viewed as the population policy measures.

List of input variables

A. *Nuptiality*
  1. Singulate mean age at marriage (years)
  2. Proportion of women never-married at age 50
  3. Proportion of women at ages 20, 35 and 50 who are in post-marital states either by divorce or death of husband

B. *Health and lactation*
  4. Expectation of life at birth (years)
  5. Level of sterility (high, medium or low level)
  6. Average length of breast-feeding (months)

C. *Motivation for family planning*
  7. Proportion of couples who have a desired family size
  8. Average number of desired children
  9. Desired birth interval
     (*a*) From marriage to the first birth; and
     (*b*) Intervals between births.

D. *Practice of family planning*
  10. Contraceptive practice rate for stopping or spacing purposes
  11. Induced abortion rate for stopping or spacing purposes
  12. Sterilization rate among eligible couples
  13. Relative level of contraceptive use-effectiveness (high, medium and low levels)

14. Distribution of contraceptors by methods
    (*a*) IUD, (*b*) orals, (*c*) condom, (*d*) withdrawal, (*e*) rhythm, (*f*) diaphragm, (*g*) abstinence, (*h*) douche, and (*i*) other.

The simplification of the input variables without sacrificing too much precision of the simulation may be illustrated by looking into the treatment of the woman's age at marriage. The age at marriage is usually determined in a micro-simulation model on the basis of a monthly probability of marriage. This requires a series of such probabilities which are not easy to obtain due to lack of data in many developing countries. It may not be so practical to depend on these, because of the amount of work needed to estimate such a schedule. In the present model the only required input variable is the singulate mean age at marriage for women in the population, which can be computed from a population census relatively easily.[8] The built-in program will then translate it into a probability distribution required to determine an individual woman's age at marriage (see annex I). Similar devices have been provided regarding the distribution of women by desired number of children to be derived from a mean number of desired children and also regarding the surviving period of new-born babies to be obtained from the expectation of life at birth for the population. Other parameters, such as percentage of sterile couples by age and the use-effectiveness of each contraceptive method, have also been pre-estimated separately for high, medium and low levels and stored in the computer program. Therefore, a single call number is required to pick up one of the ready-made estimates which best fits the population in question.

Another feature of the present model, the dynamic mode of simulation, has been developed to facilitate the study of the timing of fertility change over a period of up to 35 years. There are two modes of simulation to choose in the present model, the dynamic mode and the static mode. If one chooses the dynamic mode, the computer will simulate fertility rates for 13 successive cohorts separated from each other by five-year intervals, each of which is equipped with different input assumptions. Some assumptions are specific to each cohort and others are specific to each period. For example, the mean age at marriage is a constant for a cohort but may vary from one cohort to the next. On the other hand, the contraceptive practice rate is a constant for a period of five years across several cohorts that go through the period with different ages. After simulating fertility rates for the 13 cohorts, the model will automatically rearrange those cohort fertility rates by five-year age groups into the successive period rates. There will then be seven complete quinquennial period rates to cover a 35-year period.

One of the drawbacks of the bio-demographic model is believed to be the difficulties in obtaining biometric parameters. And this problem may have been responsible for the delay of wider applications of the bio-demographic model in fertility studies for developing countries. However, owing to the recent progress of research in this field, we now have access to a body of reasonably good estimates for the biometric parameters needed in this type of model,[9] and most of them appear to be applicable, with some modifications, to developing countries. In order to make the model readily usable for developing countries, most of the needed parameters have been estimated and stored in the computer memory. For example, the proportion of permanently sterile couples by the age of wife, which is needed to delimit the married, fecund life span of a couple, has been estimated on the basis of published historical data for three levels of sterility rates by age, namely, high, medium and low levels. Thus, one must simply specify the general level of sterility from three alternative sets of estimates. If the level of sterility is difficult to determine, simulations using these alternative estimates would likely indicate which one of the estimates is most suitable to the population. Foetal mortality rates by age of mother received similar treatment.

The technical description of the model will be presented in annex I to this paper. Nevertheless, it is appropriate to discuss a few basic problems attached to the model in order to improve understanding of the nature of the simulations that will be made in the study. They are as follows:

Fecundability

Most of the biometric variables, including fecundability, are difficult to estimate with certainty. The strategy chosen was first to obtain a plausible range of estimates for biometric variables, then to test them with the present model to see whether they can produce the fertility rates of the Hutterite women. Fecundability, intra-uterine mortality rate, and length of post-partum infecundity were decided upon when a set of those variables could simulate fertility rates which best resemble those of the Hutterites. For example, studies show that estimates of the effective fecundability vary ranging from 0.16 to 0.25[10] yet an actual childbirth to a non-contraceptive woman would be decided not only by fecundability but also by intra-uterine mortality rate among others. Therefore, in the process of formulating the simulation model, the first step taken was to estimate an intra-uterine mortality rate which was

[8] John Hajnal, "Age at marriage and proportions marrying", *Population Studies*, vol. 7, No. 2 (November 1953), pp. 11–136.

[9] Henry Leridon, "Biostatistics of human reproduction", in Chandrasekaran and Hermalin, *op. cit.*, pp. 93–131.

[10] J. Henripin, "La Population canadienne au début du XVIII siècle", *P.U.F.* (Paris, 1954); P. Vincent, "Recherches sur la fécondité biologique", I.N.E.D.-P.U.F., (Paris, 1961); W. H. James, "Estimates of fecundability", *Population Studies*, vol. 17, No. 1 (July 1963), pp. 57–65; L. Henry, "Mortalité intra-utérine et fécondabilité," *Population*, vol. 19, No. 5, pp. 899–940; R. G. Potter and M. P. Parker, "Predicting the time required to conceive", *Population Studies*, vol. 18 (July 1964), pp. 99–116; S. N. Singh, "Low estimates of fecundability", Paper presented at the London Conference, International Population Union; Mindel Sheps and Jane Menken, "On estimating the risk of conception from censored data", in T. N. E. Greville, *ed.*, *Population Dynamics* (New York, 1972), pp. 167–200; C. M. Suchindran and P. A. Lachenbruch, "Estimates of fecundability from a truncated distribution of conception times", *Demography*, vol. 12, No. 2 (May 1975), pp. 291–301; J. Bongaarts, "A method for the estimation of fecundability", *Demography*, vol. 12, No. 4 (November 1975), pp. 645–660.

obtained from Leridon's study cited above. Then, a series of simulations were made by giving various values to fecundability to find out the right value to yield a closest fit to the Hutterite rates. This happens to be the case where fecundability was assumed to be a function of the age of a woman, starting from 0.01 at age 15 to reach the maximum level of 0.28 around age 24–28, then declining to 0.10 in the late 40s.

Owing to lack of sufficient information needed to make further elaboration, it is assumed that most of the biometric variables, including fecundability and intra-uterine mortality rate, which were found to be adequate for the Hutterite women are applicable to other populations as well. In fact, the same fecundability schedule was used in this study in simulating fertility rates for the Japanese and Pakistani women in order to obtain a reasonable approximation of the respective observations.

Effects of mortality on fertility

The model assumes that the general mortality level expressed in the West Model Life Tables in the Coale-Demeny Regional Model Life Tables[11] would determine the length of survival of each live-born child on the basis of the schedules of 1_x, that is, the number of survivors at age x out of an original cohort of 100 000. Child survival is then related to reproductive behaviour in two ways. First, it is assumed to determine the number of surviving children which, in comparison with the desired number of children, would activate the motivation for contraception to stop another unwanted pregnancy. Secondly, the length of child survival is assumed to affect the length of breast-feeding and to influence the length of the post-partum infecund period.

Breast-feeding and post-partum infecundity

It has been noted in many studies that there is a certain relationship between the length of breast-feeding and the length of post-partum infecundity. Based on a study by Leridon,[12] it is assumed in this study that the relation can be expressed in the following formula, in which PPI denotes the months of post-partum infecundity and BF the months of breast-feeding. If a child dies before the normal breast-feeding period, BF will, of course, be shortened proportionally:

$$PPI = BF \times 0.5 + 2.0.$$

Contraception, sterilization and induced abortion

It is a basic assumption in the present model that contraception, sterilization and/or induced abortion will take place only when there is a motivation for it. The motivation could be either the desire to limit the size of a family (a stopping purpose) or to keep a proper spacing between births (a spacing purpose). For example, in many survey data, the practice rate is given as a ratio of contraceptive users to the total women interviewed. But single sterile and/or pregnant women can be excluded from the computation because they have no reason to practise contraception. By the same token, the argument may be put forward for excluding from the denominator of the practice rate those who have no contraceptive motives at all. Therefore, a refined contraceptive practice rate for the present model may be defined as the specific practice rate for the fecund, married women who have a motivation towards contraception.

The reason for using this refined rate instead of the conventional rate is not only that such a rate would better reflect the levels of knowledge of the attitude towards contraception and the availability of its means in the society but also that the effect of change in a desired family size and the diffusion of contraception practice among those who need them can be analysed separately by the simulation. Although such a refined practice rate has not been used very often, it can be computed from some survey data like the report of the World Fertility Survey in several countries. More specifically, a contraceptive practice rate among those who are married and fecund and do not want any more children may be used as the practice rate for the stopping purpose, and the observed rate among those who still want additional children as the practice rate for a spacing purpose.

Sampling errors in the results

Fertility rates that will be obtained from a micro-simulation are in a sense sample means and subject to a probabilistic error because they are computed on the basis of events which are determined by several probabilities. How large is the range of this error? How many "runs" are needed to obtain a desired precision of the results? These are the questions of some importance for a micro-simulation study like this one. Of many fertility indices that could be simulated by the present model, an attempt has been made to estimate the standard error of total fertility rate. The total fertility rate for a cohort is equal to the average completed family size. In other words, it can be deemed as the sample mean of individual completed family sizes. From a set of simulation for the current Pakistan fertility rates with 13 000 runs, the mean and the standard deviation of completed family size were computed as follows: $\overline{X} = 7.10$ and $s_x = 3.18$. From these statistics, the following table of standard deviation of sample mean and the 95 per cent confidence interval of the mean estimate are prepared. As may be seen, if 1 000 runs are made for a cohort, its maximum error with a 95 per cent confidence level is 0.2 or 3.1 per cent of the mean. With the mean value of 7.1, the 95 per cent confidence interval becomes 7.1 ± 0.2 or between 6.9 and 7.3.

Number of runs	*Standard deviation of sample means* $\hat{\sigma}_{\overline{x}}$	$1.96\hat{\sigma}_{\overline{x}}$	*95 per cent confidence interval*
100	0.320	0.627	6.5–7.7
300	0.184	0.361	6.7–7.5
500	0.142	0.278	6.8–7.4
1000	0.101	0.198	6.9–7.3
5000	0.045	0.088	7.0–7.2

[11] Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations* (Princeton, New Jersey, Princeton University Press, 1966).

[12] Leridon, *op. cit.*

Validity of the simulation results

Before the model is put into use for an evaluative study of population policy measures and subsequent population projections, the validity of the simulation results have to be tested so that any conclusion that may be drawn from the simulation can be accepted with reasonable confidence. In the following validity tests, Hutterite fertility in the United States and post-war Japanese fertility are used as bench-marks partly because of the availability of reliable data and partly because they represent non-contraceptive and contraceptive populations, respectively. The basic method of the test is (*a*) to estimate all the input variables from published data as precisely as possible, (*b*) to apply those estimates to the model and (*c*) to compare the simulated fertility rates with the actual observed ones. In the course of simulating the Hutterite fertility, a study may be extended to examine the possible range of natural fertility rate under various conditions, since the Hutterite fertility is one of many possibilities. In the case of Japanese fertility, the dynamic feature of the model will be examined in particular by attempting to simulate the fertility transition in Japan during the post-war period, from the late 1940s to the early 1960s.

The Hutterites

The Hutterites are an ethnic group living in several north-western states of the United States of America and neighbouring provinces of Canada. They are known to have the highest fertility ever recorded accurately in human history. Reasonably good data are available for estimating the input variables to the model. The singulate mean age at marriage, the proportion of never-married women at age 50 and the proportion of women at various ages whose marriages have been dissolved can be estimated on the basis of information given in the Eaton and Mayer study.[13] The level of sterility is assumed to be "low" because their sterility rates by age resemble closely the European model (low) in our set of estimates according to the same study. Mortality conditions of the population are believed to be slightly better than those of the general population of the United States of America but a little poorer than those of the South Dakota population. Thus, the expectation of life at birth for both sexes around 1940 was estimated at 60 years. Regarding breast-feeding, Tietze reports that it is the general practice among the Hutterites, and "at the age of six months, however, most infants appear to be at least partially weaned and breast-feeding beyond the first year of life is very uncommon".[14] From those observations, the average duration of breast-feeding is estimated at eight months. For other input variables, no couple is assumed to have a desire to limit their family size, nor to prefer to maintain a certain birth interval. Contraceptive practice and induced abortions are not assumed to be present.

[13] Joseph W. Eaton and Albert J. Mayer, "The social biology of very high fertility among the Hutterites, the demography of a unique population", *Human Biology, A Record of Research*, vol. 25, No. 3 (September 1953), pp. 206–264.

[14] Christopher Tietze, "Reproductive span and rate of reproduction among Hutterite women", *Fertility and Sterility*, vol. 8 (1957), pp. 89–97.

Three types of fertility indices for the Hutterites, that is, age-specific fertility rates, distribution of women by age and parity and birth intervals, are compared with the simulated results in the following tables 1, 2 and 3. With respect to the total fertility rate, the result of the simulation, namely, 8.68, happens to be identical with the observed rate. This agreement is, however, not totally surprising because, as already discussed in the previous chapter, some of the biometric parameters, such as fecundability, were deliberately adjusted so that the simulation results became closer to the Hutterite fertility. There are a few discrepancies in the pattern of age-specific fertility rates but they do not seem to be very important in the light of much wider variations in the observed Hutterite fertility rates themselves for three different periods: 1926–1930, 1936–1940 and 1946–1950 (see table 1).

Table 1. Comparison of the observed and simulated total fertility rates, age-specific fertility rates and crude birth rates of the Hutterites

Age group	*Observed*[a] *in 1926–1950* (1)	*Simulated* (2)	*Difference* ((2)–(1)) (3)
15–19	14.0	17.0	3.0
20–24	252.7	271.0	18.3
25–29	421.9	423.3	1.4
30–34	416.7	413.3	−3.4
35–39	376.7	359.3	−17.4
40–44	216.7	210.3	−6.4
45–49	37.7	40.7	3.0
Total fertility rate	8.68	8.68	0
Crude birth rate[b]	49.2	48.7	−0.5

[a] Average of the three periods: 1920–1930, 1936–1940, 1946–1950 from J. W. Eaton and A. J. Mayer, "The social biology of very high fertility among the Hutterites, the demography of a unique population", *Human Biology, A Record of Research*, vol. 25, No. 3 (September 1953), p. 227.

[b] Computed from the observed and simulated age-specific fertility rates and the sex-age composition of the Hutterite population in 1950.

The average parity of women over 45 seems to have small differences: the observed 8.97 *versus* the simulated 8.89. However, differences in this "completed" family size as well as in the distribution of ever-married women by parity should not be taken too seriously, because (*a*) the actual observation is based on a relatively small sample of 340 women, while the simulation is based on 1 000 women, and (*b*) the actual observation includes women from ages 45 to 85, thus probably being subject to effects of differential mortality and omission of dead children, while the simulation results refer only to those aged 45–49 (see table 2). The similarity and dissimilarity in birth intervals should also be viewed carefully because of the relatively small observations from the Hutterites, numbering 1 040 observed intervals. Incidentally, the birth intervals mentioned here exclude the intervals between marriage and first birth, which are appreciably shorter than the intervals between births (see table 3). In sum, the simulation results may be found to be reasonably close to the actual observations. We conclude that there is no indication that the model is unsuitable for simulating fertility rates for a non-contraceptive population.

TABLE 2. COMPARISON OF THE OBSERVED AND SIMULATED DISTRIBUTION OF EVER-MARRIED WOMEN OF AGE 45 AND ABOVE BY PARITY FOR THE HUTTERITES

	Percentage distribution		
Parity	*Observed*[a] *1950* *(1)*	*Simulated for ages 45–49* *(2)*	*Difference ((2)–(1))* *(3)*
0	2.9	5.3	2.4
1	1.2	1.9	0.7
2	2.6	1.6	−1.0
3	2.9	2.4	−0.5
4	2.9	4.3	1.4
5	4.1	2.7	−1.4
6	5.9	4.3	−1.6
7	7.6	7.7	0.1
8	9.1	7.9	−1.2
9	12.4	10.6	−1.8
10+	48.3	51.4	3.1
Average parity	8.97	8.89	−0.08

[a] Distribution of 340 women aged 45–85. J. W. Eaton and A. J. Mayer, "The social biology of very high fertility among the Hutterites, the demography of a unique population", *Human Biology, A Record of Research*, vol. 25, No. 3 (September 1953), p. 235.

TABLE 3. COMPARISON OF THE OBSERVED AND SIMULATED BIRTH INTERVALS FOR THE HUTTERITES

(*Months*)

Age of mother[a]	*Observed*[b] *(excluding last intervals)*	*Simulated*
Under 25	22.8	23.0
25–29	24.9	22.5
30–34	25.1	23.3
35 and over	25.7	25.5

SOURCE: C. Tietze, "Reproductive span and rate of reproduction among Hutterite women", *Fertility and Sterility*, vol. 8 (1957), p. 95, table 5.

Notes:

[a] Mother's age refers to the beginning of intervals in Tietze's observation but it refers to the ages at the end of intervals in the simulation.

[b] Number of intervals from which the above average lengths are derived: 1 040 in the observation and 7 790 in the simulation.

Now let us examine what the simulation by the present model can tell us about the possible range of the natural fertility which presumably varies considerably with respect to level and age pattern. Partly for the sake of testing the model and partly for the sake of curiosity to know why and how natural fertility can vary, several simulations were conducted by giving different but plausible values to the following input variables: age at marriage, expectation of life at birth, duration of breast-feeding and level of sterility.

Here the standard simulation was that of the Hutterites and for each variant simulation one input variable was replaced by a new value while keeping all other input variables unchanged at the Hutterite levels. In the first variant, for example, the mean age at marriage of 22.6 years for the Hutterites was replaced by 18.0 years to represent an early marriage pattern. In the second variant, the same input variable was given a new value of 27.0 years, which represents a late marriage pattern, and so forth. At the bottom of table 4, however, there appear two variants in which all four input variables, except for the sterility level, are different from those of the Hutterites. Here the input variables which gave higher or lower fertility rates in the preceding variants are put together respectively to simulate the highest and the lowest fertility rates within the given range of the input variables.

TABLE 4. SIMULATED VARIATION IN NATURAL FERTILITY BY CHANGING EACH VARIABLE WHILE KEEPING THE REMAINING CONSTANT AT THE HUTTERITE LEVELS

Variants of simulation	*Simulated total fertility rate*	*Simulated crude birth rate*[a]
Standard (The Hutterites)[b]	8.7	48.7
Variant		
1. With mean age of marriage = 18.0	10.0	59.7
2. With mean age of marriage = 27.0	6.8	34.8
3. With duration of breast-feeding = 2 months	9.8	54.6
4. With duration of breast-feeding = 12 months	8.2	45.4
5. With duration of breast-feeding = 18 months	7.3	41.1
6. With expectation of life at birth = 46 years	8.9	49.6
7. With expectation of life at birth = 72 years	8.5	47.6
8. With sterility level = medium	8.1	45.6
9. With sterility level = high	7.3	42.7
10. Highest possible fertility to be simulated from the combination of the above control variables	11.2	66.7
11. Lowest possible fertility to be simulated from the combination of the above control variables	4.5	24.2

[a] Crude birth rates are computed from simulated age-specific fertility rates and the observed age-sex composition of the Hutterites in 1950.

[b] The levels of the variables for the Hutterites are: mean age of marriage: 22.6 years old; breast-feeding period: 8 months; expectation of life at birth: 66 years; and sterility level: low.

According to the simulation presented in table 4, the possible range of variation in the natural fertility rate seems to be quite wide. Crude birth rates so calculated are 66.7 per 1 000 for the highest possible fertility combination and 24.2 per 1 000 for the lowest combination. Total fertility rates are 11.2 for the highest and 4.5 for the lowest. Levels of natural fertility observed by Henry,[15] that is, between 10.9 and 6.2 in total fertility rate, are found well within the simulated range from the highest and lowest fertility combinations. The relative importance of the variables contributing to this hypothetical variation in the simulated natural fertility are the age at marriage, the duration of breast-feeding, the level of sterility and the level of infant mortality rate in descending order of importance. Of these, the difference in mean age at marriage between 18 and 27 years, other things remaining unchanged, could explain almost 45 per cent of the above-mentioned maximum variation. The contribution of other factors are about 35 per cent by the variation in the length

[15] Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. 8, No. 2 (1961), pp. 81–91.

of breast-feeding period, about 15 per cent by the variation in the sterility level, and about 5 per cent by the variation in the infant mortality rate. The validity of these conclusions depends, among other factors, upon the accuracy of assessment of the high and low sterility rates, as well as the adequacy of formulation of the relationship between the breast-feeding period and the post-partum infecundity, which were briefly mentioned in the section above on main features of the model used. In these findings, one might also wonder why the variation in the level of mortality has relatively little influence upon fertility. It may be understandable, however, since we are dealing with uncontrolled fertility where infant mortality could possibly influence fertility level only through its effects on the length of post-partum infecundity.

Implications of these findings to the current demographic situations of less developed countries seem to be of some importance. If the basic assumptions of the present simulation model are correct, the existing significant fertility differentials among the less developed countries where family planning is practically absent are not a statistical artifact but may largely be a reflection of health conditions and social customs. And if one wishes to reduce fertility levels in those countries without seeking solutions in family planning, the most important measure appears to be marriage regulation of one kind or another. Also, the duration of breast-feeding plays a very important role. On the other hand, improvement of health conditions may have mixed effects. Improvement in an infant mortality rate has an effect of reducing fertility levels but if it is accompanied by a reduction of sterility level among parents, the two effects may offset each other. However, any further conclusions should not be drawn until the case of Pakistan is studied in the sections below.

Japanese fertility

According to various estimates, the crude birth rate in Japan had probably been fluctuating around 35 per 1 000 from the fourth quarter of the nineteenth century through 1920. Then, a slow decline followed and the crude birth rate reached around 30 in the early 1940s. After the post-war baby boom during 1947–1949 when the crude birth rate climbed again to 34 per 1 000, a spectacular decline occurred, and the same rate fell below 18 in 1957 and after. In this section, an attempt is made to simulate the Japanese fertility trends after the war because it seems to be useful for further testing the validity of the present model in two respects. First, this is a population which widely uses contraception and induced abortion so that the model can be tested for the fertility regulation mechanism. Secondly, it provides an opportunity to test the dynamic features of the model because of the recent fertility transition discussed above. Besides, there are reasonably good data that make a simulation feasible. However, it should be noted that an effort to simulate Japanese fertility for the post-war transition period is quite challenging because of the fact that the normal transition process, whatever it may have been, was obviously disturbed by the war and by the post-war baby boom that followed. Also, the age pattern of Japanese fertility rates is known to be rather unique. It has a strong concentration in the age group 25–29; about 49 per cent of all births in 1970, for example, were born to mothers in this age group. It is interesting to recognise through simulation what kinds of factors are contributing to this unique pattern.

The control variables for the simulation were estimated as follows: the quinquennial population censuses have provided the basis for estimating the singulate mean age at marriage, the proportion of women never-married at age 50 and the proportion of women whose marriages have been dissolved at ages 20, 35 or 50. The expectation of life at birth for each period is available from the official sources. The report of the World Fertility Survey of Japan conducted in 1974[16] has provided the basis for estimating the average number of desired children, contraceptive practice rates and contraceptive methods used. The duration of breast-feeding, recently about four months, was estimated from miscellaneous sources. Average length of desired birth intervals is estimated as 24 months for the first child and 18 months for successive child births for reasons that will be discussed below. The induced abortion rate for the stopping purpose, that is, a ratio of induced abortion to unwanted live births is rather arbitrarily assessed as 90 per cent after 1948, when induced abortion was legalized.

The results of simulations are presented in tables 5 and 6. In terms of trends in total fertility rate, the post-war

TABLE 5. COMPARISON OF THE OBSERVED AND THE SIMULATED FERTILITY TRENDS, JAPAN, 1950–1975

	Total fertility rate		*Crude birth rate*	
Period	*Observed*[a]	*Simulated*	*Observed*[a]	*Simulated*
1945–1949	4.40[b]	4.75	33.6[b]	37.5
1950–1954	3.04	2.93	23.7	22.8
1955–1959	2.15	2.10	18.1	17.6
1960–1964	2.08	2.07	17.2	18.0
1965–1969	2.03	2.13	17.8	19.0

[a] Japan, Ministry of Health and Welfare, *Japan Vital Statistics*, various years.
[b] 1947–1949 only.

TABLE 6. COMPARISON OF THE OBSERVED AND THE SIMULATED AGE PATTERNS OF FERTILITY RATES, JAPAN

	1950–1954		*1960–1964*	
Age group	*Observed*	*Simulated*	*Observed*	*Simulated*
15–19	9.3	1.3	3.8	1.3
20–24	133.3	145.0	110.1	121.8
25–29	206.3	227.5	193.1	212.5
30–34	146.9	121.0	83.5	59.3
35–39	78.4	65.0	21.7	14.3
40–44	24.1	24.0	4.2	5.5
45–49	1.4	1.3	0.3	0.3
Total fertility rate.	3.04	2.97	2.08	2.07

[16] Japan, Ministry of Health and Welfare, Statistics and Information Division, *Sekai Shussan-ryoku Chosa Hokoku*, Report of the World Fertility Survey, Japan, 1974 (Tokyo, 1976).

baby boom and subsequent fertility decline are reproduced by the simulation with moderate approximation. According to the simulation results, total fertility rate dropped from 4.8 in 1945–1950 to 2.1 in 1960–1965, which may be compared with the drop in total fertility rate of 4.4 (1947–1949) to 2.1 in the vital statistics recorded for the same period. If the simulation and vital statistics data are compared with each other with respect to crude birth rate, similar approximation may also be found. Regarding the shape of age-specific fertility rates, after some trial and error which will be described shortly, we could simulate a series of age-specific fertility rates which are more or less comparable to the actual observations. Two typical cases are presented in table 6.

If the simulation results on Japanese fertility are judged to be acceptable, it may be useful to reflect once again upon the input variables that brought about such results. Three factors may be pointed out as having caused the rapid decline of fertility in the simulation. They are better access to more effective contraceptive methods and the introduction of legal abortion. The contraceptive practice rate, which was estimated at about 70 per cent for the pre-war period and rose to 95 per cent in recent periods, also helped the fertility decline. In the pre-war periods, especially since around 1935, birth control had been regarded by the Government as a dangerous movement to be suppressed. Thus, contraception was not encouraged and contraceptive methods that were available were condoms of inferior quality and such non-instrumental methods as abstinence or withdrawal. But after the end of the war in 1945, the public attitude towards birth control was completely reversed and better-made condoms also became available. In addition, other modern contraceptive methods, including rhythm, IUD, diaphragm and jelly, became available for wide use. Induced abortion, which was legalized in 1948, was also responsible for the reduction of fertility. For example, the induced abortion ratio to 100 live births was 101 in 1950–1955, decreasing to 45 in 1970–1975, according to the simulation; whereas the reported induced abortion ratios were 68 in 1955 and 28 in 1972 according to official sources. Interestingly, however, such fertility reduction was simulated with only a slight decrease in the desired family size over the entire period of observation. This result seems to suggest that a very rapid fertility reduction could occur in a relatively short period of time if the desired family size had already been small and the means for achieving it had become available to the population.

Incidentally, the simulation seems to support the theory that the post-war baby boom was largely caused by the delay in age at marriage during the war period and the postponement of child-bearing to the immediate post-war period.

Regarding the age pattern of Japanese fertility in recent years, its heavy concentration in the age group 25–29 was simulated only after some modification was made regarding the age of marriage. As will be described in annex I, a usual procedure is to select a model nuptiality pattern which corresponds to the given mean age of marriage. The model nuptiality patterns which had been obtained from many actual nuptiality patterns are of two-parameter models. As will be discussed in annex I, such simplicity was preferred in this study over more sophisticated three-parameter models in order to achieve wider applications. But owing to the popularity of higher education and pre-marital work experiences among Japanese girls, marriage in this country is heavily concentrated around the mean age of marriage and seems to have caused a significant deviation from the model pattern. In order to solve this special problem, a method was improvised to deform the standard marriage frequency distribution into a more concentrated distribution around the mean. It was after this modification that age-specific fertility rates, as presented in table 6 for the period 1960–1964, were obtained. In this exercise, two additional input variables about the desired birth interval, that is, two years between the marriage and the first childbirth and one and a half years between successive intervals between births, also contributed to produce the Japanese age pattern of fertility rates.

From the two simulations for the Hutterite and Japanese fertility discussed above, it may be concluded that, if the input variables can be estimated reasonably well, the simulation results would be approximated to the actual fertility fairly well. This is true for both contraceptive and non-contraceptive populations. Similar tests could be made concerning other populations with good data in the future. However, these tests were made through simulating recorded fertility in the past. Here, the main problem was how to estimate the input variables from the available data rather than the possible changes of those variables in the future. Our next and main task is simulation for the future for which input variables must be projected. Here, factors which will affect the future input variables include Governments' population policies in addition to other socio-economic development. These are the subject of study in the following sections.

Application of the model in evaluating alternative policy measures for Pakistan

Pakistan was selected for the case study of evaluating the effects of policy measures by means of micro simulation for two reasons: its definite, if not quantitatively defined, population policy and more importantly, the availability of crucial information from the recent Pakistan Fertility Survey (World Fertility Survey of Pakistan). In this section, findings in the following four areas will be presented: (*a*) simulation of the current fertility rates for Pakistan; (*b*) evaluation of the effects of changing the value of individual input variables; (*c*) perspectives on fertility change with alternative assumptions of the changing input variables; and (*d*) alternative sets of the input variables to achieve a certain fertility reduction.

Simulation of current fertility rates for Pakistan

The Pakistan Fertility Survey (PFS) of 1975, which was conducted in conjunction with the World Fertility Survey, has provided an estimate of the current fertility level for

Pakistan, as well as other related information needed for the simulation. The survey yielded, among other things, an estimate of crude birth rate of 40.5 per 1 000 for 1974–1975; an estimate of total fertility rate of 6.3; and the age-specific fertility rates of a broad peaked type with the highest specific rate of 314 per 1 000 for the age group 25–29. These estimates are more or less in agreement with the previous estimates obtained from the Population Growth Estimation (PGE) in 1963–1965 and from the Population Growth Survey (PGS) in 1968–1972. Accepting the methodological differences among those surveys, the PFS report concludes that the similarities of the fertility estimates from different sources are "not indicative of any significant change in the fertility level over the period 1963–1975".[17]

The Pakistan Fertility Survey contains data on nuptiality, fecundity, preference of number and sex of children, knowledge and use of contraception, breast-feeding etc., which are essential to run simulations by our model. For example, PFS identifies the percentage of women who are currently using contraceptive methods. Among those who do not want to have more children, 17.1 per cent use some efficient method, 4.1 per cent, inefficient methods; while among those who want to have more children, 2.9 per cent use some efficient method and 0.5 per cent inefficient methods presumably for the spacing purpose. Although the percentage of contraception users is generally quite low, it may be said that uses for stopping purposes are six times as frequent as uses for spacing purposes. Another interesting finding of the survey is that the average length of breast-feeding is 16–17 months among women whose last closed interval exceeds 32 months and whose child survived at least 24 months. The length of breast-feeding seems to be quite stable at 16–17 months according to the survey, except those whose age at first marriage is exceptionally high and those whose education level is secondary and higher. The ideal number of children desired by the currently married women is 4.2 on the average and does not vary significantly by age. The smallest ideal number of children was 4.0 among those in the age group 20–24; the largest was 4.3 among those 40–44.

A computer simulation of fertility for Pakistan was performed in our model on the assumption that the expectation of life at birth and the contraceptive practice rate had been slowly increasing prior to 1975, due to the increasing health and family planning activities in Pakistan, but with other factors, such as age at marriage, desired family size, breast-feeding practice etc., not having changed significantly. The demographic indicators of the dynamic simulation are compared with those of PFS in table 7 below. The simulated fertility level for 1970–1975 happens to be higher than the level obtained from PFS for 1975 but slightly lower than the United Nations estimate for 1970–1975. The simulation yields a total fertility rate of 7.1, whereas the same rate was 6.3 by PFS and 7.2 by the United Nations. In terms of crude birth rate, three

TABLE 7. COMPARISON OF THE OBSERVED AND THE SIMULATED FERTILITY RATES: PAKISTAN, AROUND 1975

	Pakistan Fertility Survey, 1975 (1)	*United Nations estimate, 1970–1975* (2)	*Simulated, 1970–1975* (3)
	Age-specific fertility rates		
Age groups			
15–19	104	170	113
20–24	266	348	362
25–29	314	346	349
30–34	264	281	297
35–39	204	188	197
40–44	93	91	102
45–49	8	19	9
Total fertility rate	6.3	7.2	7.1
Gross reproduction rate	3.1	3.5	3.5
Crude birth rate	40.5	47.6	46.5

corresponding estimates are 47, 41 and 48, respectively.

The results of the simulation are subject to errors to the extent that our assessment of the input variable errs. Especially if our estimate of the expectation of life at birth of 49.8 years for 1970–1975 was too optimistic, the simulated fertility rate could have underestimated the actual rate because, as will be seen very shortly, an improved mortality condition has the effect of reducing the total fertility rate. Incidentally, the PFS report admits that "the actual rate . . . is considered to be higher than those rates. For example, the Planning Commission estimates that the current CBR in Pakistan is about 43–45".[18]

Evaluation of the effects of changing the value of individual input variables

The current high fertility level in Pakistan appears to be, according to the simulation, the consequence of joint effects of young age at marriage of women (16.6 years on the average), a large desired family size (an average of 4.2 children desired), a relatively long period of breast-feeding (16.2 months) and low contraceptive practice rate (21 per cent among those who have already acquired their desired family size) and others. If one wishes to reduce the fertility rate, as the Government of Pakistan does, what kind of strategy must be adopted to achieve it? Is the effort to promote the contraceptive practice enough to bring down the fertility level to a desired one? Would an improvement of contraceptive use-effectiveness help to achieve the same end? Or do other variables, such as age at marriage or desired family size, have to be modified to get satisfactory results? As a first step in answering all these questions, an attempt has been made in this section to evaluate the effects of changes of the individual input variables one by one, while other variables are kept unchanged at the current values for Pakistan. Table 8, below, shows the results of such simulation.

One caution is due here. The simulated fertility rates in table 8 show the cohort rates which would ultimately be

[17] Pakistan, Population Planning Council, *World Fertility Survey, Pakistan Fertility Survey*, First Report (Lahore, 1976).

[18] Pakistan, Ministry of Labour, Manpower, Health and Population Planning, *Pakistan Population Planning Programme, A Profile, 1976.*

TABLE 8. SIMULATIONS OF VARIATIONS OF FERTILITY RATES WITH THE STATIC MODE, WHERE A SINGLE INPUT VARIABLE IS REPLACED BY A NEW ONE WHILE OTHER VARIABLES IN PAKISTAN ARE UNCHANGED AT CURRENT LEVELS

Assumed new level of each control variable with ( ) indicating current level	*Total fertility rate*	*Crude birth rate*
Current fertility in Pakistan[a]	7.1	47
Variant		
Mean age at marriage (16.6 years)		
1. = 20.0 years	6.5	41
2. = 23.0 years	5.8	35
Expectation of life at birth (49.8 years)		
3. = 60 years	6.7	45
4. = 70 years	6.5	44
Level of sterility (medium)		
5. = high	6.4	43
6. = low	7.2	47
Breast-feeding (16.2 months)		
7. = 6 months	7.2	48
8. = 30 months	6.0	40
Percentage of couples who want to limit family size (90 per cent)		
9. = 98 per cent	6.8	45
Desired number of children (4.2 children)		
10. = 3.0 children	6.1	41
11. = 2.0 children	5.9	40
Desired birth interval (18 months)		
12. = 24 months	6.8	45
Contraceptive practice rate for stopping purposes (21 per cent)		
13. = 50 per cent	6.4	43
14. = 70 per cent	6.0	41
15. = 95 per cent	5.8	40
Contraceptive practice rate for spacing purposes (4 per cent)		
16. = 20 per cent	6.8	44
17. = 60 per cent	6.3	41
18. = 80 per cent	6.0	39
Level of contraceptive use-effectiveness (low)		
19. = medium	6.9	46
20. = high	6.5	44
Rate of sterilization among those who have achieved the desired family size (0 per cent)		
21. = 3 per cent	7.1	46
22. = 6 per cent	7.0	46
Rate of induced abortion among those who have achieved the desired family size (0 per cent)		
23. = 5 per cent	7.0	46
24. = 10 per cent	7.0	46
25. = 30 per cent	6.7	45

[a] See table 7.

attained if the given input variables are kept constant for the period of one generation. They are the results of the "static mode" of the simulation. The question of the time perspective for fertility change with successively changing input variables will be discussed in the next section.

Apparently, the promotion of contraceptive practice alone can produce some fertility reduction. An increase of the contraceptive practice rate for stopping purposes from a current level of 21 per cent to 50 per cent, 70 per cent and 95 per cent, would decrease the total fertility rate from 7.1 to 6.4, 6.0 and 5.8, respectively (variant 13–15). In terms of crude birth rate, the reductions would be from 47 to 43, 41 and 40, respectively. A promotion of contraception for spacing purposes seems to produce a similar but slightly less satisfactory result (variant 16–18). Given the current low practice rate for contraception, an improvement of use-effectiveness could hardly improve the situation (variants 19, 20). Voluntary sterilization and induced abortions may not change the situation very much, partly because the current cultural and political situation does not seem to allow a big spread of such means and partly because of people's preference for a large family (variants 21–25).

On the other hand, changes in the demographic variables alone cannot reduce fertility very much either. The single most effective measures are an increase of age at marriage and an increase in the length of the breast-feeding period. An increase of the mean age at marriage from 16.6 to 23.0 would bring the total fertility down from 7.1 to 5.8 and the crude birth rate down from 47 to 35 (variants 1, 2); a lengthening of breast-feeding from 16.2 months to 30 months would lead to a total fertility value of 6.0 and a crude birth rate of 40 (variants 7, 8). However, the reduction of desired family size from 4.2 to 2 children would only result in a reduction of the total fertility rate to 5.9 and of the crude birth rate to 40, apparently due to the prevailing low contraceptive practice (variants 10, 11).

The assumption of single variable change is unrealistic because many variables are likely to change together. Therefore, simulations have been made by changing two or more input variables together. Some of the results are shown in table 9. It is most likely that contraception for stopping purposes and that for spacing purposes will change simultaneously and a combination of practice rate of 95 per cent for stopping and 80 per cent for spacing could bring down the total fertility rate to 4.8 and the crude birth rate to 34 (variants A–C). An improvement of contraceptive use-effectiveness seems to reduce them further but only slightly (variant D–F). Further fertility reductions can also be achieved by raising the mean age of marriage for women (variants G–I). These are significant reductions of the current rates but may not be satisfactory as a permanent level of fertility for this country of over 70 million population. A real fertility reduction can be achieved, according to our simulation, only when a high rate of contraceptive practice is combined with a reduction of desired family size (variants J–L). This condition for fertility reduction may seem to be too ambitious but it must be remembered that, in this last variant, neither sterilization nor induced abortion is assumed at all. When we consider all the factors, a more realistic picture may emerge, as indicated in the next section.

Time perspectives of fertility change

The purpose of this section is to examine through simulations the time perspectives of future fertility reduction in Pakistan if a particular set of population policy measures is chosen and if the time-table for their implementation is given. In this exercise the policy measures adopted need not be limited to one scenario, instead several alternative scenarios will be provided for the simulations. Under the population planning programme for the fifth five-year plan of 1975–1980, population policies are incorporated with socio-economic development programmes, such as rural development programmes, health programmes and school education at

TABLE 9. SIMULATED VARIATIONS OF FERTILITY RATE WITH THE STATIC MODE, WHERE SEVERAL INPUT VARIABLES ARE REPLACED BY NEW ONES WHILE OTHER VARIABLES ARE KEPT UNCHANGED AT THE CURRENT PAKISTAN LEVELS

	Assumptions						
Variant	*Practice rate for stopping*	*Practice rate for spacing*	*Level of use-effective-ness*	*Desired family size*	*Mean age at marriage*	*Total fer-tility rate*	*Crude birth rate*
Pakistan [a] (current)	12	2	low	4.2	16.6	7.1	47
Variants			*New contraceptive practice rate*				
A	50	20	low	4.2	16.6	6.0	41
B	70	60	low	4.2	16.6	5.2	36
C	95	80	low	4.2	16.6	4.8	34
			Improved use-effectiveness added				
D	50	20	medium	4.2	16.6	5.5	38
E	70	60	medium	4.2	16.6	5.1	36
F	95	80	high	4.2	16.6	4.4	31
			Increased mean age at marriage added				
G	50	20	medium	4.2	20.0	5.3	35
H	70	60	medium	4.2	20.0	4.9	33
I	95	80	high	4.2	20.0	4.4	30
			Reduced desired number of children added				
J	50	20	medium	3.5	20.0	4.8	32
K	70	60	medium	2.5	20.0	3.7	26
L	95	80	high	2.0	20.0	2.7	20

[a] See table 7.

primary and secondary levels, supplemented by more comprehensive surveys and reporting systems, and backed up by researches on the promotion of small family norm and delayed marriage and by wider consideration of the relationship between population change and development. All these programmes are directed to a common goal of reducing the nation's currently high birth-rate, which is now considered hazardous for the socio-economic development of the country, although there appears to be no numerically defined fertility goal as such.

The population policies programmed in the past were not very successful and did not accomplish the intended fertility change. In spite of the apparent intensity attached to the current programmes, the real achievement is yet to be seen. However, owing to the active population programmes as well as the programmes for socio-economic development, it would be proper to expect that some of the key input variables of fertility determination in our model would be affected at least modestly. Thus, in the first scenario for the simulation, a moderate increase in the contraceptive practice rate in the future is assumed. Other input variables, such as age at marriage, desired family size, or sterilization, will be kept unchanged in the first variant of the dynamic simulation, because these factors are still at the preliminary stage of study according to the government report.

More specifically, our first assumptions were as follows: the current contraceptive practice rate of 21 per cent among those who do not want any more children would increase to 45 per cent by the end of this century and the contraceptive practice rate for spacing purposes would also increase from the current level of about 4 per cent to 20 per cent during the same period.

In view of the acute problems arising from the rapid population increase in Pakistan, it is possible and even likely that the Government may decide upon more accelerated population programmes in the future. Therefore, the second scenario for the simulation would be that of an accelerated population programme. In this scenario it is assumed that the contraceptive practice rate for the stopping purpose will increase much more rapidly after 1980, reaching 60 per cent by the end of the century. Contraceptive practice rates for spacing will also increase more rapidly in this scenario, reaching 40 per cent in 1995–2000. Although major emphasis is placed on the promotion of a family planning programme in this version of assumptions, a gradual reduction of desired family size is also assumed. In this variant the assumed change is from the currently desired number of 4.2 to 3.4 by the end of the century.

The third scenario on the other hand assumes a more rapid increase of family planning and a moderate change in the social norms. Here, the contraceptive practice rate for stopping will reach 95 per cent and the desired number of children will decline to 2.5 by the end of the century.

The fourth and final variant of the dynamic simulation has been made with assumptions that family planning progress will be much more accelerated and the change in social norms on the desired family size and others will be more rapid. Specifically, it was assumed that the practice rate for the stopping purpose will reach 95 per cent and the desired number of children will become 2.0 by the end of this century. All the assumptions used in the four variants of the dynamic simulations are presented in table 10.

TABLE 10. ASSUMPTIONS USED IN THE FOUR VARIANTS OF THE SIMULATIONS OF FERTILITY FOR PAKISTAN

	Base period	Variant 1		Variant 2		Variant 3		Variant 4	
	1970–1975	1985–1990	1995–2000	1985–1990	1995–2000	1985–1990	1995–2000	1985–1995	1995–2000
A. *Input variables specific to each cohort*									
1. Mean age at marriage	16.6	16.6	16.6	18.0	20.0	19.0	22.0	20.0	24.0
2. Desired number of children	4.2	4.2	4.2	3.8	3.4	3.0	2.5	2.5	2.0
B. *Input variables specific to each period*									
3. Expectation of life at birth (years)	49.8	57.3	61.9	57.3	61.9	57.3	61.9	57.3	61.9
4. Practice rate for stopping (percentage)	21	35	45	45	65	55	85	65	95
5. Practice rate for spacing (percentage)	4	15	20	20	30	25	40	30	50
6. Level of use-effectiveness	low	low	low	low	medium	medium	high	high	high
7 Sterilization rate (percentage)	0	0	1	1	2	2	4	3	4
8 Abortion rate for stopping (percentage)	0	0	0	0	2	2	5	4	10
9. Abortion rate for spacing (percentage)	0	0	0	0	1	1	3	2	6

Summary of assumptions

	Input variables in Group A	Input variables in Group B
Variant 1	No change	Slow change
Variant 2	Slow change	Moderate change
Variant 3	Moderate change	Rapid change
Variant 4	Rapid change	Very rapid change

The four variants of the dynamic simulation, which presumably correspond to four scenarios for the future development of population policies, show clear differences in the future course of fertility change (table 11). The current total fertility rate of 7.1 would decrease to 5.5, 4.1, 2.7 and 2.1 by the beginning of the next century according to the four variants, respectively. The current crude birth rate of 47 per 1 000 would also decrease to 38, 28, 19 and 14 according to the four variants respectively during the same period of time. Incidentally, crude birth rates given in table 11 are standardized for sex and age composition by using the 1970 population composition of Pakistan as the standard. As the table indicates, the relative reduction in the fertility rate in the coming 25 years would be 15 per cent by the first variant, roughly 35 per cent in the second variant, in which somewhat accelerated family planning and a slow change in the social norms are assumed, and over 50 per cent in the third variant, in which more accelerated family planning combined with a moderate change in social norms are assumed. With the fourth variant, in which extreme progress in family planning and rapid change in social norms are assumed, an expected fertility reduction in a quarter of a century would be as much as 65 per cent. These differences are clearly significant.

TABLE 11. SIMULATED FERTILITY TRENDS PRODUCED BY FOUR VARIANTS OF THE SIMULATIONS FOR PAKISTAN

Period	Variant 1	Variant 2	Variant 3	Variant 4
		Total fertility rate		
1970–1975	7.1	7.1	7.1	7.1
1975–1980	6.7	6.7	6.7	6.7
1980–1985	6.4	6.2	6.0	5.7
1985–1990	6.2	5.7	5.2	4.4
1990–1995	6.0	5.1	4.3	3.3
1995–2000	5.7	4.4	3.4	2.6
2000–2005	5.5	4.1	2.7	2.1
		Crude birth rate		
1970–1975	47	47	47	47
1975–1980	45	44	44	44
1980–1985	43	41	40	38
1985–1990	42	38	35	30
1990–1995	40	34	29	23
1995–2000	39	30	23	18
2000–2005	38	28	19	14

Dynamic simulations with a given goal

How can the dynamic simulation help to select a set of policy targets when a certain goal for fertility reduction in a specific time period is given? In the absence of detailed information, this question may be restated as follows: If the most plausible course of fertility change in the near future is believed to be variant 2 in the dynamic simulations and if the Government wishes to achieve a faster fertility reduction comparable to variant 3 but with different policy measures, then what are the possible substitutes?

Instead of trying to increase the contraceptive practice rate or to increase the mean age at marriage, a selection is made of three different policy measures, namely, enforcement of a legal minimum age at marriage, significant improvement in the use-effectiveness of contraceptive methods employed and adoption of induced abortions and sterilizations on a voluntary basis as a policy tool. As shown in table 12, three dynamic simulations with such assumptions failed to achieve the desired fertility reduction. It is only when these three policy measures, together with the reduction in the desired family size to the level assumed in variant 3, are invoked simultaneously that the results are satisfactory. In other words, a set of four policy measures is one of the substitutes for those assumed in variant 3 in the previous section. Therefore, policy makers have now an option to choose one out of two alternative policy packages. The problem would then be to evaluate which policy package is more practical, plausible, economical and politically feasible. The final decision on the choice of policy implementation will be made after considering these factors. Of course, many other policy packages could achieve the same magnitude of fertility reduction.

Population projections according to alternative population policies

This study originated during the preparation of the United Nations population projections as assessed in 1973 when a need was felt to incorporate population policy factors into projections. In this chapter, we will examine the possible ways of making population projections by using the results of fertility simulations. Comparisons will be made between the previous projections prepared by the United Nations and various variants of the projected population trends.

In the United Nations population projections prepared in 1973 assumptions about the future were made separately for fertility, mortality and migration.[19] In the following new projections for Pakistan, mortality and migration assumptions will be kept unchanged from those of the United Nations in order to make comparisons easier. In place of the fertility assumptions, use will be made of the results of four variants of dynamic simulations on age-specific fertility rates which were described in the preceding chapter. Three variants of fertility assumptions, namely the moderate family planning variant, the accelerated family planning variant and the family planning combined with small-family norm and delay

[19] *World Population Prospects as Assessed in 1973*, Population Studies No. 60 (United Nations publication, Sales No. E.76.XIII.4).

Table 12. Simulated fertility trends with alternative set of assumptions about minimum age at marriage, improved use-effectiveness of contraceptive methods, induced abortion and sterilization for Pakistan

Period	*Variant I.* *Minimum age at marriage*	*Variant II.* *Improved use-effectiveness*	*Variant III.* *Abortion and sterilization*	*Variant IV. Combination of 1, 2 and 3, plus desired number of children*
		Total fertility rate		
1970–1975	7.1	7.1	7.1	7.1
1975–1980	6.7	6.7	6.7	6.2
1980–1985	6.2	6.3	6.3	5.5
1985–1990	5.7	5.4	5.5	4.9
1990–1995	5.3	4.8	4.9	4.3
1995–2000	4.8	4.4	4.0	3.4
2000–2005	4.3	4.0	4.1	2.9
		Crude birth rate		
1970–1975	47	47	47	47
1975–1980	44	44	44	39
1980–1985	41	41	40	36
1985–1990	38	36	37	33
1990–1995	34	32	33	29
1995–2000	31	30	30	24
2000–2005	28	27	28	20

Assumptions used	*Minimum age at marriage*	*Level of use-effectiveness*	*Induced abortion rate (percentage)*	*Sterilization rate (percentage)*	*Desired number of children*
1970–1975	none	medium	0	0	4.2
1985–1990	19.0	high	20	2	3.0
1995–2000	19.0	high	35	10	2.5

marriage variant seem to be somewhat comparable to the high, medium and low variants of the United Nations 1973 projections. The fourth may be labelled as an extra-low variant in comparison. However, possible projection assumptions have not necessarily been confined to these four family planning variants. In fact, four variants of simulations were made from more or less arbitrary assumptions on the input variables. Questions may therefore arise about the criteria by which projection assumptions may be formulated.

In the case of Pakistan, simulated fertility trends seem to give a wider variation in future fertility assumptions than the United Nations three variants. For example, the total fertility rate expected to be achieved by the end of this century ranged between 2.6 and 5.7 according to the simulations, whereas the range was between 4.1 and 4.9 according to the United Nations projections as assessed in 1973 (table 13). This would probably mean that the possible range of future fertility change is much wider than is generally considered. This conjecture may be confirmed if one sees that the above simulations have been made by assuming changes in the limited number of input variables and the results could vary even more widely if all the possible values of the input variables are tried out. Moreover, there also seems to be a notable variety in the alternative paths to the final level of fertility within the observed period. For example, variant 2 in the simulated fertility has about the same total fertility rate for 1995–2000 as the medium variant of the United Nations projections but the decline in fertility is apparently much more rapid in the simulations than in the United Nations projections.

Pakistan's population of 60 million in 1970 would grow to 159 million or 128 million by the end of this century according to variants 1 and 4 based on the simulations. The possible range of variation in 2000 will be 31 million. The annual growth rate of population will stay at 3 per cent or more according to variant 1, slightly decreasing from 3 per cent to 2.7 per cent according to variant 2, decreasing more rapidly to 1.9 per cent according to variant 3 and dropping to 1.6 according to variant 4 (table 14).

TABLE 13. COMPARISON OF NEW FERTILITY ASSUMPTIONS ON TOTAL FERTILITY RATE WITH THOSE OF THE UNITED NATIONS AS ASSESSED IN 1973, PAKISTAN, 1970–2000

	New assumptions				*United Nations assumptions*		
Period	*Variant 1*	*Variant 2*	*Variant 3*	*Variant 4*	*High*	*Medium*	*Low*
1970–1975	7.1	7.1	7.1	7.1	7.2	7.2	7.1
1975–1980	6.7	6.7	6.7	6.7	7.2	7.0	6.7
1980–1985	6.4	6.2	6.4	6.4	6.8	6.6	6.2
1985–1990	6.2	5.7	5.2	6.2	6.3	6.0	5.5
1990–1995	6.0	5.1	4.3	3.3	5.7	5.2	4.9
1995–2000	5.7	4.4	3.4	2.6	4.9	4.5	4.1

TABLE 14. COMPARISON OF TOTAL POPULATION TRENDS BY NEW ASSUMPTIONS WITH PREVIOUS UNITED NATIONS, ASSUMPTIONS, PAKISTAN, 1970–2000

	Projections based on the results of simulations				*United Nations projections*		
Year	*1*	*2*	*3*	*4* *(millions)*	*High*	*Medium*	*Low*
1970	60	60	60	60	60	60	60
1975	70	70	70	70	71	71	70
1980	82	82	81	82	84	83	82
1985	96	96	94	94	100	97	95
1990	114	113	108	107	117	113	108
1995	135	130	121	118	136	130	123
2000	159	149	133	128	157	147	137
Period				*Annual rate of increase (percentage)*			
1970–1975	3.0	3.0	3.0	3.0	3.1	3.1	3.0
1975–1980	3.1	3.2	3.0	3.2	3.4	3.2	3.0
1980–1985	3.2	3.2	2.9	2.9	3.4	3.2	2.9
1985–1990	3.3	3.1	2.7	2.4	3.3	3.0	2.7
1990–1995	3.3	3.0	2.3	1.9	3.0	2.7	2.5
1995–2000	3.3	2.7	1.9	1.6	2.8	2.5	2.2

Conclusion

The possibility of applying a computer micro-simulation model to the evaluation of population policy measures and concomitantly to the population projections has been explored. With respect to the substantive findings, one of the most important conclusions may be found in the simulation results which clearly indicate the limited potential of family planning programmes in the effort to reduce fertility levels. If a family planning programme consists in the promotion of contraception, sterilization and/or induced abortion on a voluntary basis, it may not be able to bring a fertility level down sufficiently in a country such as Pakistan where most people prefer a large family. As was shown in table 9, an improvement of the contraceptive practice rate from the current level of 21 per cent up to 95 per cent among those who are eligible to use contraception, for example, could decrease the current total fertility rate in Pakistan of 7.1 to 4.8, and the crude birth-rate of 47 to 34. The reduction is about 30 per cent but may still be too low to moderate the unfavourable effects of rapid population increase on the social and economic development of the country.

The simulation results indicate that, if people in a society with high fertility goals use contraceptive methods only when they are motivated to do so, a family planning programme must be combined with some measures aimed at reducing desired family size. It has also been shown that the desire among couples to keep a proper interval between successive births must be another important target of policy measures. In addition to these behavioural factors, women's age at marriage appears to be a crucial social factor which is quite effective in achieving a fertility reduction, if used as a policy measure.

As discussed above, child mortality and adult sterility, both subject to change with the improvement of health conditions in a country, have opposite effects of some importance on fertility change. Breast-feeding also seems to make a substantial contribution as a factor affecting fertility. All these points in addition to those mentioned in the previous paragraphs suggest that an effective population policy must consist of a well-balanced package of all relevant measures. Choice of such measures should be made partly upon a consideration of their feasibility and partly upon their relative effectiveness. In a variety of situations, a simulation model similar to the present one could be useful for such a task of designing a most effective policy package aimed at influencing fertility prospects.

Regarding the technical aspects of the present study, it may be agreed that a micro-simulation model with bio-demographic components such as the present one can be useful to simulate fertility rates under a variety of conditions, especially where data are limited. The use of the model for developing nations has thus become possible by the selection of rather simple input variables and by their conversion into probability distributions. Because of this process of conversion, the model appears to be capable of reproducing fine characteristics of fertility rates of various kinds in spite of simplistic input variables. Even when all input variables could not be estimated from reliable data, a few trials at substituting alternative estimates for the few input variables could bring about acceptable levels and patterns of fertility.

Moreover, the micro-simulation model with a dynamic feature as developed in this study can simulate a time series of fertility changes under changing conditions. This dynamic feature makes it possible to simulate not only past but also future fertility trends by assuming future input variables expected as a result of implementation of population policies or socio-economic development in general. It is this characteristic of the model that is useful for the evaluation of policy impact on fertility. If we can estimate future trends of the input variables with and without certain policies, then the difference in the simulated fertility rates demonstrate the expected policy effects. It has been shown in this study that such simulations are useful in two ways: first, in making an appraisal of the current population programmes and, secondly, in formulating more effective and more appropriate policy packages.

If the simulated future fertility trends are used in population projections, it would be possible to give more substantial meaning to the assumptions under which projections are made. In place of the traditional high, medium and low variants, we could have, for example, no policy variant, policy A variant, and policy B variant etc. Although simulation may not improve the predictability of the future population change very much, it should be useful at least for planning for development.

It may generally be agreed that the simulation model can add a new approach to the study of fertility and population policies. But application of the model to a few populations seems to suggest a need for further refinement in three respects. The first is the closer evaluation of specific policy programmes in the selected countries. The study so far has been done for Pakistan by assuming probable combinations of the input variables as the result of alternative policies. But evaluation may need to be done more systematically, taking into consideration every possible policy measure such as sterilization, more effective contraceptive methods, breast-feeding practice, birth intervals and so on. After these individual evaluations, it would become possible to delineate the most effective combination of policy measures under the given conditions. This line of research can ultimately be expanded to facilitate policy goal setting, such as a reduction of fertility rate to the replacement level within a certain period of time and so on. The model could provide a number of ways to accomplish such a target.

Another aspect of needed research is the study of trends and differentials of some input variables in the context of development. Desired number of children, for example, would be primarily a function of social and economic development. How it will change in the presence or absence of population policies is the topic of research needed to improve the preparation of the input variables for the simulation. And this line of study will make it possible to link the present scheme of fertility micro-simulation with a macro model containing socio-economic and demographic variables.

Finally, the application of the simulation results to population projections requires more preparatory works. Obviously, it is not feasible to obtain detailed information about population policy implementation for a large number of countries. Probably what is needed for applying the simulation model is a simplification of alternative policy scenarios in order that several typical future courses of fertility can be prepared for projections.

Annex I

TECHNICAL NOTES

The major features of the model have already been discussed in the report. The following are explanations of the details of the model structure.

AGE AT MARRIAGE

The age at marriage for individual women, excluding those who never marry, will be decided on the basis of the input variable "singulate mean age at marriage" (SMAM) with the aid of model nuptiality tables which have been prepared specifically for this study. The model nuptiality tables consist of 23 sets of nuptiality schedules each of which shows a schedule of cumulative relative distribution of ever-married women by age. Each of these schedules corresponds to a singulate mean age at marriage which extends from 16.0 to 27.0 years of age, with half-year intervals (see example in annex II, table 15). An interpolation from two adjacent model nuptiality schedules will be made if the given input variable falls between the two levels in the model schedules. After a nuptiality schedule is established for the cohort of women, the age at marriage for individual women will be decided by the Monte Carlo method.

The model nuptiality tables were prepared in the following way. First, data were collected from nearly 100 countries about the proportion of women who are ever-married, by five-year age groups. After scrutinizing apparently erroneous data, the singulate mean age at first marriage (SMAM) and the proportion of women never-married at age 50 were computed for each set of data. Each set of data was then standardized so that the proportion never-married at age 50 became zero. The standardized data were then grouped by the level of singulate mean age of marriage, from which the average age-specific proportions of ever-married women was computed for every level. Then the proportions by *single year* of age were computed from the grouped estimates through an interpolation by Sprague formulae. The final results were obtained after minor adjustments at the lower and upper ends of the distribution. A further interpolation of the model schedule into months of age is done by the computer using a conventional linear interpolation method.

This method, as briefly discussed here and also in the section on main features of the model used, has an advantage for this study over the more conventional methods of using a nuptiality life table function providing marriage probabilities by age. One limitation of the conventional method is that there is seldom a nuptiality life table readily available for developing countries and constructing it each time would be tedious and laborious. Moreover, if the conventional method is used, a large number of random numbers (R) must be generated in order to be compared with monthly probabilities of marriage (p), month after month until $R < p$ is found. This is more expensive in terms of computer time because it is necessary to repeat the procedure to a maximum of 420 times to cover a woman's reproductive life span from 15 to 50 years of age. On the other hand, the advantage of the proposed method is that it requires only a single random number to select the age of marriage for a woman, a considerable saving of computer time.

The model nuptiality schedules outlined above are what may be called a one-parameter model and concomitantly less flexible than the two-parameter model similar to the model nuptiality table proposed by Ansley Coale.[a] In spite of its theoretical superiority, the Coale model seems to pose two practical problems. First, the quality of nuptiality data obtained from less developed countries often fails to match the level of precision the Coale model requires. Secondly, the nature of the three parameters used in the Coale model may not be very practical for the purpose of this study in which the parameters are to be used as policy measures. For example, it would be much more sensible for a policy planner to say that the mean age at marriage has to be increased from 16 to 18 years of age than to suggest changes in certain parameter, a and k, which are more difficult to translate into policy terms.

[a] Ansley J. Coale, "Age pattern of marriage", *Population Studies*, vol. 25, No. 2 (July 1971), pp. 193–214.

EXTENT OF MARRIAGE DISRUPTION

A marriage may be dissolved by divorce, separation or death of a spouse. In the present model these events are treated in a simplistic way because accurate data are difficult to obtain, especially from less developed countries, and the choice of a method on this matter does not seem to affect the results of simulation very much. When the pattern of change in the percentage of women at each age group whose marriages were dissolved and who had not remarried was analysed, it was found that the percentage often starts increasing very rapidly after age 35 in many countries. On the basis of this observation, it is assumed in the present model that the percentage of those in post-marital states increases linearly from 15 to 35 years and from 35 to 50 years of age separately. The post-marital percentages for these pivotal ages will be estimated easily from censuses. The computer then will automatically compute the schedule of percentages of those whose marriages were dissolved by single months of age for the cohort. The age of marriage dissolution for individual women will then be decided by the Monte Carlo method.

In this simulation model a remarriage is implicitly allowed for, since marital disruption estimates refer to those who are currently disrupted, i.e., to those who had not remarried. In this sense we are modelling "net" disruptions rather than "gross" ones.

NEVER-MARRIED WOMEN

When the model nuptiality table is used to decide the individual age of marriage, an allowance should be made for women who will never marry before age 50. This allowance is made in the present model by the use of an input variable, "Proportion of women never-married at age 50". If, for example, 5 per cent of women do not marry, the nuptiality schedule will be deflated by that much. A woman will be treated as never-married, in this instance, if a random number to decide the age at marriage happens to be between 0.95 and 1.00.

PERMANENT STERILITY

In the present model, all women, except for those who never become fecund, are assumed to be fecund at age 15, although in reality some women may yet acquire fecundity after age 15. This treatment was chosen for the sake of simplicity. The possible deviation of the assumption from reality can only be small, since the assumed fecundability functions give very low probability of conception in ages immediately following 15.

Several studies show that the proportion of sterile couples by age of women considerably differs from one population to another. For example, Louis Henry compares a low sterility among European populations with a higher one among the rural population in pre-war Japan.[b] Christopher Tietze also reported on the low sterility level among the Hutterites,[c] which may be compared with moderately higher levels of sterility among Australian couples reported by John C. Caldwell, *et al.*[d] Considering these sterility differentials among populations, three model schedules of proportion of sterile couples by age of women, each of which represents the high, medium or low sterility level of population, have been assembled for use in this study (annex II, table 16).

[b] Henry, *loc. cit.* pp. 81–89.

[c] Tietze, *loc. cit.*

[d] John C. Caldwell, Christabel Yound, Hellen Ware, Donald Lavis and Ahn-Thu Davis, "Australia: knowledge, attitudes and practice of family planning in Melbourne, 1971", *Studies in Family Planning*, vol. 4, No. 3 (March 1973), pp. 49–59.

One of the input variables, "levels of sterility", will be used to select one of the three model schedules which appears to be most suitable to the population under investigation. Once a model sterility schedule is chosen for the cohort of women in question, the computer programme will assign each woman an age at which she becomes permanently sterile by the Monte Carlo method.

REPRODUCTIVE LIFE SPAN

The reproductive life span in the present model begins with marriage and ends with marriage dissolution or loss of fecundity, whichever comes first. The reproductive life span would be zero if no marriage takes place or if permanent sterility comes before a marriage takes place.

Although fecundity or infecundity is related to both husband and wife, it is expressed as a woman's attribute in the model. For example, when the husband becomes infecund, the wife is treated as becoming infecund. Therefore, the model schedule of sterility is given only according to the age of wife. Temporary sterility due to conception and post-partum amenorrhoea is not considered as termination of fecund status according to the above definition. That is, sterility that accounts for delimitation of the reproductive life span is the only permanent sterility.

The reproductive life span of each woman in the simulation can be decided as follows. If A, B and C represent the starting age of marriage, marriage dissolution and permanent sterility respectively, then

(1) If $A \geqq B$, No reproductive life span;
(2) If $A \geqq C$, No reproductive life span;
(3) If $A < B \leqq C$, Reproductive life span: A to B;
(4) If $A < C < B$, Reproductive life span: A to C .

FOETAL MORTALITY RATE

Intra-uterine mortality rates are very difficult to estimate correctly. Leridon reviewed several relevant studies and concluded that an over-all intra-uterine mortality rate would be as large as 20–25 per cent of total conceptions. Based on the study by French and Bierman, he also gave his estimates of intra-uterine mortality rates by the age of women. However, when Leridon's estimates were used in our model, it appeared that the age differentials in the intra-uterine mortality rates were too large to produce satisfactory simulation results for the Hutterites. To avoid this difficulty, a new set of intra-uterine mortality rates by the age of women was prepared based on the original estimates by age of French and Bierman but keeping Leridon's estimate for the over-all rate unchanged (annex II, table 17). In the simulation new estimates were further interpolated by the Karup-King formula into single years of age.

DESIRED FAMILY SIZE

When contraception is practised, actual probability of conception will be reduced to a fraction of the original fecundability. In the present model, contraception is introduced only when there are some motivations for it, namely, limitation of family size and spacing of childbirths. The motivation to limit family size is introduced when the expected number of surviving children reaches or exceeds the desired number. Therefore, the desired number of children for individual couples plays a critical role.

The average desired family size varies considerably from one population to another and from one generation to the next. At the same time, the desired family size also varies among individual couples within a population. Therefore, it is necessary in the simulation to give the average number of children desired in the population and the corresponding distribution of couples by the desired number. On the basis of the latter, a desired family size can be assigned to individual couples by the Monte Carlo method. Although the average number of desired children could be obtained from a KAP-type survey, it is very difficult to obtain information on the frequency distribution for it. Because of this difficulty a *Beta* distribution is used in the present model.

Regarding the desired family size, it must be mentioned here that there is sometimes quite a substantial proportion of couples who leave their preference to God or otherwise fail to express a numerical target. Then, the average number of desired children is presumably computed by excluding them from the calculation. Although it is not clear whether these couples are just not interested in thinking about it or indeed prefer a large family size, the end results indicate a lack of concern for contraception. Therefore, in the simulation model a distinction is made between those who want to limit family size and those who do not. Selected desired numbers are assigned only to the former groups designated by an input variable, "proportion of couples who have a desired family size". And those who did not fall in to this group are treated as having no motivation for contraception for limitation of their children, although they may have a motivation for spacing of children.

SURVIVING AND EXCESS NUMBER OF CHILDREN

The survival of a new-born baby has two implications in the model. In one way, infant death will affect length of lactation and hence post-partum infecundity. In another, survival of the infant is a key element in conjunction with the number of children which would motivate a couple to stop further childbearing. The survival of children is determined in our simulation model in the following way.

The life span of each child born alive is estimated individually according to the life table function of l_x. In the first place, a proper schedule of l_x will be selected or interpolated from the model life tables. For this purpose, the West models of the Princeton regional model life tables are used. The input variable on "expectation of life at birth" will be used for the selection and interpolation of the survival ratio schedule. Secondly, whether the baby survives beyond 12 months is decided by comparing l_1 value with a random number. If he or she happens to survive one year or more, the same random number will be used again against the series of l_x values to determine how long he or she can survive. On the other hand, if the child is found to live less than one year, the simulation moves to the next step using the table of the model distribution of infant deaths by survival months (annex II, table 19).

It is known that the patterns of monthly survival of infants within a year after birth are different for high and low mortality populations. Infant deaths are presumably heavily concentrated in the early months in a low mortality population. However, since there are only a few reliable data on the survival of infants by months and no model life table provides monthly survival rates of infants, three model schedules of infant mortality by months have been prepared, representing respectively a high, medium and low mortality condition (annex II, table 19). Data used for the preparation of the model schedules were taken from Mauritius (1962–1966) to represent the high mortality condition and Sweden (1962–1966) to represent the low mortality condition, respectively. The model schedule to represent the medium mortality condition was obtained by taking the average of the two schedules mentioned above. The computer then selects the high mortality model if the expectation of life at birth is less than 50 years, the medium model if 50 years or more but less than 65 years, and the low mortality model if 65 years or more. Another random number was used to determine how many months the child is going to survive according to the selected model schedule of infant mortality by months.

The longevity of each child is then converted into the mother's age at the time of his or her death. Thus it becomes possible to count the number of surviving children when their mother reaches 50. The "excess" number of children is defined as the difference between the desired number of children and the expected number of children surviving by this age of the mother.

SPACING OF CHILDBEARING

Another type of motivation towards contraception or induced abortion which is incorporated in the simulation model is the desire for spacing of births. The input variable on "desired birth intervals" will give two kinds of desired birth intervals:(*a*) from marriage to first birth, and (*b*) interbirth interval. However, the possible variation in the desired birth intervals among individual couples is not included in the model because of the complete lack of data on the subject. Incidentally, the distinction between the marriage-to-first-birth and the interbirth intervals has been found significant in shaping the age pattern of fertility.

Contraceptive methods and their use-effectiveness

It is known that a couple often uses different contraceptive methods at different times in their reproductive life span. It is not so rare to find a couple who uses plural contraceptive methods simultaneously or interchangeably. But for the sake of simplicity, it is assumed in this simulation study that a couple uses a single method of contraception throughout their reproductive life span. The selection of a method by each couple is made by a random number on the basis of the input variable on "frequency distribution of contraceptors by methods". The methods are grouped in the following 10 items (1) IUD, (2) orals, (3) condom, (4) withdrawal, (5) rhythm, (6) diaphragm and jelly, (7) abstinence, (8) douche and (9) other.

Once contraception is practised, fecundability would be reduced by as much as the chosen method is effective. In this connexion, there are two questions which call for some attention, namely a question concerning the choice of measurement of use-effectiveness and another concerning the relationship between use-effectiveness and residual fecundability. With regard to the measurement of contraceptive effectiveness, the method used here is extended use-effectiveness. Choice was made as the measurement most suitable to the present model primarily because only one method should be chosen by a woman in the model even though the couple may stop using or change the method. The second reason for preferring the extended use-effectiveness to the simple use-effectiveness is that the residual fecundability implied from the extended use-effectiveness has been found relatively stable over various durations of use. As illustrated in the table below, the implied residual fecundability from data on the use of the pill in the Philippines is almost constant at 0.02 for the duration of use for 6, 12, 18 or 24 months.[e] On the other hand, the simple use-effectiveness implies a residual fecundability which varies considerably as the duration of use increases.

Comparison of simple and extended use-effectiveness of pill as expressed by cumulative failure rate and implied residual fecundability, Philippines, 1972

Months of use	*Failure rate* — *Simple use-effectiveness*	*Failure rate* — *Extended use-effectiveness*	*Implied residual fecundability* — *Simple use-effectiveness*	*Implied residual fecundability* — *Extended use-effectiveness*
6	2.0	12.3	0.0033	0.022
12	3.2	22.3	0.0027	0.021
18	3.7	30.2	0.0021	0.020
24	4.1	36.4	0.0017	0.019

Extended use-effectiveness for specific methods would vary depending on skill, continuation and shift of method. It is probably safe to assume, for example, that extended use-effectiveness is higher for the highly educated population than for the less educated population. For this reason, the extended use-effectiveness has been estimated for three levels of effectiveness (table 20). And an input variable, "Level of extended use-effectiveness of contraceptive method", can designate a proper set of estimations. Once the selection is made, the computer programme will automatically convert the extended use-effectiveness into a residual fecundability.

Residual fecundability

When the extended use-effectiveness which is expressed by the cumulative failure rate after 12 months of use is given, the residual fecundability, or the implied monthly probability of conception with the use of the method, will be computed as follows:

If a residual fecundability per month is given as p, the failure rate e (12 months) may be equal to

$$e = 1 - (1-p)^{12}$$

That is,

$$p = 1 - \sqrt[12]{1-e}$$

If f stands for the fecundability, the ratio of the residual fecundability to fecundability will be

$$R = \frac{p}{f} = (1 - \sqrt[12]{1-e})/f$$

Since an extended use-effectiveness often refers to women at the prime ages, the ratio of a residual fecundability to a fecundability, R, may be equal to:

$$R = (1 - \sqrt[12]{1-e})/0.28$$

The residual fecundability, $ff(a)$, which may also change with age will be given as:

$$ff(a) = f(a) \times R$$

Induced abortion rate and the result of conception

The input variable "induced abortion rate" refers to either an abortion rate for the stopping purpose or for the spacing purpose. The first is a ratio of induced abortions to live births with the purpose of avoiding an unwanted birth because of the excessive number of surviving children, while the second is the same ratio with the purpose of avoiding a birth after too short an interval. In any case, the induced abortion rate is given as a ratio of such abortions against live births. On the other hand, foetal death, another possible outcome of unsuccessful pregnancies, is given as a ratio of foetal deaths against total pregnancies. Thus, the probability of a conception to end in a live birth (PB), a foetal death including still birth (PF) and an induced abortion (PA) is computed in the present model by

$$PB = (1 - PF) \div (1 + a)$$
$$PF = m$$
$$PA = a \times PB$$

where m refers to a foetal mortality rate and a to an induced abortion rate.

Post-partum infecundity

The period of temporary infecundity would vary largely depending on the result of a pregnancy. Two months of such temporary infecundity are assumed in the present model for a foetal death and for an induced abortion. In the case of a live birth, however, the length of temporary infecundity would be longer and vary according to the survival of the child and the practice of lactation. On the basis of Leridon's observation[f] the following formula to estimate the length of post-partum infecundity (y) from a given length of breast-feeding (x) has been obtained. In the formula, x will be replaced by the longevity of an infant if the latter happens to be of shorter duration than the breast-feeding period.

$$y = 2.0 + 0.5 \times x$$

Dynamic mode and static mode

In the dynamic mode, the input variables may be classified into two groups. The first group of input variables are specific to each cohort and will remain unchanged as long as simulation continues for the same cohort of women. The second group of input variables is changeable every five years as the age of cohort increases. For example, a contraceptive practice rate C_1 is applicable to women aged 15 to 19 in the same cohort, another practice rate C_2 will be applicable to the same cohort of women when they become 20 to 24 years old and so on. For the next cohort of women who are five years younger than the first group the

[e] John E. Laing, "Differentials in contraceptive use effectiveness in the Philippines", *Studies in Family Planning*, vol. 5, No. 10 (October 1975), pp. 302–315.

[f] Leridon, *op. cit.*

applicable practice rate will be C_2 rather than C_1 when the second group of women are 15 to 19 years old. Their practice rate in ages 20 to 24 will be C_3. As can be seen in the illustration, the second group of input variables are period-specific irrespective of the different cohorts. The list of input variables that are included in each group is as follows:

Group 1

Input variables specific to cohorts

1. Singulate mean age of marriage
2. Proportion of women never-married at age 50
3. Proportion of women at age 20, 35 and 50 who are in post-marital states
4. Level of sterility
5. Average length of breast-feeding
6. Proportion of couples who have a desired family size
7. Average number of children desired
8. Desired birth intervals

Group 2

Input variables specific to periods

1. Expectation of life at birth
2. Contraceptive practice rate
3. Induced abortion rate
4. Sterilization rate
5. Level of contraceptive use-effectiveness
6. Distribution of contraceptor by methods

Annex II

TABLE 15. SELECTED MODEL SCHEDULES OF PROPORTION OF WOMEN EVER-MARRIED BY SINGLE YEARS OF AGE FOR VARIOUS LEVELS OF SINGULATE MEAN AGE OF MARRIAGE[a]

Age	*18.0*	*18.5*
15	0.29550	0.20810
16	0.42380	0.34870
17	0.53810	0.47410
18	0.63830	0.58450
19	0.72430	0.67960
20	0.79640	0.75980
21	0.85480	0.82520
22	0.90020	0.87660
23	0.93350	0.91510
24	0.95650	0.94220
25	0.97100	0.96000
26	0.97900	0.97060
27	0.98310	0.97670
28	0.98530	0.98040
29	0.98710	0.98330
30	0.98940	0.98660
31	0.99200	0.98990
32	0.99370	0.99220
33	0.99480	0.99370
34	0.99570	0.99490
35	0.99640	0.99600
36	0.99710	0.99700
37	0.99750	0.99760
38	0.99790	0.99800
39	0.99820	0.99840
40	0.99850	0.99870
41	0.99880	0.99890
42	0.99910	0.99920
43	0.99940	0.99940
44	0.99960	0.99960
45	0.99980	0.99980
46	1.00000	0.99990
47	1.00000	1.00000
48	1.00000	1.00000
49	1.00000	1.00000

[a] The model schedules are prepared for every 0.5 year of the mean age of marriage starting from age 16 and ending at 27. The figures shown here are only examples for the mean ages of marriage at 18.0 and 18.5 years.

TABLE 16. THREE MODEL SCHEDULES OF PROPORTIONS OF WOMEN WHO ARE PERMANENTLY STERILE BY AGE FOR THE HIGH, MEDIUM AND LOW LEVELS OF STERILITY

Age of wife	*Low*	*Medium*	*High*
15	0.0250	0.0500	0.0500
16	0.0252	0.0518	0.0509
17	0.0258	0.0537	0.0518
18	0.0268	0.0557	0.0534
19	0.0282	0.0578	0.0559
20	0.0300	0.0600	0.0600
21	0.0342	0.0623	0.0653
22	0.0397	0.0649	0.0714
23	0.0461	0.0679	0.0790
24	0.0530	0.0726	0.0883
25	0.0600	0.0800	0.1000
26	0.0670	0.0905	0.1140
27	0.0743	0.1034	0.1300
28	0.0821	0.1182	0.1480
29	0.0906	0.1339	0.1680
30	0.1000	0.1500	0.1900
31	0.1093	0.1661	0.2138
32	0.1182	0.1831	0.2395
33	0.1286	0.2002	0.2673
34	0.1419	0.2200	0.2974
35	0.1600	0.2400	0.3300
36	0.1788	0.2600	0.3634
37	0.1972	0.2800	0.3975
38	0.2212	0.3040	0.4349
39	0.2568	0.3350	0.4782
40	0.3100	0.3700	0.5300
41	0.3908	0.4573	0.5974
42	0.4954	0.5738	0.6787
43	0.6155	0.6998	0.7633
44	0.7151	0.8151	0.8600
45	0.8000	0.9000	0.9500
46	0.8733	0.9500	0.9850
47	0.9255	0.9750	0.9950
48	0.9620	0.9900	0.9990
49	0.9850	0.9980	0.9995
50	1.0000	1.0000	1.0000

Notes: The high, medium and low models correspond to the sterility estimates for Japan (rural), Australia and Europe. See Japan (rural): Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. 8, No. 2 (1961) 81–91; Australia: Caldwell, Young, . . . , "Australia: knowledge, attitudes, and practice of family planning in Melbourne, 1971", *Studies in Family Planning*, vol. 4 No. 3 (March 1974), pp. 49–59: Europe: Henry, *loc. cit.*

Percentage of sterile women at age 45 are estimated on the basis of the data for the Hutterite women of the same age by Tietze. See Christopher Tietze, "Reproductive span and rate of reproduction among Hutterite women", *Fertility and Sterility*, vol. 8 (1957), pp. 89–97.

Interpolations were made by the Karup-King formula with moderate adjustments near the youngest and oldest ages.

TABLE 17. THREE ESTIMATES OF FOETAL MORTALITY RATES BY AGE OF WOMEN

Age groups	*French and Bierman*[a]	*Leridon*[a]	*New estimate*
15–19	118	186	235
20–24	122	193	239
25–29	135	214	250
30–34	160	253	272
35–39	200	316	306
40–44 / 45–49	270	426	367
Average	150	237	237

[a] Estimates presented in Henry Leridon, "Biostatistics of human reproduction", in Chandrasekaran and Hermalin, eds., *Measuring the Effects of Family Planning Programs on Fertility*, (Dolhain, Belgium, 1975), pp. 93–131.

TABLE 18. RELATIVE FREQUENCY DISTRIBUTION OF WOMEN BY THE DESIRED NUMBER OF CHILDREN, COMPUTED BY THE USE OF A BETA FUNCTION

Number of children desired	Mean number of children desired						Observed[a] distribution, Japan, mean number of children desired
	2.0	2.5	3.0	4.0	5.0	6.0	
0	0.026	0.006	0.002	0.000	0.000	0.000	0.035
1	0.255	0.116	0.048	0.012	0.006	0.005	0.076
2	0.448	0.385	0.252	0.083	0.035	0.021	0.444
3	0.228	0.361	0.399	0.037	0.107	0.056	0.336
4	0.040	0.117	0.238	0.329	0.207	0.110	
5	0.002	0.013	0.056	0.238	0.265	0.171	
6	0.000	0.000	0.005	0.087	0.226	0.214	
7	0.000	0.000	0.000	0.014	0.119	0.211	0.103 (4–10)
8	0.000	0.000	0.000	0.001	0.032	0.149	
9	0.000	0.000	0.000	0.000	0.003	0.058	
10	0.000	0.000	0.000	0.000	0.000	0.004	

[a] SOURCE: Japan, Ministry of Health and Welfare, *Report of the Sixth National Fertility Survey in 1972* (Tokyo, 1973), vol. 1, p. 107.

TABLE 19. MODEL DISTRIBUTIONS (CUMULATIVE) OF INFANT DEATHS BY SURVIVAL MONTHS

Survival months	Model 1	Model 2	Model 3
0	0.50232	0.39020	0.27808
1	0.57300	0.51214	0.45128
2	0.63490	0.60270	0.57049
3	0.68828	0.67848	0.66788
4	0.73349	0.73393	0.73436
5	0.77724	0.78445	0.79165
6	0.82354	0.83341	0.84327
7	0.86376	0.87437	0.88498
8	0.90434	0.91339	0.92243
9	0.94382	0.94838	0.95294
10	0.97502	0.97740	0.97977
11	1.00000	1.00000	1.00000

SOURCE: *Demographic Yearbook, 1967* (United Nations publication, Sales No. E. 68. XIII.1), table 15. Model 1: Sweden 1962–1966; Model 2: average of Sweden and Mauritius: Model 3: Sweden 1962–1966.

TABLE 20. EXTENDED USE-EFFECTIVENESS OF CONTRACEPTIVE METHODS ACCORDING TO HIGH, MEDIUM AND LOW EFFECTIVENESS LEVELS

Contraceptive methods	Levels of use-effectiveness		
	High	Medium	Low
1. IUD	5	10	15
2. Orals	5	13	30
3. Condom	5	15	20
4. Rhythm	20	30	45
5. Jelly, diaphragm	5	20	35
6. Withdrawal	5	20	40
7. Abstinence	0	5	10
8. Douche	20	30	40
9. Other	20	40	60

Note: Figures indicate failure rates per 100 women in 12 months after start of usage.

ASSISTANCE TO FERTILITY REGULATION PROJECTS WITHIN THE UNITED NATIONS SYSTEM

Ranjan K. Som*

INTRODUCTION

The World Population Plan of Action recommended that monitoring of population trends and policies discussed in the Plan should be undertaken continuously as a specialized activity of the United Nations and reviewed annually by the appropriate bodies of the United Nations system, beginning in 1977.[1] Following the discussions at the eleventh and special sessions of the Administrative Co-ordination Committee's Sub-Committee on Population, the present review of the monitoring of technical assistance on fertility regulation within the United Nations system is being undertaken by the Population Division of the United Nations Secretariat.[2]

Reference should be made in this connexion to the studies prepared by the United Nations Fund for Population Activities (UNFPA) on levels and trends of the volume of international population assistance provided by Governments, intergovernmental organizations (including the United Nations and its agencies) and non-governmental organizations.[3]

Within the United Nations system, the major funding bodies on fertility regulation projects are the United Nations Fund for Population Activities and the World Bank; the major executing agencies are the United Nations, United Nations Children's Fund, UNFPA, International Labour Organisation, Food and Agricultural Organization of the United Nations, United Nations Educational, Scientific and Cultural Organization, and the World Health Organization.[4]

This paper summarizes information on the amount of technical assistance on fertility regulation projects provided by organizations in the United Nations system, noting the emerging trends in the categories and geographical allocation of assistance. The paper is divided into five parts. Sections following the introduction deal successively with data base; assistance to population and fertility regulation projects; World Bank projects; and concluding remarks. A summary is provided at the end.

The technical assistance projects on fertility regulation have been classified into major population sectors. These indicate broadly the areas of activity of the different agencies, although the executing agencies themselves have not been identified in regard to groups of project categories. The present review has been mainly concerned with the two aspects of assistance on fertility regulation: the major population sectors (such as, service delivery system and fertility regulation techniques, described later on) and the level of operation—global, interregional, regional and country. The dimension of time has been included in order to observe the time trend in these.

In discussing the assistance to population projects, one may first note the functions of the two major funding organizations in the United Nations system. The primary purpose of the United Nations Fund for Population Activities is to provide assistance to population activities in the developing countries. Its projects are normally executed through organizations in the United Nations system within their respective fields of competence. The Fund has not only been instrumental in stimulating and expanding the over-all capability of the United Nations system in population in response to the needs of these countries but has also, to some extent, assisted organizations playing a similar role outside that system. Ultimately, responsibility for execution of projects will be with recipient Governments, and the Fund is increasingly giving assistance directly to countries.

The decision in 1968 for the World Bank and its soft-loan affiliate, the International Development Association (IDA), to enter the field of population assistance was based on the conviction that rapid population growth is a major barrier to the economic and social progress of many developing countries. The Bank uses a three-step programme which begins with an assessment of the impli-

* Population Division of the Department of Economic and Social Affairs, United Nations Secretariat. Grateful acknowledgements are due to the United Nations Fund for Population Activities and the World Bank for supplying data and commenting on the draft.

[1] *Report of the United Nations World Population Conference, 1974* (United Nations publication, Sales No. E.75.XIII.3), para. 107.

[2] Report of the eleventh session of the ACC Sub-Committee on Population, Geneva, 16–18 June 1975.

[3] "Role of international assistance in the population fields", World Population Conference, 1974 (E/CONF.60/CBP/24); "International population assistance: before and after Bucharest", UNFPA/United Nations Interregional Consultative Group of Experts of the World Population Plan of Action, Geneva, 1975 (UNFPA/WPPA/11); H. Gille, "Recent trends in international population assistance", Fourth Bellagio Conference on Population, 6–9 June 1977.

[4] The World Health Organization, through its Expanded Programme of Research, Development and Research Training in Human Reproduction, co-ordinates a world-wide effort for the assessment of the safety, effectiveness and efficacy of current fertility regulating methods, their improvement and the development of new methods and their provision in different service settings. A major component of the programme is the strengthening of national capabilities to carry out such research. However, more often than not, the activities connected with this programme do not conform, at least in the short and medium term, to the strict definition of assistance to family planning programmes and their management adopted here, and therefore are not considered here.

cations of population growth on development as part of the Bank's periodic economic reviews; it then undertakes, on request, sectoral analyses; finally, it provides financial assistance to specific projects on conventional Bank terms or, to especially weak economies, on highly subsidized soft-loan terms (no interest, 50-year repayment period).

Data base

Information on projects funded by UNFPA was available in the form of computer printouts. These indicated the amount of assistance by each major population sector to projects grouped under different levels of operation, including country, regional, global or interregional, for the period before 1972, and for each of the years 1972 through 1976 (that for 1976 being the planned amount, others being actual). Information on the projects executed by the agencies was also available for work plan categories but not their breakdown by the geographical level of operation, that is, by each country for country projects, by each region for regional projects etc.

For the World Bank, the distribution of the total amount approved for each of the country projects according to functional categories such as management, training, delivery of services, information, education, communication and motivation, and research and evaluation was available. Bank loans and IDA credits are available to the borrowers for withdrawal from the date a loan or credit becomes effective until the closing date, which is normally fixed at about one year after project completion. The borrower can withdraw loan proceeds as and when the need arises and there is no annual allocation. Because of the differences in the types of data available, the assistance of the Bank is being treated separately from that of UNFPA.

Assistance to population and fertility regulation projects

The assistance to fertility regulation projects detailed in this section relates to those funded by UNFPA and executed either singly or jointly by the United Nations and its specialized and operating agencies or, less commonly, by bodies outside the United Nations system.

Definition of population and fertility regulation projects

The assistance to fertility regulation projects detailed in this section should, of course, be considered in the context of the total assistance to all population projects. While it is difficult to have a clear-cut and generally agreed upon definition of the term "population activities", a standard classification of population activities has been evolved by organizations within the United Nations system that includes the following categories: basic data collection, population dynamics, formulation and evaluation of population policies and programmes, implementation of policies, family planning programmes, communication and education, programmes not elsewhere classified, such as the status of women, and multisector activities.

Within this standard classification for population activities, projects on fertility regulation were defined by us to include the following: family planning programmes—delivery system, programme management and fertility regulation techniques; communication for family planning motivation; out-of-school programme for family planning; and programme development for family planning. Delivery systems of family planning programmes comprise both those that were community based and those that were not, the latter category including maternal and child health systems, integrated maternal, child health and family planning system or independent family planning systems. Fertility regulation techniques include research and training on aspects of fertility regulation such as biomedical and epidemiological, development, production and delivery of fertility regulating methods. Programme management includes the administration, management and evaluation of family planning programmes. Under the item "out-of-school programmes for family planning" were included only projects solely or explicitly concerned with family planning, such as family planning education for workers and youth. Other out-of-school programmes which might have important components on family planning are not included, since it was not possible to separate out their share. The estimated amount on fertility regulation projects would therefore be somewhat of an underestimate. Programme development included costs associated with field staff, infrastructure, capacities at United Nations agencies, as well as specialized and operating agencies of the United Nations system, and overhead. Because these costs are incurred for all projects, the pro-rated share was estimated as equal to the share of assistance to projects concerned with fertility regulation, as defined here.

Although a standard classification of population activities has been adopted recently by the United Nations organizations,[5] the previous classification has been adhered to as data were available in this form. The classification may include some overlap of the sectors but not double counting.

At the level of operation are country projects as well as regional, interregional and global projects. Regional projects are designed either to provide assistance to a group of countries within a given region in a given field of activity or to provide a better informational base and technical support for such assistance, through the conduct of research for improving knowledge of specific aspects of the regional situation. Interregional projects have the same aims as those of regional projects except that they deal in specific groups of countries in more than one region or in all regions. Global projects are those whose benefits are potentially applicable to countries, regions or groups of countries or regions but which are not specifically limited to any of these from their inception.

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[5] "Key to the standard classification of population activities", ACC Sub-Committee on Population, Geneva, 20–24 May 1977 (POP/SC/WP/91), and report of the thirteenth session of the ACC Sub-Committee on Population, Geneva, 20–24 May 1977.

Number of countries with fertility regulation projects

Assistance to fertility regulation projects was provided during the period up to 1976 to a major proportion of the developing countries in the world. They total 68, comprising 24 in Asia and the Pacific, 20 in Latin America, 5 in Northern Africa, 12 in Africa (other than Northern) and 7 in Western Asia.

In addition, of course, there are regional, interregional and global projects executed by bodies in the United Nations system.

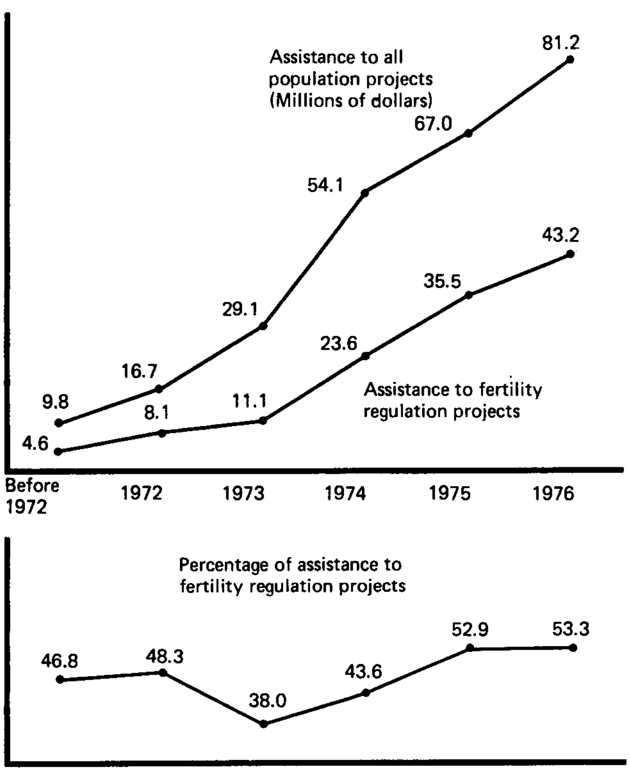
Amount of assistance to fertility regulation projects

Since projects vary in dimension and form of assistance, a more meaningful measure than their number would be the inputs of assistance. The inputs in amount have been analysed in this review.

Total assistance to fertility regulation projects

The total assistance to fertility regulation and all population projects up to 1972 and for each of the years 1972 through 1976 is shown in table 1 in the annex and figure I. From $4.6 million before 1972, the assistance to fertility regulation projects increased to $43.2 million in 1976, an increase of 842 per cent; at the same time, the assistance to all population projects, including those on fertility regulation, increased from $9.8 million before 1972 to $81.1 million in 1976, an increase of 727 per cent.

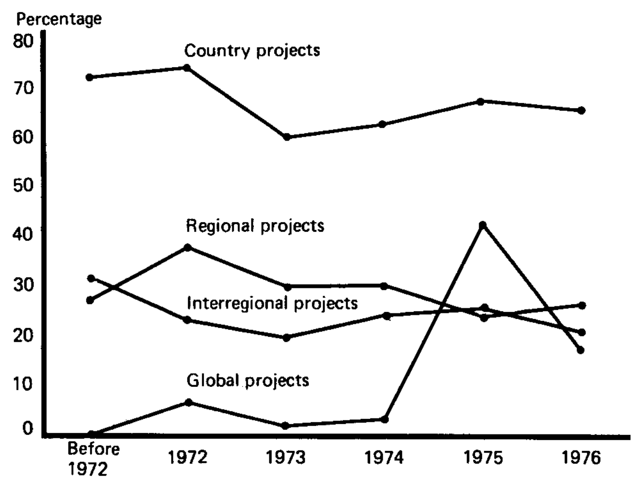
Figure I. Assistance to projects relating to fertility regulation and all population projects, funded by UNFPA, and percentage of assistance to fertility regulation projects



The percentage amount of assistance to fertility regulation projects, out of all population projects, varied from 38 per cent in 1973 to 53 per cent in 1975 and 1976; for the total period it was 49 per cent, accounting for $126 million out of the total assistance expenditures of $258 million. The relative decline in 1973 was associated with the relative increase in activities for the World Population Year and population censuses.

The proportion of assistance to fertility regulation as part of the total assistance to all population projects—country, regional, interregional and global—in the different regions has been shown in table 2 in the annex and figure II; the absolute amounts are given in tables 6.A–6.H

Figure II. Assistance to fertility regulation projects as percentage of total assistance to all population projects at each operational level



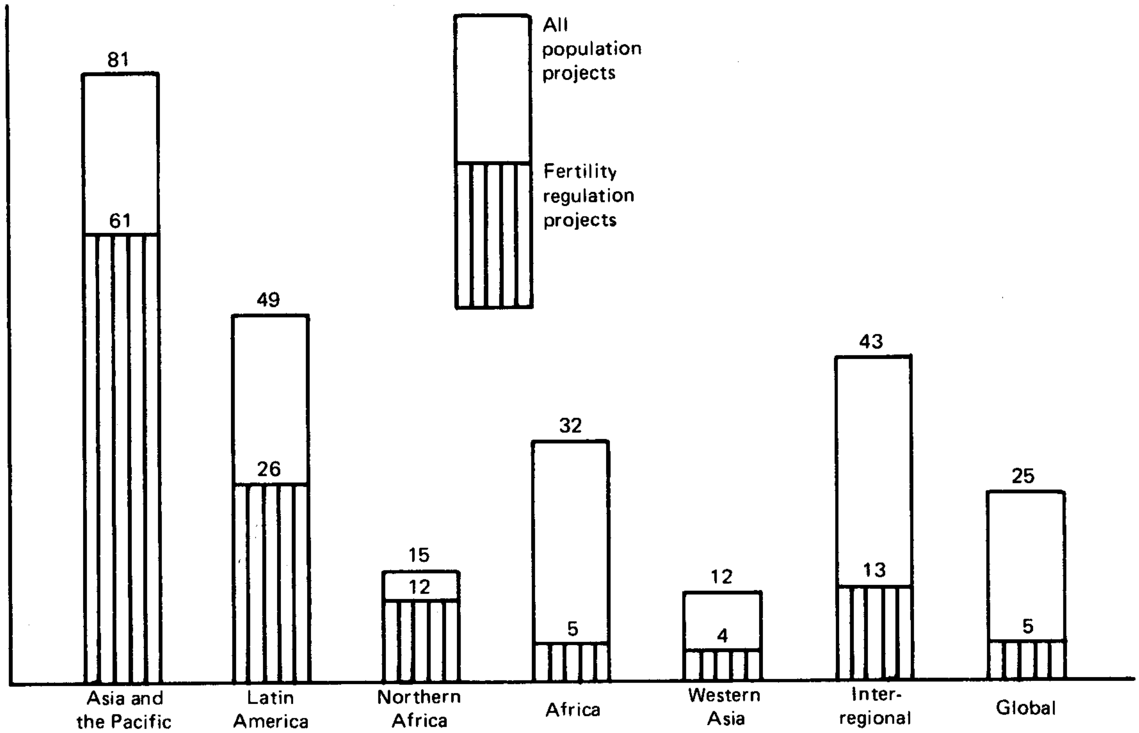
in the annex and are also shown in figure III. Considering the country and regional projects together, fertility regulation projects accounted for the high 74 and 81 per cent of total population assistance in Asia and the Pacific and Northern Africa, respectively; the lowest proportion, 16 per cent, was in Africa. For all the regions taken together, fertility regulation projects constituted 57 per cent of assistance to all population projects. The proportional assistance to fertility regulation was naturally much higher, 70 per cent, for the country projects as compared to the regional projects, which was 25 per cent. Of the total assistance to all interregional projects on population, those on fertility regulation averaged 30 per cent, the figure showing a slight decline after the level of 39 per cent in 1972 and 31 per cent in 1973 and 1974. Of the global projects on population, those on fertility regulation accounted for 21 per cent of the assistance reaching a high of 44 per cent in 1975, owing mainly to stockpiling of contraceptives.

Assistance to country, regional interregional and global projects

The pattern of allocation of the assistance to country, regional, interregional and global projects on fertility

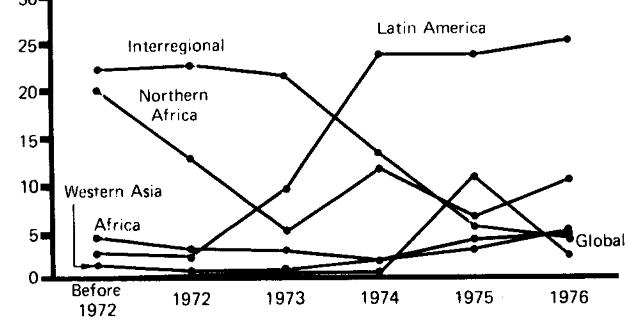
Figure III. Assistance to fertility regulation and population projects, up to 1976

(Millions of dollars)



regulation is shown in table 3 in the annex in amounts and in table 4 in the annex in percentages (see also fig. IV). Of the total amount of assistance in fertility regulation,

Figure IV. Percentage allocation of assistance to fertility regulation projects into different operational levels



interregional projects had accounted for over 22 per cent up to 1973; the proportion has shown a declining trend from 13 per cent in 1974 to 5 per cent in 1976. Global projects had comprised 1 per cent or less of the total assistance in fertility regulation up to 1974, increased to 10 per cent in 1975 (due to increased contraceptive stockpiling), but was down to 3 per cent in 1976. Since, in practice, the distinction between interregional and global projects may not always be very clear, it may be useful to consider them together in the present context. Interregional and global projects on fertility regulation had, together, accounted for 22–25 per cent up to 1973, the proportion declining to 7 per cent in 1976; the total amount also declined between 1975 and 1976. For the whole period, interregional projects accounted for 10 per cent and global projects 4 per cent, together 14 per cent of the total assistance to fertility regulation.

Country projects on fertility regulation have shown a consistent increase over the years in all the regions taken together, from 60 per cent before 1972 to 87 per cent in 1976; the average for the whole period was 77 per cent. On the other hand, regional projects have declined from 18 per cent before 1972 to 6 per cent in 1976, and there has also been a decline in the absolute amount in 1976 from that in 1975. The average for the whole period was 9 per cent.

Again, the regional patterns vary markedly. The country projects in Asia and the Pacific have moved within a relatively narrow range of 42 to 47 per cent, except before

1972, when these accounted for 36 per cent. The most marked increase in country projects, in both relative and absolute terms, has been in Latin America; these increased from less than 1 per cent before 1972 to 24 per cent in 1976 (from $43,000 to $10.4 million). For the whole period, the average proportion ranged from 2–3 per cent in Western Asia and Africa to 18 per cent in Latin America and 43 per cent in Asia and the Pacific.

For the regional projects, the general decline is shared by Asia, the Pacific and the Northern Africa regions. The most marked increase was, until 1975, in the Latin American region. The average for the period was 4.5 per cent in Asia and the Pacific, 2.5 per cent in Latin America and less than 1 per cent in the other regions.

Taking the country and regional projects on fertility regulation together, the total amount in Asia and the Pacific had increased from $2.3 million before 1972 to $20.2 million in 1976, but the percentage share declined from 50 per cent to 47 per cent; in Latin America, these projects increased from $124,000 to $10.9 million (from 3 per cent up to 21 per cent). In Northern Africa, there were dips in 1973 and 1975, and the 1976 proportion was 10 per cent. Africa and Western Asia continued to have fairly low shares of fertility regulation projects with increases in 1976 to 5 per cent each. For the whole period, the average was less than 0.5 per cent in Europe, 3–4 per cent in Western Asia and Africa, 10 per cent in Northern Africa, 21 per cent in Latin America and 48 per cent in Asia and the Pacific.

The *per capita* assistance in population and fertility regulation in developing countries is shown in table 5 in the annex. This is a crude measure of the regional distribution of funds being devoted to these needs for it does not take into account the investments of the countries themselves or the assistance by other organizations, either bilateral or multilateral. However, the situation noted earlier continues.[6] As compared to the average of 3 cents per head of assistance in all country and regional population projects in the developing countries in 1976, the highest figures of 5 to 6 cents were shown in Latin America, Northern Africa and Western Asia; the figure was 4 cents in Africa and 2 cents in Asia and the Pacific. On fertility regulation projects, against the average of 2 cents per head in country and regional projects, the highest figure of 4.5 cents obtained in North Africa; it was 3.33 cents in Latin America; 2.5 cents in West Asia; 1.5 cents in Asia and the Pacific; and eight tenths of a cent in Africa. For the whole period, assistance in country and regional population projects in the regions averaged 9.5 cents per head; the figure had ranged from 6.5 cents per head in Asia and the Pacific to 16.5 cents in Latin America. For the fertility regulation projects for the same period, assistance *per capita* averaged 5.5 cents per head, ranging from 2 cents in Africa, 5 cents in Asia and the Pacific, to 8 cents in Latin America and 12 cents in Northern Africa. The range was wider for assistance per head on fertility regulation (1:6.5) in the different regions than that on all population projects (1:2.5), no doubt reflecting the different regional needs as perceived by the countries and regions themselves. It has yet to be investigated to what extent these figures of *per capita* assistance on fertility regulation and all population projects have direct or inverse relationship with the investments by the governments of the regions themselves.

It may be noted in this connexion that the total annual cost for all population activities has been estimated at $1.50 *per capita* or $2 900 million for the developing world as a whole, of which the provision of family planning and maternal and child health services accounts for 84 cents *per capita*. The total population assistance from all international sources, including those from Governments, United Nations and other international organizations, as well as non-governmental organizations, has been estimated at $300 million or 15 cents *per capita* in 1975, that is, 10 per cent of the requirement.[7] The assistance provided by UNFPA was less than 4 cents *per capita*, or about one fourth of the total assistance available and one fourteenth of that required. On fertility regulation, the UNFPA assistance was 2 cents *per capita*, about one twentieth of that required.

Assistance by major population sectors

The allocation of the total amount of assistance in fertility regulation projects into the different major population sectors adopted is given in table 6 of the annex in amounts and in table 7 in the annex in percentages (see also fig. V). One notes first that family planning delivery systems account, expectedly, for the major share, about two thirds up to 1974 and three fourths in 1975 and 1976, averaging 71 per cent. Management of family planning programmes accounted for 7 to 12 per cent of the total assistance in fertility regulation, averaging 8 per cent, and fertility regulation techniques from 2 to 8 per cent, averaging 3 per cent. Altogether, these three components of family planning constituted from 79 to 86 per cent of the total amount on fertility regulation, with an average of 82 per cent. Communication for family planning motivation accounted for 7 to 12 per cent of the total amount, with an average of 10 per cent and an increasing absolute share. Out-of-school programmes concerned with family planning now account for about 2 per cent of the assistance to fertility regulation. Finally, programme development for family planning has shown a slight relative decline, from 11 per cent total assistance in fertility regulation before 1972 to 5.5 per cent in 1976, although there has been no decline in the absolute amount.

Assistance by major population sectors: the different regions

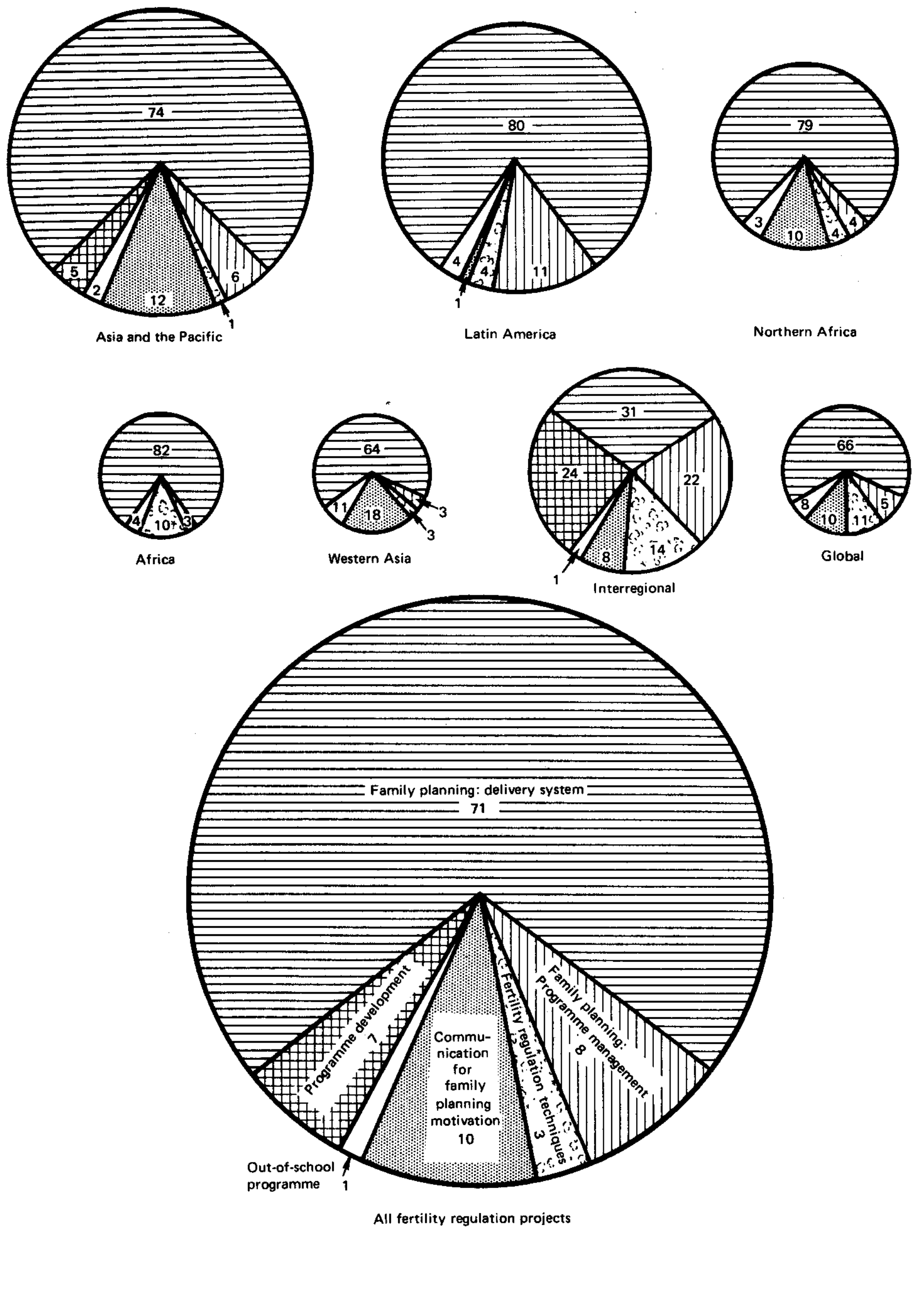
The allocation of assistance in projects relating to fertility regulation according to the work plan categories in the different regions and on the basis of interregional and global projects on fertility regulation is shown in

[6] "Role of international assistance . . .", para. 48 and foot-note 16.

[7] H. Gille, *op. cit.*, pp. 13–14.

Figure V. Allocation of assistance to fertility regulation projects classified by major population sectors

(*Percentage*)



tables 6 and 7 in the annex. For all the regions taken together, and combining country and regional projects, the major share, between 70 and 80 per cent of the assistance on fertility regulation, is spent on family planning delivery services. The assistance to programme management ranged from 5 to 10 per cent of the total amount, while the assistance to fertility regulation techniques had accounted for a small proportion, with a maximum of 5 per cent, of the total. Of the other three components of fertility regulation projects, communication for family planning motivation accounted for 8 to 13 per cent of the assistance on fertility regulation, out-of-school programme for family planning from 1 to 2 per cent and programme development from 3.5 to 5 per cent.

This average pattern is followed in Asia and the Pacific region. In Latin America, family planning delivery systems accounted for over four fifths of the amount of assistance to fertility regulation, except before 1972 and in 1974; programme management was generally 5 to 10 per cent, except before 1972 and in 1974 when it was 24–28 per cent; and no, or insignificant, assistance was reported for the development or assessment of fertility regulation techniques in the region. In Northern Africa, delivery systems had accounted for 43 per cent in 1972 and 85 per cent or more before 1972 and in 1975 and 1976. In Africa, delivery systems accounted for 70 to 86 per cent of the total assistance in fertility regulation; the next significant component was communication for family planning motivation, which was 22 per cent in 1974.

World Bank-supported projects

The Bank/IDA lending to population projects is shown in tables 8 and 9 of the annex according to functional categories. Beginning with loans to one country (Jamaica) in 1970 and two countries (Trinidad and Tobago, and Tunisia) in 1971, loans have now been extended to a total of 12 countries (India and Indonesia in 1972, Iran and Malaysia in 1973, Egypt and Kenya in 1974, Bangladesh and the Philippines in 1975, the Dominican Republic and Jamaica, a new loan, in 1976).

The loans are used to finance "hardware" items such as building, vehicles, furniture and equipment, as well as "software" items, including training, demographic research, and evaluation, management and technical assistance. Contingencies are added to accommodate cost escalation or unforeseen needs to permit projects to be successfully completed; the contingency funds are disbursed for activities within the specified functional categories or reallocated to project components.

By the end of 1976, the Bank had committed a total of $134.5 million to 13 projects. In seven of these—Bangladesh, India, Indonesia, Jamaica (1970), Kenya, Malaysia, and the Philippines—additional external donor Governments or organizations have been involved in co-financing arrangements.

Except in Indonesia and Bangladesh, delivery of services was the major single component of the loans. For all the countries taken together, service delivery accounted for 42 per cent of the total amount of loans. After the "contingency" category (25 per cent), training took the next large share: for all the countries taken together, it accounted for 20 per cent of the total amount of loans, ranging from a low of 6 per cent or less in Jamaica, Malaysia and Tunisia to 41 per cent in Bangladesh. However, without additional information on the amount of assistance from other external sources and the allocations by the countries themselves, such a categorization would provide only a partial picture and would not indicate the importance that the Bank, IDA and the countries themselves place on the different functional categories.

For the countries for which information was available, the advisory services provided ranged from 1 man-year in Egypt to 68 man-years in Indonesia. In between were Kenya (4 man-years), the Philippines (5 man-years), Jamaica (minimum of 17 man-years) and Malaysia (minimum of 26.5 man-years). Again, this does not give a complete picture, for in India and a few other countries the bulk of advisory and research services was being provided from internal resources.

Concluding observations

The present review has focused on the growth and present volume of assistance in fertility regulation projects in the United Nations system. There are other important aspects of assistance, such as the adequacy of technical assistance in terms of current and future needs, the terms on which it is given, the problems of making it effective and the difficulties of co-ordinating multiple sources of assistance. Some of these aspects have been covered in the reviews prepared by UNFPA, to which reference has already been made.

Within the framework of the present review can be observed the remarkable increase in assistance to fertility regulation projects by organizations in the United Nations system. The different components of such assistance, whether on family planning delivery systems, programme management, fertility regulation techniques, communication for family planning motivation, out-of-school programme for family planning, programme development or training, research and evaluation, have also been noted. The distribution of technical assistance on fertility regulation projects to the different country and regional projects has shown emerging trends, notably the relative decline of the importance of interregional projects and the relative increase in the importance of global projects and of country and regional projects in Latin America.

Lack of data and limitations of those that were available did not permit all of the desired analysis. An important missing element was the number of expert man-months spent on different types of assistance—family planning delivery system, programme management etc. Another limitation was the non-availability of the data in standardized, comparable form. Given an improvement in the data situation, a future review could go into more specific details and a deeper analysis.

At the same time, a framework could be developed for monitoring, including interpretation and analysis, of technical assistance in fertility regulation within the United Nations system. Such a framework could also bring in other components of the total inputs in fertility regulation projects—additional external assistance from intergovernmental, governmental and non-governmental organizations—and also the inputs from within the countries themselves, from both the governmental and the non-governmental sectors. Information on the total inputs, in terms of both financial expenditure and man-months, along with information on social, economic, and demographic factors in the countries, could provide the basis for a better assessment than at present of the effects of both programme and non-programme factors on fertility regulation at national levels.

Summary

This paper reviews the monitoring of financial assistance to fertility regulation projects within the United Nations system, financed by UNFPA and the World Bank. Assistance provided to country projects, as well as regional, interregional and global projects up to and including 1976 have been analysed. Up to 1976, 68 developing countries had been receiving or had received assistance in fertility regulation projects.

As defined here, fertility regulation projects comprise : family planning delivery systems, programme management and fertility regulation techniques; communication for family planning motivation; out-of-school programme for family planning; and programme development for family planning.

Taking the projects funded by UNFPA and executed by the United Nations, its agencies and other organizations, the total assistance to fertility regulation projects increased from $4.6 million before 1972 to $43.2 million in 1976, an increase of over 840 per cent. In proportion to the assistance to all population projects, fertility regulation averaged 49 per cent for the period and was 53 per cent in 1976.

Of the total amount of assistance in fertility regulation, inter-regional projects declined from 22 per cent before 1972 to 5 per cent in 1976, averaging 10 per cent for the period: and global projects averaged 4 per cent.

For all the regions taken together, country projects on fertility regulation have shown a consistent increase over the years, from six tenths (60 per cent) before 1972 to almost nine tenths (87 per cent) in 1976, averaging three fourths (76 per cent) for the period. On the other hand, regional projects have declined from 18 per cent before 1972 to 5 per cent in 1976, and there has also been a decline in the absolute amount in 1976 from that in 1975; the average for the period was 9 per cent.

As between the regions, the country projects in Asia and the Pacific have, except before 1972, moved within a relatively narrow range of 42 to 47 per cent, averaging 43 per cent. The most marked increase in country projects, in both relative and absolute terms, has been in Latin America, from 2 per cent before 1972 to 24 per cent in 1976 (from $43 000 to $10.4 million), averaging 18 per cent. For the regional projects, the general decline was shared by the Asia and Pacific region and the Northern Africa region.

Per capita assistance in fertility regulation for the whole period averaged 5.5 cents per head in the developing countries, ranging from 12 cents in Northern Africa and 8.5 cents in Latin America to 5 cents in Asia and the Pacific and 2 cents in Africa. The range was wider for assistance per head on fertility regulation (1:6.5) in the different regions as compared to that on all population projects (1:2.5), no doubt reflecting the different regional needs as perceived by the countries and regions themselves.

Family planning delivery systems accounted for the major share of the assistance in fertility regulation, about two thirds up to 1974 and four fifths in 1975 and 1976, averaging 71 per cent. Management of such programmes accounted for 8 per cent and fertility regulation techniques, 3 per cent. Communication for family planning motivation accounted for 10 per cent, out-of-school programmes 1 per cent and programme development 7 per cent.

The World Bank/IDA lending was made to 12 countries by the end of 1976, committing a total of $134.5 million. The loans financed "hardware" items such as building, vehicles, furniture and equipment, as well as "software", including training, demographic research and evaluation, management and other technical assistance. Service delivery accounted for the single major share of the total amount of loans, averaging 42 per cent.

Lack of data and limitations of those available did not permit all the desired analysis in the present review. An important missing element was information on the expert man-months spent on different types of assistance—family planning delivery systems, programme management etc. Another limitation was the non-availability of the data in standardized, comparable form. Given an improvement in the data situation, a future review could go into more specific details and a deeper analysis and could also deal with other aspects of assistance, such as the adequacy of technical assistance in terms of current and future needs, the terms on which it is given, the problems of making it effective and the difficulties of co-ordinating multiple sources of assistance.

Annex

TABLE 1. TOTAL ASSISTANCE TO PROJECTS RELATING TO FERTILITY REGULATION AND TO ALL POPULATION PROJECTS, FUNDED BY UNITED NATIONS FUND FOR POPULATION ACTIVITIES: COUNTRY, REGIONAL, INTERNATIONAL AND GLOBAL PROJECTS COMBINED

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
Fertility regulation projects (thousands of dollars)	4 588.7	8 051.4	11 093.8	23 587.2	35 460.1	43 220.1	126 001.3
All population projects (thousands of dollars)	9 815.4	16 685.9	29 154.2	54 138.5	67 025.2	81 158.0	257 977.2
Fertility regulation projects (percentage)	46.8	48.3	38.0	43.6	52.9	53.5	48.8
Index of amount on fertility regulation projects (pre-1972 = 100)	100	175	242	514	773	942	2 746
Index of amount on all population projects (pre-1972 = 100)	100	170	297	552	683	827	2 628

SOURCE: Computer printouts, United Nations Fund for Population Activities.

TABLE 2. ASSISTANCE TO FERTILITY REGULATION PROJECTS AS PERCENTAGE OF TOTAL ASSISTANCE TO ALL POPULATION PROJECTS

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
Country projects[a] in:							
Asia and the Pacific	88.5	90.8	83.3	81.5	86.8	82.7	84.3
Latin America	13.7	25.8	46.7	60.7	74.4	70.8	66.9
Northern Africa	99.2	99.0	56.3	81.1	85.8	75.3	80.3
Africa (other than Northern)	61.1	34.6	17.9	8.6	18.4	21.2	18.8
Western Asia	39.7	26.3	20.5	33.8	32.8	50.7	39.7
All country projects	73.6	76.4	61.7	63.9	68.9	66.9	70.0
Regional projects[a] in:							
Asia and the Pacific	51.1	45.9	34.8	27.3	31.9	33.8	34.6
Latin America	21.4	3.5	11.3	30.3	25.6	13.5	21.0
Northern Africa	100	100	100	100	100	100	100
Africa (other than Northern)	8.4	2.9	5.0	9.7	14.6	11.4	9.9
Western Asia	–	4.0	4.5	27.5	37.9	27.2	24.8
Europe	–	36.1	45.6	34.6	61.2	48.0	46.2
All regional projects	33.1	23.7	20.9	25.5	26.8	21.9	24.6
Country and regional projects in:							
Asia and the Pacific	73.3	76.8	69.2	68.2	77.4	76.8	74.3
Latin America	17.9	13.6	31.9	50.3	59.3	59.0	53.3
Northern Africa	99.3	99.0	58.2	81.4	86.0	75.7	80.8
Africa (other than Northern)	23.4	33.7	11.7	9.0	17.2	18.8	15.8
Western Asia	33.9	15.3	15.0	31.5	33.9	45.8	35.9
Europe	–	36.1	44.5	32.4	58.0	47.0	44.7
All country and regional projects	60.4	55.9	47.5	53.2	59.1	59.5	56.8
Interregional projects[a]	27.7	39.3	30.7	30.7	24.6	27.2	29.7
Global projects	0.6	8.2	2.7	3.9	43.6	18.0	21.2
All projects	46.8	48.3	38.0	43.6	52.9	53.3	48.8

SOURCE: Computer printouts, United Nations Fund for Population Activities

[a] All regional infrastructure, some previously included in interregional projects, being assigned to the regions.

TABLE 3. ASSISTANCE TO FERTILITY REGULATION PROJECTS: AMOUNT

(*Thousands of dollars*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
Country projects[a] in:							
Asia and the Pacific	1 631.0	3 545.7	5 169.6	9 786.3	14 965.8	19 128.1	54 226.5
Latin America	43.1	175.3	927.7	4 408.0	7 283.5	10 376.4	23 214.0
Northern Africa	860.9	946.1	542.3	2 652.8	2 303.0	4 299.9	11 605.0
Africa (other than Northern)	154.9	242.4	294.6	324.6	1 130.4	1 876.4	4 023.3
Western Asia	66.6	73.2	134.8	390.9	861.6	1 923.3	3 450.4
TOTAL: COUNTRY PROJECTS[a]	2 756.5	4 982.7	7 069.0	17 562.6	26 544.3	37 604.1	96 519.2
Regional projects[a, b] in:							
Asia and the Pacific	647.3	808.0	881.3	1 059.6	1 138.1	1 084.5	5 618.8
Latin America	81.4	28.4	160.5	1 143.4	1 122.5	509.0	3 045.2
Northern Africa	39.1	57.9	44.8	53.5	49.6	101.6	346.5
Africa (other than Northern)	51.6	32.1	77.1	197.8	394.3	314.7	1 067.6
Western Asia	–	10.8	15.5	186.9	289.7	272.7	775.6
Europe	–	49.6	95.2	59.6	137.9	166.3	508.6
TOTAL: REGIONAL PROJECTS[a]	819.4	986.8	1 275.0	2 700.8	3 132.1	2 448.8	11 362.9
Country and regional projects[a] in:							
Asia and the Pacific	2 278.3	4 353.7	6 050.9	10 845.9	16 103.9	20 212.6	59 845.3
Latin America	124.5	203.7	1 088.2	5 551.4	8 406.0	10 885.4	26 259.2
Northern Africa	900.0	1 004.0	587.1	2 706.3	2 352.6	4 401.5	11 951.5
Africa (other than Northern)	206.5	274.5	372.3	522.4	1 524.7	2 191.1	5 091.5
Western Asia	66.6	84.0	150.3	577.8	1 151.3	2 196.0	4 226.0
Europe	–	49.6	95.2	59.6	137.9	166.3	508.6
TOTAL: COUNTRY AND REGIONAL PROJECTS[a]	3 575.9	5 969.5	8 344.0	20 263.4	29 676.4	40 052.9	107 882.1
Interregional projects[a, b]	1 011.4	2 008.5	2 670.7	3 086.8	2 010.1	2 024.5	12 812.0
Global projects[a]	1.4	73.4	79.1	237.0	3 773.6	1 142.7	5 367.2
All projects[a]	4 588.7	8 051.4	11 093.8	23 587.2	35 460.1	43 220.1	126 001.3

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

[b] All regional infrastructure, some previously included in interregional projects, being assigned to the regions.

TABLE 4. ASSISTANCE TO FERTILITY REGULATION PROJECTS: PERCENTAGE

	Pre-1972	1972	1973	1974	1975	1976	Total
Country projects[a] in:							
Asia and the Pacific	35.5	44.0	46.6	41.5	42.2	44.3	43.0
Latin America	0.9	2.2	8.4	18.7	20.5	24.0	18.4
Northern Africa	18.8	11.8	4.9	11.2	6.5	10.0	9.2
Africa (other than Northern)	3.4	3.0	2.7	1.4	3.2	4.3	3.2
Western Asia	1.4	0.9	1.2	1.7	2.4	4.4	2.7
TOTAL: COUNTRY PROJECTS[a]	60.1	61.9	63.7	74.5	74.9	87.0	76.6
Regional projects[a, b] in:							
Asia and the Pacific	14.1	10.4	7.9	4.5	3.2	2.5	4.5
Latin America	1.8	0.4	1.4	4.8	3.2	1.2	2.4
Northern Africa	0.8	0.7	0.4	0.2	0.1	0.2	0.3
Africa (other than Northern)	1.1	0.4	0.7	0.8	1.1	0.7	0.8
Western Asia	–	0.1	0.1	0.8	0.8	0.6	0.6
Europe	–	0.6	0.9	0.2	0.4	0.4	0.4
TOTAL: REGIONAL PROJECTS[a]	17.9	12.3	11.5	11.4	8.8	5.7	9.0
Country and regional projects[a] in:							
Asia and the Pacific	49.6	54.1	54.5	46.0	45.4	46.8	47.5
Latin America	2.7	2.5	9.8	23.5	23.7	25.2	20.8
Northern Africa	19.6	12.5	5.3	11.5	6.6	10.2	9.5
Africa (other than Northern)	4.5	3.4	3.4	2.2	4.3	5.1	4.0
Western Asia	1.4	1.0	1.4	2.4	3.2	5.1	3.4
Europe	–	0.6	0.9	0.2	0.4	0.4	0.4
TOTAL: COUNTRY AND REGIONAL PROJECTS[a]	77.9	74.1	75.2	85.9	83.7	92.7	85.6
Interregional projects[a, b]	22.0	25.0	24.1	13.1	5.7	4.7	10.2
Global projects[a]	–	0.9	0.7	1.0	10.6	2.6	4.2
All projects[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.
[a] Relating to fertility regulation.
[b] All regional infrastructure, some previously included in interregional projects, being assigned to the regions.

TABLE 5. *PER CAPITA* ASSISTANCE IN POPULATION AND FERTILITY REGULATION PROJECTS TO DEVELOPING COUNTRIES

(Cents per person)

	Fertility regulation projects			All population projects		
Region	Pre-1972	1976	Cumulative to 1976	Pre-1972	1976	Cumulative to 1976
Regional and country projects in:						
Asia and the Pacific	0.2	1.5	4.8	0.3	2.0	6.4
Latin America	0.04	3.3	8.5	0.3	5.5	16.0
Northern Africa	1.0	4.4	12.2	1.1	5.8	15.1
Africa (other than Northern)	0.1	0.8	1.9	0.4	4.1	12.1
Western Asia	0.1	2.4	5.0	0.3	5.3	14.1
All regions	0.2	1.9	5.4	0.3	3.1	9.4
All projects[a]	0.2	2.0	6.3	0.5	3.7	12.9

SOURCE: Table 2 and United Nations medium population projections.
[a] Including interregional and global projects.

TABLE 6A. ASSISTANCE TO FERTILITY REGULATION PROJECTS

(*Thousands of dollars*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	3 015.1	5 093.6	7 186.4	14 993.7	27 415.8	32 221.1	89 925.7
(ii) Programme management	463.4	497.5	838.0	2 943.1	2 708.7	2 884.4	10 335.2
(iii) Fertility regulation techniques	148.2	671.9	778.2	789.2	517.1	845.4	3 750.0
SUBTOTAL OF (*a*)	3 626.7	6 263.0	8 802.6	18 725.9	30 641.7	35 882.4	103 942.3
(*b*) Communication for motivation	401.1	1 021.3	1 106.9	2 716.9	2 697.6	4 239.6	12 183.4
(*c*) Out-of-school programme	49.4	100.9	102.9	267.5	233.4	747.5	1 501.6
(*d*) Programme development	511.5	696.2	1 081.5	1 877.4	1 887.4	2 350.6	8 404.6
TOTAL OF 1[a]	4 588.7	8 051.4	11 093.8	23 587.2	35 460.1	43 220.1	126 001.3
TOTAL OF ALL PROJECTS[b]	9 815.4	16 685.9	29 154.2	54 138.5	67 025.2	81 158.0	257 977.2
2. All interregional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	379.4	807.1	1 151.3	773.9	430.3	382.0	3 924.0
(ii) Programme management	76.6	188.6	307.0	880.6	634.5	781.7	2 869.0
(iii) Fertility regulation techniques	130.9	360.2	423.1	349.9	355.5	162.9	1 782.5
SUBTOTAL OF (*a*)	586.9	1 355.9	1 881.4	2 004.4	1 420.3	1 326.6	8 575.5
(*b*) Communication for motivation	104.8	156.8	232.2	281.8	92.5	107.7	975.8
(*c*) Out-of-school programme	3.3	34.5	16.4	96.8	0	0	151.0
(*d*) Programme development	316.4	491.3	540.7	703.8	497.3	590.2	3 139.7
TOTAL OF 2[a]	1 011.4	2 008.5	2 670.7	3 086.8	2 010.1	2 024.5	12 812.0
TOTAL OF ALL INTERREGIONAL PROJECTS[b]	3 654.0	5 107.8	8 691.6	10 044.7	8 155.7	7 430.0	43 083.8
3. All global projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	–	–	–	68.3	3 251.7	167.5	3 487.5
(ii) Programme management	–	–	–	–	48.3	226.8	275.1
(iii) Fertility regulation techniques	–	–	–	–	75.4	500.0	575.4
SUBTOTAL OF (*a*)	–	–	–	68.3	3 375.4	894.3	4 338.0
(*b*) Communication for motivation	1.4	73.4	78.8	167.3	113.9	112.9	547.7
(*c*) Programme development	–	–	0.3	1.4	284.3	135.5	421.5
TOTAL OF 3[a]	1.4	73.4	79.1	237.0	3 773.6	1 142.7	5 307.2
TOTAL OF GLOBAL PROJECTS[b]	241.9	900.1	2 893.6	6 014.9	8 662.0	6 363.7	25 076.2

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6B. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN ALL REGIONS

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	2 343.0	3 756.4	5 360.9	13 485.2	23 014.0	30 723.9	78 683.4
(ii) Programme management	280.2	193.6	323.8	731.0	748.9	1 510.1	3 787.6
(iii) Fertility regulation techniques	17.3	311.7	355.1	411.8	86.2	182.5	1 364.6
SUBTOTAL OF (*a*)	2 640.5	4 261.7	6 039.7	14 627.9	23 849.2	32 416.6	83 835.6
(*b*) Communication for motivation	89.0	598.1	571.6	1 772.0	1 636.5	3 314.6	7 981.8
(*c*) Out-of-school programme	12.0	17.7	36.9	166.3	233.4	555.2	1 021.5
(*d*) Programme development	15.0	105.2	420.8	996.5	825.2	1 317.7	3 680.4
TOTAL OF 1[a]	2 756.5	4 982.7	7 069.0	17 562.6	26 544.3	37 604.1	96 519.2
TOTAL OF ALL COUNTRY PROJECTS[b]	3 745.0	6 521.4	11 463.3	27 486.1	38 516.3	56 178.2	137 910.3
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	292.7	530.1	674.2	666.3	719.8	879.1	3 762.2
(ii) Programme management	106.6	115.3	207.2	1 331.5	1 277.0	365.8	3 403.4
(iii) Fertility regulation techniques	–	–	–	27.5	–	–	27.5
SUBTOTAL OF (*a*)	399.3	645.4	881.4	2 025.3	1 996.8	1 244.9	7 193.1
(*b*) Communication for motivation	205.9	193.0	224.3	495.4	854.7	704.4	2 677.7
(*c*) Out-of-school programme	34.1	48.7	49.6	4.4	–	192.3	329.1
(*d*) Programme development	180.1	99.7	119.7	175.7	280.6	307.2	1 163.0
TOTAL OF 2[a]	819.4	986.8	1 275.0	2 700.8	3 132.1	2 448.8	11 362.9
TOTAL OF ALL REGIONAL PROJECTS[b]	2 474.5	4 156.5	6 105.7	10 592.6	11 691.1	11 186.0	46 206.4
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	2 635.7	4 286.5	6 035.1	14 151.5	23 733.8	31 603.0	82 445.6
(ii) Programme management	386.8	308.9	531.0	2 062.5	2 025.9	1 875.9	7 191.0
(iii) Fertility regulation techniques	17.3	311.7	355.1	439.3	86.2	182.5	1 392.1
SUBTOTAL OF (*a*)	3 039.8	4 907.1	6 921.1	16 653.2	25 846.0	33 661.5	91 028.7
(*b*) Communication for motivation	294.9	791.1	795.9	2 267.4	2 491.2	4 019.0	10 659.5
(*c*) Out-of-school programme	46.1	66.4	86.5	170.7	233.4	747.5	1 350.6
(*d*) Programme development	195.1	204.9	540.5	1 172.2	1 105.8	1 624.9	4 843.4
TOTAL OF 3[a]	3 575.9	5 969.5	8 344.0	20 263.4	29 676.4	40 052.9	107 882.1
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	5 919.5	10 677.9	17 659.0	38 078.7	50 207.4	67 364.2	189 816.7

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6C. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN ASIA AND THE PACIFIC

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	1 365.8	2 919.9	3 808.6	7 182.2	12 144.4	14 654.3	42 075.2
(ii) Programme management	180.9	130.4	229.9	359.0	680.1	782.5	2 362.8
(iii) Fertility regulation techniques	15.7	205.3	288.1	117.4	14.7	7.4	648.6
SUBTOTAL OF (*a*)	1 562.5	3 255.6	4 326.5	7 658.6	12 839.2	15 444.2	45 086.6
(*b*) Communication for motivation	41.5	186.8	500.9	1 419.0	1 309.4	2 508.1	5 965.7
(*c*) Out-of-school programme	12.0	1.6	36.9	166.3	226.5	540.2	983.5
(*d*) Programme development	15.0	101.7	305.3	542.4	590.7	635.6	2 190.7
TOTAL OF 1[a]	1 631.0	3 545.7	5 169.6	9 786.3	14 965.8	19 128.1	54 226.5
TOTAL OF ALL COUNTRY PROJECTS[b]	1 842.2	3 906.8	6 206.2	12 009.7	17 251.0	23 134.6	64 350.5
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	236.2	407.8	463.0	493.2	426.1	481.4	2 507.7
(ii) Programme management	88.4	108.1	146.7	327.7	291.4	165.0	1 127.3
(iii) Fertility regulation techniques	–	–	–	27.5	–	–	27.5
SUBTOTAL OF (*a*)	324.6	515.9	609.7	848.4	717.5	646.4	3 662.5
(*b*) Communication for motivation	141.1	167.9	156.5	146.3	337.5	308.3	1 257.6
(*c*) Out-of-school programme	28.3	37.2	25.4	–	–	–	90.9
(*d*) Programme development	153.3	87.0	89.7	64.9	83.1	129.8	607.8
TOTAL OF 2[a]	647.3	808.0	881.3	1 059.6	1 138.1	1 084.5	5 618.8
TOTAL OF ALL REGIONAL PROJECTS[b]	1 267.4	1 761.4	2 535.7	3 883.3	3 568.7	3 201.3	16 217.8
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	1 602.0	3 327.7	4 271.6	7 675.4	12 570.5	15 135.7	44 582.9
(ii) Programme management	269.3	238.5	376.6	686.7	971.5	947.5	3 490.1
(iii) Fertility regulation techniques	15.7	205.3	288.1	144.9	14.7	7.4	676.1
SUBTOTAL OF (*a*)	1 887.1	3 771.5	4 936.2	8 507.0	13 556.7	16 090.6	48 749.1
(*b*) Communication for motivation	182.6	354.7	657.4	1 565.3	1 646.9	2 816.4	7 223.3
(*c*) Out-of-school programme	40.3	38.8	62.3	166.3	226.5	540.2	1 074.4
(*d*) Programme development	168.3	188.7	395.0	607.3	673.8	765.4	2 798.5
TOTAL OF 3[a]	2 278.3	4 353.7	6 050.9	10 845.9	16 103.9	20 212.6	59 845.3
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	3 109.6	5 668.2	8 741.9	15 893.0	20 819.7	26 335.9	80 568.3

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6D. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN LATIN AMERICA

(*Thousands of dollars*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	18.3	161.2	829.6	3 848.6	7 040.6	9 152.0	21 050.3
(ii) Programme management	17.3	4.4	12.5	331.6	–	430.3	796.1
(iii) Fertility regulation techniques	–	–	–	–	–	62.4	62.4
SUBTOTAL OF (*a*)	35.6	165.6	842.1	4 180.2	7 040.6	9 644.8	21 908.9
(*b*) Communication for motivation	7.5	9.4	15.7	4.0	99.1	379.7	515.4
(*d*) Programme development	–	0.3	69.9	223.8	143.8	351.9	789.7
TOTAL OF 1[a]	43.1	175.3	927.7	4 408.0	7 283.5	10 376.4	23 214.0
TOTAL OF ALL COUNTRY PROJECTS[b]	314.3	679.6	1 986.1	7 258.9	9 786.2	14 664.5	34 689.6
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	–	6.4	57.7	–	–	–	64.1
(ii) Programme management	18.2	7.2	60.5	1 000.3	916.9	150.8	2 153.9
SUBTOTAL OF (*a*)	18.2	13.6	118.2	1 000.3	916.9	150.8	2 218.0
(*b*) Communication for motivation	42.5	2.4	20.2	109.4	166.9	144.6	486.0
(*c*) Out-of-school programme	5.8	10.1	10.9	4.4	–	192.3	223.5
(*d*) Programme development	14.9	2.3	11.2	29.3	38.7	21.3	117.7
TOTAL OF 2[a]	81.4	28.4	160.5	1 143.4	1 122.5	509.0	3 045.2
TOTAL OF ALL REGIONAL PROJECTS[b]	380.2	813.9	1 421.6	3 769.4	4 381.9	3 770.7	14 537.7
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	18.3	167.6	887.3	3 848.6	7 040.6	9 152.0	21 114.4
(ii) Programme management	35.5	11.6	73.0	1 331.9	916.9	581.1	2 950.0
(iii) Fertility regulation techniques	–	–	–	–	–	62.4	62.4
SUBTOTAL OF (*a*)	53.8	179.2	960.3	5 180.5	7 957.5	9 795.6	24 126.9
(*b*) Communication for motivation	50.0	11.8	35.9	113.4	266.0	524.3	1 001.4
(*c*) Out-of-school programme	5.8	10.1	10.9	4.4	–	192.3	223.5
(*d*) Programme development	14.9	2.6	81.1	253.1	182.5	373.2	907.4
TOTAL OF 3[a]	124.5	203.7	1 088.2	5 551.4	8 406.0	10 885.4	26 259.2
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	694.5	1 493.5	3 407.7	11 028.3	14 168.1	18 435.2	49 227.3

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6E. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN NORTHERN AFRICA

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	760.4	371.9	338.9	1 877.3	2 054.1	3 670.7	9 073.3
(ii) Programme management	59.0	58.8	69.5	38.9	17.7	232.0	475.9
(iii) Fertility regulation techniques	1.6	106.4	55.0	213.1	55.4	80.0	511.5
SUBTOTAL OF (*a*)	820.9	537.1	463.4	2 129.3	2 127.2	3 982.7	10 060.6
(*b*) Communication for motivation	40.0	392.1	45.7	349.0	144.5	170.0	1 141.3
(*c*) Out-of-school programme	–	16.1	–	–	6.9	–	23.0
(*d*) Programme development	–	0.8	33.2	174.5	24.4	147.2	380.1
TOTAL OF 1[a]	860.9	946.1	542.3	2 652.8	2 303.0	4 299.9	11 605.0
TOTAL OF ALL COUNTRY PROJECTS[b]	867.5	955.9	963.7	3 271.1	2 685.6	5 710.4	14 454.2
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	39.1	56.5	31.5	53.5	49.6	101.6	331.8
(*c*) Out-of-school programme	–	1.4	13.3	–	–	–	14.7
TOTAL OF 2[a]	39.1	57.9	44.8	53.5	49.6	101.6	346.5
TOTAL OF ALL REGIONAL PROJECTS[b]	39.1	57.9	44.8	53.5	49.6	101.6	346.5
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	799.5	428.4	370.4	1 930.8	2 103.7	3 772.3	9 405.1
(ii) Programme management	59.0	58.8	69.5	38.9	17.7	232.0	475.9
(iii) Fertility regulation techniques	1.6	106.4	55.0	213.1	55.4	80.0	511.5
SUBTOTAL OF (*a*)	860.0	593.6	494.9	2 182.8	2 176.8	4 084.3	10 392.4
(*b*) Communication for motivation	40.0	392.1	45.7	349.0	144.5	170.0	1 141.3
(*c*) Out-of-school programme	–	17.5	13.3	–	6.9	–	37.7
(*d*) Programme development	–	0.8	33.2	174.5	24.4	147.2	380.1
TOTAL OF 3[a]	900.0	1 004.0	587.1	2 706.3	2 352.6	4 401.5	11 951.5
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	906.6	1 013.8	1 008.5	3 324.6	2 735.2	5 812.0	14 800.7

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

[b] On population, including fertility regulation.

TABLE 6F. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN AFRICA (OTHER THAN NORTHERN)

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	154.9	230.2	281.4	304.9	1 068.1	1 734.8	3 774.3
(ii) Programme management	–	–	–	1.5	51.1	65.3	117.9
SUBTOTAL OF (*a*)	154.9	230.2	281.4	306.4	1 119.3	1 800.1	3 892.3
(*b*) Communication for motivation	–	9.8	9.3	–	–	–	19.1
(*c*) Out-of-school programme	–	–	–	–	–	15.0	15.0
(*d*) Programme development	–	2.4	3.9	18.2	11.1	61.3	96.9
TOTAL OF 1[a]	154.9	242.4	294.6	324.6	1 130.4	1 876.4	4 023.3
TOTAL OF ALL COUNTRY PROJECTS[b]	253.4	701.1	1 644.7	3 777.6	6 150.5	8 865.9	21 393.2
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	17.4	9.8	26.8	60.0	133.7	160.1	407.8
(ii) Programme management	–	–	–	3.5	25.4	–	28.9
SUBTOTAL OF (*a*)	17.4	9.8	26.8	63.5	159.1	160.1	436.7
(*b*) Communication for motivation	22.3	16.6	40.1	112.6	201.2	117.6	510.4
(*d*) Programme development	11.9	5.7	10.8	21.7	34.0	37.0	121.1
TOTAL OF 2[a]	51.6	32.1	77.7	197.8	394.3	314.7	1 068.2
TOTAL OF ALL REGIONAL PROJECTS[b]	618.3	1 114.2	1 548.7	2 034.8	2 701.3	2 763.5	10 780.8
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	172.3	240.0	308.2	364.9	1 201.8	1 894.9	4 182.1
(ii) Programme management	–	–	–	5.0	76.5	65.3	146.8
SUBTOTAL OF (*a*)	172.3	240.0	308.2	369.9	1 278.4	1 960.2	4 329.0
(*b*) Communication for motivation	22.3	26.4	49.4	112.6	201.2	117.6	529.5
(*c*) Out-of-school programme	–	–	–	–	–	15.0	15.0
(*d*) Programme development	11.9	8.1	14.7	39.9	45.1	98.3	218.0
TOTAL OF 3[a]	206.5	274.5	372.3	522.4	1 524.7	2 191.1	5 091.5
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	871.7	1 815.3	3 193.4	5 812.4	8 851.8	11 629.4	32 174.0

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6G. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN WESTERN ASIA

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	43.6	73.2	102.4	272.2	706.8	1 512.1	2 710.3
(ii) Programme management	23.0	–	11.9	–	–	–	34.9
(iii) Fertility regulation techniques	–	–	12.0	81.3	16.1	32.7	142.1
SUBTOTAL OF (*a*)	66.6	73.2	126.3	353.4	722.9	1 544.8	2 887.2
(*b*) Communication for motivation	–	–	–	–	83.5	256.8	340.3
(*d*) Programme development	–	–	8.5	37.6	55.2	121.7	223.0
TOTAL OF 1[a]	66.6	73.2	134.8	390.9	861.6	1 923.3	3 450.4
TOTAL OF ALL COUNTRY PROJECTS[b]	167.6	278.0	657.6	1 156.9	2 630.5	3 794.8	8 685.4
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(ii) Programme management	–	–	–	–	43.3	50.0	93.3
(*b*) Communication for motivation	–	6.1	7.5	127.1	149.1	133.9	423.7
(*d*) Programme development	–	4.7	8.0	59.8	97.3	88.8	258.6
TOTAL OF 2[a]	–	10.8	15.5	186.9	289.7	272.7	775.6
TOTAL OF ALL REGIONAL PROJECTS[b]	59.4	271.8	346.1	679.6	764.3	1 002.8	3 124.0
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	43.6	73.2	102.4	272.2	706.8	1 512.1	2 710.3
(ii) Programme management	23.0	–	11.9	–	43.3	50.0	128.2
(iii) Fertility regulation techniques	–	–	12.0	81.3	16.1	32.7	142.1
SUBTOTAL OF (*a*)	66.6	73.2	126.3	353.4	766.2	1 594.8	2 980.5
(*b*) Communication for motivation	–	6.1	7.5	127.1	232.6	390.7	764.0
(*d*) Programme development	–	4.7	16.5	97.4	152.5	210.5	481.6
TOTAL OF 3[a]	66.6	84.0	150.3	577.8	1 151.3	2 196.0	4 226.0
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	196.5	549.9	1 003.7	1 836.5	3 394.8	4 797.6	11 779.0

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 6H. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN EUROPE

(Thousands of dollars)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation .	–	–	–	–	–	–	–
TOTAL OF ALL COUNTRY PROJECTS[b]	–	–	5.0	11.9	12.9	8.0	37.8
2. All regional projects on fertility regulation							
(*a*) Family planning:							
Delivery system	–	49.6	95.2	59.6	110.4	136.0	450.8
(*d*) Programme development.............	–	–	–	–	27.5	30.3	57.8
TOTAL OF 2[a]	–	49.6	95.2	59.6	137.9	166.3	508.6
TOTAL OF ALL REGIONAL PROJECTS[b]	10.1	137.3	208.8	172.0	225.3	346.1	1 099.6
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
Delivery system	–	49.6	95.2	59.6	110.4	136.0	450.8
(*d*) Programme development.............	–	–	–	–	27.5	30.3	57.8
TOTAL OF 3[a]	–	49.6	95.2	59.6	137.9	166.3	508.6
TOTAL OF ALL COUNTRY AND REGIONAL PROJECTS[b]	10.1	137.3	213.8	183.9	237.8	354.1	1 137.0

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.
[b] On population, including fertility regulation.

TABLE 7A. ASSISTANCE TO FERTILITY REGULATION PROJECTS

(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	65.7	63.3	64.8	63.6	77.3	74.5	71.4
(ii) Programme management	10.1	6.2	7.6	12.5	7.6	6.7	8.2
(iii) Fertility regulation techniques	3.2	8.4	7.0	3.4	1.5	2.0	3.0
SUBTOTAL OF (*a*)	79.0	77.8	79.4	79.4	86.4	83.1	82.5
(*b*) Communication for motivation	8.7	12.7	10.0	11.5	7.6	9.8	9.7
(*c*) Out-of-school programme	1.1	1.2	0.9	1.1	0.7	1.7	1.2
(*d*) Programme development	11.2	8.9	9.8	8.0	5.3	5.4	6.7
TOTAL OF 1[a]	100	100	100	100	100	100	100
2. All interregional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	37.5	40.2	43.1	25.1	21.4	18.9	30.6
(ii) Programme management	7.6	9.3	11.5	28.5	31.6	38.6	22.4
(iii) Fertility regulation techniques	12.9	17.9	15.8	11.3	17.6	8.0	13.9
SUBTOTAL OF (*a*)	58.0	67.5	70.4	64.9	70.7	65.5	66.9
(*b*) Communication for motivation	10.4	7.8	8.7	9.1	4.6	5.3	7.6
(*c*) Out-of-school programme	0.3	1.7	0.6	3.1	0	0	1.2
(*d*) Programme development	31.3	24.5	20.2	22.8	24.7	29.2	24.5
TOTAL OF 2[a]	100	100	100	100	100	100	100
3. All global projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	–	–	–	28.8	86.2	14.7	65.7
(ii) Programme management	–	–	–	–	1.3	19.8	5.2
(iii) Fertility regulation techniques	–	–	–	–	2.0	43.8	10.8
SUBTOTAL OF (*a*)	—	—	—	28.8	89.4	78.3	81.7
(*b*) Communication for motivation	100	100	99.6	70.6	3.0	9.9	10.3
(*d*) Programme development	—	—	0.4	0.6	7.5	11.9	7.9
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7B. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN ALL REGIONS

(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	65.5	62.9	64.2	66.5	77.5	76.7	72.9
(ii) Programme management	7.8	3.2	3.9	3.6	2.5	3.8	3.5
(iii) Fertility regulation techniques	0.5	5.2	4.3	2.0	0.3	0.5	1.3
SUBTOTAL OF (*a*)	73.8	71.4	73.0	72.2	80.4	80.9	77.7
(*b*) Communication for motivation	2.5	10.0	6.9	8.7	5.5	8.3	7.4
(*c*) Out-of-school programme	0.3	0.3	0.4	0.8	0.8	1.4	1.0
(*d*) Programme development	0.4	1.8	5.0	4.9	2.8	3.3	3.4
TOTAL OF 1[a]	77.1	83.5	84.7	86.7	89.4	93.9	89.5
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	8.2	8.9	8.1	3.3	2.4	2.2	3.5
(ii) Programme management	3.0	1.9	2.5	6.6	4.3	0.9	3.2
(iii) Fertility regulation techniques	–	–	–	0.1	–	–	–
SUBTOTAL OF (*a*)	11.2	10.8	10.6	10.0	6.7	3.1	6.7
(*b*) Communication for motivation	5.8	3.2	2.7	2.4	2.9	1.8	2.5
(*c*) Out-of-school programme	1.0	0.8	0.6	0.0	0	0.5	0.3
(*d*) Programme development	5.0	1.7	1.4	0.9	0.9	0.8	1.1
TOTAL OF 2[a]	22.9	16.5	15.3	15.3	10.6	6.1	10.5
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	73.7	71.8	72.3	69.8	80.0	78.9	76.4
(ii) Programme management	10.8	5.2	6.4	10.2	6.8	4.7	6.7
(iii) Fertility regulation techniques	0.5	5.2	4.3	2.2	0.3	0.5	1.3
SUBTOTAL OF (*a*)	85.0	82.2	82.9	82.2	87.1	84.0	84.4
(*b*) Communication for motivation	8.2	13.3	9.5	11.2	8.4	10.0	9.9
(*c*) Out-of-school programme	1.3	1.1	1.0	0.8	0.8	1.9	1.2
(*d*) Programme development	5.5	3.4	6.5	5.8	3.7	4.1	4.5
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7C. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN ASIA AND THE PACIFIC

(Percentage)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	59.9	67.1	63.0	66.2	75.4	72.5	70.3
(ii) Programme management	7.9	3.0	3.8	3.3	4.2	3.9	4.0
(iii) Fertility regulation techniques	0.7	4.7	4.8	1.1	0.1	–	1.1
SUBTOTAL OF (*a*)	68.6	74.8	71.5	70.6	79.7	76.4	75.3
(*b*) Communication for motivation	1.8	4.3	8.3	13.1	8.1	12.4	10.0
(*c*) Out-of-school programme	0.5	–	0.6	1.5	1.4	2.7	1.6
(*d*) Programme development	0.7	2.3	5.0	5.0	3.7	3.1	3.7
TOTAL OF 1[a]	71.6	81.4	85.4	90.2	93.0	94.6	90.6
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	10.3	9.4	7.7	4.5	2.6	2.4	4.2
(ii) Programme management	3.9	2.5	2.4	3.0	1.8	0.8	1.9
(iii) Fertility regulation techniques	–	–	–	0.3	–	–	–
SUBTOTAL OF (*a*)	14.2	11.8	10.1	7.8	4.5	3.2	6.1
(*b*) Communication for motivation	6.2	3.9	2.6	1.3	2.1	1.5	2.1
(*c*) Out-of-school programme	1.2	0.9	0.4	–	–	–	0.2
(*d*) Programme development	6.7	2.0	1.5	0.6	0.5	0.6	1.0
TOTAL OF 2[a]	28.4	18.6	14.6	9.8	7.1	5.4	9.4
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	70.3	76.4	70.6	70.8	78.0	74.9	74.5
(ii) Programme management	11.8	5.5	6.2	6.3	6.0	4.7	5.8
(iii) Fertility regulation techniques	0.7	4.7	4.8	1.3	0.1	–	1.1
SUBTOTAL OF (*a*)	82.8	86.6	81.6	78.4	84.2	79.6	81.5
(*b*) Communication for motivation	8.0	8.1	10.9	14.4	10.2	14.0	12.1
(*c*) Out-of-school programme	1.8	0.9	1.0	1.5	1.4	2.7	1.8
(*d*) Programme development	7.4	4.3	6.5	5.6	4.2	3.8	4.7
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7D. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN LATIN AMERICA
(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	14.7	79.1	76.2	69.3	83.8	84.1	80.2
(ii) Programme management	13.9	2.2	1.1	6.0	–	4.0	3.0
(iii) Fertility regulation techniques	–	–	–	–	–	0.6	0.2
SUBTOTAL OF (*a*)	28.6	81.3	77.4	75.3	83.8	88.6	83.4
(*b*) Communication for motivation	6.0	4.6	1.4	0.1	1.2	3.5	2.0
(*c*) Programme development	–	0.1	6.4	4.0	1.7	3.2	3.0
TOTAL OF 1[a]	34.6	86.1	85.3	79.4	86.6	95.3	88.4
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	–	3.1	5.3	–	–	–	0.2
(ii) Programme management	14.6	3.5	5.6	18.0	10.9	1.4	8.2
SUBTOTAL OF (*a*)	14.6	6.7	10.9	18.0	10.9	1.4	8.4
(*b*) Communication for motivation	34.1	1.2	1.9	2.0	2.0	1.3	1.8
(*c*) Out-of-school programme	4.7	5.0	1.0	0.1	–	1.8	0.8
(*d*) Programme development	12.0	1.1	1.0	0.5	0.5	0.2	0.4
TOTAL OF 2[a]	65.4	13.9	14.7	20.6	13.4	4.7	11.6
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	14.7	82.3	81.5	69.3	83.8	84.1	80.4
(ii) Programme management	28.5	5.7	6.7	24.0	10.9	5.3	11.2
(iii) Fertility regulation techniques	–	–	–	–	–	0.6	0.2
SUBTOTAL OF (*a*)	43.2	88.0	88.2	93.3	94.7	90.0	91.9
(*b*) Communication for motivation	40.2	5.8	3.3	2.0	3.2	4.8	3.8
(*c*) Out of-school programme	4.7	5.0	1.0	0.1	–	1.8	0.8
(*d*) Programme development	12.0	1.3	7.5	4.6	2.2	3.4	3.5
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7E. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN NORTHERN AFRICA

(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	8.4	37.0	57.7	69.4	87.3	83.4	75.9
(ii) Programme management	6.6	5.9	11.8	1.4	0.8	5.3	4.0
(iii) Fertility regulation techniques	0.2	10.6	9.4	7.9	2.4	1.8	4.3
SUBTOTAL OF (*a*)	91.2	53.5	78.9	78.7	90.4	90.5	84.2
(*b*) Communication for motivation	4.4	39.1	7.8	12.9	6.1	3.9	9.6
(*c*) Out-of-school programme	–	1.6	–	–	0.3	–	0.2
(*d*) Programme development	–	0.8	5.7	6.4	1.0	3.3	3.2
TOTAL OF 1[a]	95.7	94.2	92.4	98.0	97.9	97.7	97.1
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	4.3	5.6	5.4	2.0	2.1	2.3	2.8
(*c*) Out-of-school programme	–	0.1	2.3	–	–	–	0.1
TOTAL OF 2[a]	4.3	5.8	7.6	2.0	2.1	2.3	2.9
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	88.8	42.7	63.1	71.3	89.4	85.7	78.7
(ii) Programme management	6.6	5.9	11.8	1.4	0.8	5.3	4.0
(iii) Fertility regulation techniques	0.2	10.6	9.4	7.9	2.4	1.8	4.3
SUBTOTAL OF (*a*)	95.6	59.1	84.3	80.7	92.5	92.8	87.0
(*b*) Communication for motivation	4.4	39.1	7.8	12.9	6.1	3.9	9.6
(*c*) Out-of-school programme	–	1.7	2.3	–	0.3	–	0.3
(*d*) Programme Development	–	0.1	5.7	6.4	1.0	3.3	3.2
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7F. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN AFRICA (OTHER THAN NORTHERN)

(Percentage)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	75.0	83.9	75.6	58.4	70.0	79.2	74.1
(ii) Programme management	–	–	–	0.3	3.4	3.0	2.3
SUBTOTAL OF (*a*)	75.0	83.9	75.6	58.7	73.4	82.2	76.4
(*b*) Communication for motivation	–	3.6	2.5	–	–	–	0.4
(*c*) Out-of-school programme	–	–	–	–	–	0.7	0.3
(*d*) Programme development	–	0.9	1.0	3.5	0.7	2.8	1.9
TOTAL OF 1[a]	75.0	88.3	79.1	62.2	74.1	85.7	79.0
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	8.4	3.6	7.2	11.5	8.8	7.3	8.0
(ii) Programme management	–	–	–	0.7	1.7	–	0.6
SUBTOTAL OF (*a*)	8.4	3.6	7.2	12.2	10.5	7.3	8.6
(*b*) Communication for motivation	10.8	6.0	10.8	21.5	13.2	5.4	10.0
(*d*) Programme development	5.8	2.1	2.9	4.1	2.2	1.7	2.4
TOTAL OF 2[a]	25.0	11.7	20.9	37.8	25.9	14.4	21.0
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	83.4	87.4	82.7	69.8	78.8	86.5	82.1
(ii) Programme management	–	–	–	1.0	5.0	3.0	2.9
SUBTOTAL OF (*a*)	83.4	87.4	82.7	70.8	83.8	89.5	85.0
(*b*) Communication for motivation	10.8	9.6	13.3	21.6	13.2	5.4	10.4
(*c*) Out-of-school programme	–	–	–	–	–	0.6	0.3
(*d*) Programme development	5.8	3.0	4.0	7.6	3.0	4.5	4.3
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7G. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN WESTERN ASIA

(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	65.5	87.1	68.1	47.1	61.4	68.9	64.1
(ii) Programme management	34.5	–	7.9	–	–	–	0.8
(iii) Fertility regulation techniques	–	–	8.0	14.1	1.4	1.5	3.4
SUBTOTAL OF (*a*)	100	87.1	84.0	61.2	62.8	70.3	68.3
(*b*) Communication for motivation	–	–	–	–	7.3	11.7	8.0
(*d*) Programme development	–	–	5.7	6.5	4.8	5.5	5.3
TOTAL OF 1[a]	100	87.1	89.7	67.7	74.8	87.6	81.6
2. All regional projects on fertility regulation							
(*a*) Family planning:							
(ii) Programme management	–	–	–	–	3.8	2.3	2.2
(*b*) Communication for motivation	–	7.3	5.0	22.0	13.0	6.1	10.0
(*d*) Programme development	–	5.6	5.3	10.3	8.5	4.0	6.1
TOTAL OF 2[a]	–	12.9	10.3	32.3	25.2	12.4	18.4
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
(i) Delivery system	65.5	87.1	68.1	47.1	61.4	68.9	64.1
(ii) Programme management	35.5	–	7.9	–	3.8	0.2	3.0
(iii) Fertility regulation techniques	–	–	8.0	14.1	1.4	1.5	3.4
SUBTOTAL OF (*a*)	100	87.1	84.0	61.2	66.6	72.6	70.5
(*b*) Communication for motivation	–	7.3	5.0	22.0	20.2	17.8	18.1
(*d*) Programme development	–	5.6	11.0	16.9	13.2	9.6	11.4
TOTAL OF 3[a]	100	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 7H. ASSISTANCE TO FERTILITY REGULATION PROJECTS IN EUROPE

(*Percentage*)

	Pre-1972	*1972*	*1973*	*1974*	*1975*	*1976*	*Total*
1. All country projects on fertility regulation	–	–	–	–	–	–	–
2. All regional projects on fertility regulation							
(*a*) Family planning:							
Delivery system	–	100	100	100	80.1	81.8	88.6
(*d*) Programme development	–	–	–	–	19.9	18.2	11.4
TOTAL OF 2[a]	–	100	100	100	100	100	100
3. All country and regional projects on fertility regulation							
(*a*) Family planning:							
Delivery system	–	100	100	100	80.1	81.8	88.6
(*d*) Programme development	–	–	–	–	19.9	18.2	11.4
TOTAL OF 3[a]	–	100	100	100	100	100	100

SOURCE: Computer printouts, United Nations Fund for Population Activities.

[a] Relating to fertility regulation.

TABLE 8. COST BREAKDOWNS BY FUNCTIONAL CATEGORIES FOR WORLD BANK/IDA LENDING TO POPULATION PROJECTS: TOTAL AMOUNT

(Thousands of dollars)

Financial year project approved	Country	Total amount	Amount: Management	Training	Service delivery	IECM[a]	Research and evaluation	Contingencies
1970..................	Jamaica	2 000	15.6	28.8	1 276.6	–	15.6	663.4[b]
1971..................	Trinidad and Tobago	3 000	44.6	768.3	1 437.9	16.2	20.3	712.7[b]
	Tunisia	4 800	168.6	264.5	3 734.7	–	22.7	609.5
1972..................	India	21 200	1 503.3	2 189.6	13 136.1	303.3	663.7	3 404.0
	Indonesia	13 200	1 373.0	3 587.9	1 882.9	2 495.6	1 587.5	2 273.1
1973..................	Iran	16 500	250.0	4 760.0	8 935.0	–	200.0	2 355.0
	Malaysia	5 000	443.8	183.6	1 102.9	497.0	780.3	1 992.4[b]
1974..................	Egypt	5 000	365.0	586.7	2 548.6	130.5	19.5	1 349.7
	Kenya	12 000	598.5	2 649.7	5 846.8	583.7	136.6	2 184.7
1975..................	Bangladesh	15 000	66.5	6 202.6	–	1 911.9	1 196.1	5 622.9
	Philippines	25 000	169.5	3 439.0	11 663.9	300.0	620.0	8 807.6
1976..................	Dominican Republic	5 000	586.0	1 693.0	1 693.0	–	104.0	924.0
	Jamaica	6 800	–	178.0	3 291.7	462.7	543.6	2 324.0[b]
	TOTAL	134 500	5 584.4	26 531.7	56 550.1	6 700.9	5 909.9	33 223.0

SOURCE: World Bank, Population Projects Department.

[a] Information, communication, education and motivation.
[b] Including interest and other charges.

TABLE 9. COST BREAKDOWNS BY FUNCTIONAL CATEGORIES FOR WORLD BANK/IDA LENDING TO POPULATION PROJECTS

(Percentage)

Financial year project approved	Country	Total	Management	Training	Service delivery	IECM[a]	Research and evaluation	Contingencies
1970	Jamaica	100	0.8	1.4	63.8	–	0.8	33.2
1971	Trinidad and Tobago	100	1.5	25.6	47.9	0.5	0.7	23.8
	Tunisia	100	3.5	5.5	77.8	–	0.5	12.7
1972	India	100	7.1	10.3	62.0	1.4	3.1	16.1
	Indonesia	100	10.4	27.2	14.3	18.9	12.0	17.2
1973	Iran	100	1.5	28.8	54.2	–	1.2	14.3
	Malaysia	100	8.9	3.7	22.1	9.9	15.6	39.8
1974	Egypt	100	7.3	11.7	51.0	2.6	0.4	27.0
	Kenya	100	5.0	22.1	48.7	4.9	1.1	18.2
1975	Bangladesh	100	0.4	41.4	–	12.7	8.0	37.5
	Philippines	100	0.7	13.8	46.7	1.2	2.5	35.2
1976	Dominican Republic	100	11.7	33.9	33.9	–	2.1	18.5
	Jamaica	100	–	2.6	48.4	6.8	8.0	34.2
	TOTAL	100	4.2	19.7	42.0	5.0	4.4	24.7

SOURCE: World Bank, Population Projects Department.

[a] Information, education, communication and motivation.

DEMOGRAPHIC MODELS NEEDED FOR DEVELOPMENT PLANNING: THE YUGOSLAV EXPERIENCE

Miroslav Macura and Miloš Macura *

In the course of the past 30 years or so, marked progress has been made in development planning along two different yet interconnected lines. As a consequence of growing concern over current and prospective social and population problems, the scope of planning has gradually been extended to include, in addition to economic phenomena, social and demographic phenomena. This move calls for a wider data base and new methods and techniques. In particular, demographic models have gradually been developed to treat both the dynamic and the structural population variables, which have consequently been linked with a variety of economic and social variables. Advances in systems analysis, computer technology and modelling have facilitated this process of adapting demographic models to new planning needs. The principal components of that process are summarized in the present paper, with special reference to the Yugoslav experience.

THE EXPANDING SCOPE OF DEMOGRAPHY IN DEVELOPMENT PLANNING

Three distinct periods can be distinguished in the use of demographic variables in development planning. During the first period, population was considered an exogenous variable, and was virtually reduced—in terms of planning variables—to the growth of population. In the second period, population change was understood to be a more complex process, related to the formation of manpower, employment, health, education and the like, and having multiple economic and social implications. In the latest period, which is still evolving, it is increasingly recognized that the fabric of development consists of many interwoven threads including dynamic and structural changes in the population and in the family and geographical location which are in continuous interaction with the growth and structural modification of the economy and the society.

In considering the first period, characterized by the early plans of socialist countries and of developing nations, we realize how little attention was given to population as a factor of development. Emphasis was placed on the growth of the economy with industrialization as a key component, and the major effort was focused on issues relating to savings, investment and production. Population was treated as an exogenous variable, while demographic projections—rather rudimentary at that time—were primarily used for estimating the *per capita* effects. Only limited attempts were made to link the anticipated population growth with labour force formation, education or employment. It is true that, in the early days of planning, the concept of structural change was introduced through sectoral disaggregation but none of the sectors was projected taking into account the corresponding demographic variables. Notwithstanding these comments, we must appreciate the early realization of the importance of population growth to development, at least in some developing countries. Considering that a high rate of population growth was detrimental to their development, India and Pakistan had introduced, in the 1950s, family planning as a component of their development plans, although on a rather modest scale.

In the second period planning was still considered a Marxist device in most of the Western countries. Subsequent developments were nevertheless affected by the experience of some Western European countries in which planning was considered an appropriate method for medium-range policy-making. An interchange of experience greatly contributed to the advancement of planning methodology, the concept of comprehensive planning was gradually adopted and demographic considerations found a more prominent place in development plans. Characteristic of this period was the attention given to social development, which in turn stimulated planning of social services. Sectoral planning originally dealing only with the economic sectors was gradually extended to the social spheres, such as education, public health, child care, social security, housing, urban growth and the like. An increasing awareness of the role of human factors in development has re-emphasized the dual function of population as consumer and producer, thereby underlining the necessity of manpower and employment planning. Manpower and sectoral planning thus became major users of demographic projections, which were disaggregated and structured to supply data on working-age contingents and specific segments of the population, such as children, youth, working adults, the retired, the elderly and others. Significant efforts were made in many countries to work out approaches to and methods of comprehensive demographic projections corresponding to the concept of comprehensive planning. But the planning exercise did not come up to expectations, at least as far as the utilization of demographic projections was concerned. It is unclear whether this was because of missing data, or of limited understanding of interrelationships between

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demographic, economic and social variables or of failure of planning techniques and demographic models to integrate population into the development process.[1]

One preoccupation of the current period is how to better incorporate social and demographic factors in development planning. If population is an important component of development, as it obviously is, provision must be made in the planning model for relating demographic variables to relevant economic and social ones. This simple requirement is rather difficult to satisfy for it involves a "variety of economic-demographic interactions, usually both indirect and complex", while "many variables in the economic system are interposed between population change and employment change"[2] as a key relation between economy and population.

Among the many directions of research and experimentation in this area, mention should be made of at least two. The first one emerges from national planning practices of European countries and is based on a concept of "systems of models", by which it is understood that the totality of models consists of several parts interconnected through links which are not all strictly formalized.[3] An example is a system of models described by Fedorenko as "long term forecasting models of macro-economic development indicators".[4] It consists of five systems of "forecasting models" comprising: (*a*) scientific and technological progress, (*b*) social objectives, (*c*) population and labour force, (*d*) natural resources and (*e*) national income formation and distribution. The second direction is geared towards the building of "comprehensive economic-demographic models" consisting of two or more subsystems interconnected with formalized links involving dynamic, structural and behavioural relationships. The population is treated here in a separate subsystem but many of its components are dealt with in other subsystems as well. The Bachue family of models, which will be discussed below, belongs to the latter.

Evolution of demographic projections

For some 280 years, total population was the only subject of demographic projections. World-wide improvements in, and the promotion of, projection techniques have taken place only since the 1950s.[5] That appeared to be the decade of projections by sex and age, as well as the initial period of experimentation with individual sectoral projections, such as that of the labour force, its industrial structure, education etc. At the international level, the United Nations Secretariat has produced a series of regional population projections by sex and age, culminating in a report entitled *The Future Growth of World Population*, published in 1958. Subsequently, the Secretariat supplied as much demographic substance as possible at that time for use during the First United Nations Development Decade.

In the 1960s, the idea of comprehensive demographic projections needed for planning was advanced in several quarters. It was discussed, *inter alia*, in many United Nations meetings, and following a recommendation by the United Nations Population Commission, a report was published in which conceptual issues were discussed relatively to projections of total population, labour force, education and educational structure, as well as households and families.[6] Actual work on such projections for the regions and countries of the world was undertaken by United Nations agencies in the late 1960s. Some of the projections have been used as inputs for economic projection prepared as a basis for formulating the International Development strategy for the Second United Nations Development Decade. The work of the United Nations system in this area, in terms of methodology as well as projections, has proven to be very productive; it has promoted a wide use of demographic projections throughout the world, and stimulated production of national projections in many countries.

At the national level, Yugoslav experience in applying demographic projections to development planning appears to broadly follow the three periods previously mentioned. Of course, the first five-year plan for 1947–1951 had a rather weak demographic foundation. Owing to war conditions, it had not been possible to take the 1941 population census, while current population estimates were unreliable because of large demographic losses, both direct and indirect. Population estimates and projections, as poor as they were, were used in the plan for projecting the growth of national *per capita* income, in addition to estimating the *per capita* growth of some key commodities. It was not possible to project either the labour force and employment or the size of individual population groups deserving special attention at that time. The same was true for fertility, mortality and migration.

Following the 1948 population census, Ivo Lah produced population projections by sex and age till 1960,[7] which were replaced by a new set of projections after the 1953 census data became available. Current estimates and projections of population thus became part of the information needed for planning and administrative purposes. However, by the early 1950s it was clear that planning demanded additional demographic projections suitable for estimating change in the industrial structure of manpower as well as shifts of population from agriculture to the non-agricultural sector, both of which were likely to take place in the course of industrialization.

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[1] *Cf. The Deteminants and Consequences of Population Trends*, vol. I, (United Nations publication, Sales No.E.71.XIII.5), p. 591.

[2] G. B. Rodgers and R. Wéry, "Population and employment: a strategy for research" (Geneva, International Labour Organisation, March 1974) (mimeographed).

[3] *Use of Systems of Models in Planning* (United Nations publication, Sales No. E.75.II.E.9), pp. 1–2.

[4] N. P. Fedorenko, "Econometric models for planning". In *Use of Systems* . . ., pp. 17–19.

[5] *Manual III: Methods for Population Projections by Sex and Age* (United Nations publication, Sales No. E.56. XIII.3).

[6] *General Principles for National Programmes of Population Projections as Aids to Development Planning* (United Nations publication, Sales No. 65.XIII.2).

[7] Ivo Lah, "Stanovništvo FNRJ u periodu 1948–1960 godine", *Statistička revija*, No. 3–4 (1951), pp. 372–391. Projections were produced for six republics and two provinces by single calendar and age years and proved to be surprisingly realistic when compared to 1961 census data.

By the mid 1950s such projections were prepared for Yugoslavia as a whole for a five-year period.[8] Total labour force was projected by applying the 1953 rate of economic activity (which was the only information available) to Lah's projections of total population. This procedure proved to be inadequate because of modifications in sex-age specific activity rates for young and old age groups. Employment in each of the three sectors had to be projected as a function of sectoral value added and sectoral productivity, the former being derived from economic projections, the latter defined as a target. However, because of large underemployment in subsistence agriculture and owing to technical difficulties, projected employment in the primary sector was in fact taken as the difference between total labour force and employment in secondary and tertiary sectors. Total agricultural and non-agricultural populations were projected by applying specific dependency rates to the respective sectoral employment groups. The techniques used were rather crude, since, except for the sectoral employment projections, the model relied on a number of empirical rates. These were not capable of expressing the interrelationships among population change, labour force formation, production, employment and productivity, nor the relation between employment and dependency. Moreover, the data base was inadequate and made it difficult, if not impossible, to carry the projection work further.

In the course of preparation of the 1957–1961 plan, efforts were made to better understand the demographic situation and to re-examine the role of population and labour in development. Consequently, the plan placed additional emphasis on non-agricultural employment and on the change in socio-economic structures of manpower and population. No progress was made in demographic projections at that time because of the inadequate data base. Since that time, however, demographic study and projections have become an important part of the plan preparation.

The question of demographic projections was reconsidered in the early 1960s in several papers, and a rather ambitious programme was proposed for implementation. In addition to projections of total population by sex and age, the following partial projections were proposed: (*a*) labour force by sex and age, on the supply side; (*b*) industrial or occupational structure of the labour force, on the demand side; (*c*) agricultural labour force, a special case of (*b*), and agricultural population; (*d*) school-age population (by-product of projections of total population) and school attendance; (*e*) educational structure of the population (educational levels and literacy); (*f*) urban and rural population; and (*g*) households by size groups and socio-economic characteristics, most of which were for the six republics and two provinces. It was hoped that the 1961 population census together with the current vital, educational, employment and other statistics would provide sufficient statistical information for the purpose.

[8] Miloš Macura, "Projekcije ekonomske strukture radne snage i stanovništva Jugoslavije", *Ekonomist*, No. 1 (1955), pp. 1–29.

The proposed system was never fully implemented either because of deficient resources or by reason of technical problems. However, since 1962 the Demographic Research Centre has regularly prepared the following projections: total population by sex and age, labour force supply by sex and age, agricultural and non-agricultural labour force and population, migration effects and the projections of households, for each of the eight major regions. As a result, in the plans for 1966–1970 and 1971–1975, there are several policy statements on fertility and family planning, mortality, internal and external migration and the change in socio-economic structure of the population. The projections of non-agricultural employment, which is a significant part of labour force demand, are produced separately within the economic model. Educational projections and projections of urban-rural population are not produced systematically, although many projections are produced for individual cities, subregions and the like apart from the system of comprehensive demographic projections. More recently, projections of total population by sex and age have been produced for some subregions taking into account, in addition to fertility and mortality, assumptions on migration.

From the volume of information on fertility and mortality and the age structure available in projections of the total population, as well as information on the structural aspects generated in the partial projections, it would appear that the system of demographic projections prepared for planning purposes in Yugoslavia is quite satisfactory. The techniques used also appear to be satisfactory. Total population projections are produced in accordance with the United Nations technical recommendations, in four variants and by single age and calendar years, while the partial projections dealing with changes in socio-economic structures of the population rely on commonly used techniques of sex-age specific rates. Consequently, structuring in most of the partial projections is twofold, since it takes into account the change in both the sex-age structure of population and the sex-age specific rates. The data which are generated seem to be abundant, allowing for a variety of analyses relative to future change in population, economy and the society.

While there are many advantages in using a system of demographic projections in planning, a careful examination of the data it generates and of its usage for a longer period point to some deficiencies. First, a system of comprehensive demographic projections by necessity depends on a series of assumptions worked out exogenously, which makes it impossible to specify and build into the model the interactions between demographic and socio-economic variables. Secondly, the system as it has been developed thus far makes no provision for formalizing the linkages between all the components of population growth, since there is no place in the existing model for migration variables. Thirdly, despite the refinements made, the techniques used for the construction of partial projections are rather crude. Sex-age specific rates are understood to condense a variety of economic, social and other factors, the effects of which on the particular population structure are neither measured nor explicitly stated. Comprehensive demographic projections therefore rely more on an individual's judgement, experience and intuition than on actual relationships. Fourthly, in the course of elaborating the partial projections, it is very difficult to achieve adequate co-ordination in assumption-building. Consequently, the lack of interconnexion between between individual partial projections and within the whole system may constitute a serious defect. Fifthly, being produced externally rather than as an integral component of the planning process, demographic projections are not properly linked with economic and social variables constituting the planning model. Partial projections are therefore primarily used for sectoral planning, while their direct utilization in comprehensive planning seems to be marginal. Finally, a recent reform of planning in Yugoslavia, which has emphasized the role of self-government and decentralization in decision-making, appears to require many variants of economic, social and demographic projections sufficiently disaggregated and able to describe alternative development paths, as well as their determination and implications.

Of course, there is plenty of room for further improvements in the system of demographic projections developed thus far in Yugoslavia. Yet, there are planners and demographers who feel that, in addition to developing the existing system, efforts should be made to construct a model which would satisfy the requirements of economic and social development planning by providing sufficient opportunity for a simultaneous treatment of population change. The concept of a system of models referred to earlier, in so far as it rests on non-formalized links between the population and the other models, does not seem to satisfy this requirement. In fact, a population model of that kind by necessity shares the disadvantages of a system of comprehensive demographic projections mentioned above. A third approach, that of economic-demographic modelling, appears to be suitable for the purpose, at least according to the studies carried out so far.

Comments on economic-demographic modelling

The idea of constructing a planning or policy evaluation model large enough to treat both the economic and demographic variables is a quite recent one. It perhaps reflects the criticism that demographic variables have been neglected in development planning and policy-making. The objective was to develop a large-scale economic-demographic model as an instrument of policy evaluation and planning in many spheres of public interest.[9] The models which have been developed thus far are all multipurpose, largely endogenous, computerized structures, each having at least two central blocks: multisectoral economy and disaggregated population.

To this type of model belongs a series of BACHUE models built expressly for the Philippines, Kenya, Brazil and Yugoslavia by the International Labour Office in collaboration with research institutions of the countries concerned. Being members of the same family, BACHUE models have many features in common. These are all yearly, large-scale, largely endogenous, dualistic, computerized, policy simulation models, each covering economy, population, educational process and labour market. In addition to the similarities, individual models reflect peculiar characteristics of the respective countries to the extent deemed appropriate. Where conditions require and data make it possible, as is the case in Brazil and Yugoslavia, the models are regionalized.

A comparison of the BACHUE models with the earlier ones, notably those built in the Coale-Hoover tradition, suggests that the complexity and size of the former is largely due to an effort directed towards removing the limitations of the latter. A major novelty in the BACHUE series, as well as in similar models of recent years, is the endogenous treatment of dynamic and structural change in the population. This seems to be an important qualitative feature which deserves considerable attention from planners as well as demographers.

The philosophy underlying BACHUE modelling has been expounded on several occasions.[10] Individual country models have been described to the extent made possible by the progress of work done thus far.[11] Therefore, our intention here is not to discuss the approaches adopted in the BACHUE modelling in general, nor to analyse their application to the Yugoslav model. Instead, our aim is to outline the structure and the main characteristics of the BACHUE-Yugoslavia model as a whole, and to describe the treatment of population in the model.

The main characteristics of BACHUE—Yugoslavia

The model consists of five mutually linked subsystems: *Economy*, *Social services*, *Population*, *Education* and *Labour allocation*.[12] The subsystems treat respectively the growth and structural change of the economy, determination of demand for and consumption of social services growth and structural change of population, the educational process and formation and utilization of the labour force. The model is disaggregated along two principal dimensions: regional and sectoral. The first consists of eight regions representing six republics and

[9] R. A. Brown, *Survey of TEMPO Economic-Demographic Studies*, Santa Barbara, General Electric, Tempo, Center for Advanced Studies (July 1974); J. E. Quinn, *The Use of the LRPM and PDM Models for Structural Analysis and Development Planning*, United States Bureau of the Census (Washington, D.C., 1975) mimeographed); G.B. Rodgers, M. J. D. Hopkins and R. Wéry, "Economic-demographic modelling for development: BACHUE-Philippines" (International Labour Organisation and World Employment Programme, Working Paper 45, Geneva, 1977).

[10] See Rodgers and others, *ibid.*; Gerry B. Rodgers, René Wéry and Michael J. D. Hopkins, "The myth of the cavern revisited: are large-scale behavioural models useful?", *Population and Development Review*, vol. 2, Nos. 3 and 4 (1976) pp. 395–409.

[11] Rodgers and others, "Economic-demographic modelling . . ."; Miroslav Macura, Bojan Popović and Miroslav Rašević, "BACHUE-Yugoslavia: policy simulation economic-development model of Yugoslavia—conceptual basis" (International Labour Organisation and World Employment Programme, Working Paper 55, Geneva, 1977).

[12] A full description of the model is given in: Miroslav Macura, and others, *ibid.*

two provinces of Yugoslavia. The two sectors are agriculture and non-agriculture, the former covering population and economic activities of the peasants' agriculture, the latter embracing population and economic activities of the socialist sector.

While the division of the model into five subsystems is self-explanatory, its disaggregation along the two principal dimensions requires a few comments. First, being a federation founded on principles of self-governing socialism, Yugoslavia is a country with a great deal of decentralized decision-making. Most of the economic, educational, employment, and other policies are promoted by the republics and provinces, while many decisions are taken at the commune level within the framework of common policies. Secondly, Yugoslavia is in many respects a heterogeneous country. Individual regions are passing through different stages of economic development and demographic transition, so that the spectrum of regional economic-demographic situations ranges from those typically found in developing countries to those found in advanced industrial societies. Thirdly, two major sectors coexist within the national economy. One is, small-scale, mostly traditional and largely subsistence agriculture of private peasants, and the other sector is modern, socialist and predominantly non-agricultural. Modes of behaviour and the ways in which economic, demographic and other variables interact vary across the sectors and regions; for this reason a disaggregation along the two dimensions is introduced.

Not all the subsystems of the model are equally elaborated. Economy, and Population are chosen to stand as central subsystems, while Social services, Education and Labour allocation are more or less supporting subsystems. Consequently, Economy and Population are worked out in greater detail than the rest of the model. However, irrespective of disaggregation or the detail, all the subsystems are interconnected through formalized links which make the model a unique and consolidated analytic entity. The links provide for both direct and indirect interactions of the relevant variables, regardless of their location in the model. Furthermore, the links provide not only for long-term interactions but also for those of short- and medium-term nature.

The model is intended to be a reasonably realistic picture of the real world. Therefore, behavioural and technological relationships built into the model are estimated from a large body of economic, demographic, educational, employment and related data, rather than on the basis of hypothetical assumptions. The data come exclusively from official statistical sources and are either of time-series or cross-section type. These are all macro data, available for some 500 communes, and for eight regions in a time series. Major features of the legal and consensual framework governing the behaviour of institutions and economic units are built into the model to the extent deemed appropriate.

Most of the events and variables contained in the model that either stem from or affect the behaviour of individuals, families and institutions are modelled in an endogenous manner. Beyond this, there are specific variables, other than policy ones, as well as specific areas which are treated exogenously. This is so either because the cost of treating them endogenously would far outweigh the benefits or because data needed for an endogenous modelling, otherwise desirable, are lacking. Indeed, there is ample provision for policy variables in the model. The choice of the variables and their distribution by the model's subsystems reflect to a large extent both the scope of and the methods for regulating socio-economic processes in Yugoslavia.

The model's subsystems with reference to population

It should be noted that many relationships involving population cut across two or three subsystems, directly or indirectly, and that, in addition to fertility, mortality and migration, there is ample provision in the model for analysis of partial population structures. The latter interconnect Population with Economy, Labour allocation, Education and Social services, as appropriate, and take an aliquot part in fertility, mortality and migration determination. For the sake of simplicity, Economy and Social services are briefly described first, followed by a discussion of the demographic subsystems, and by comments on Education and Labour allocation.

Economy

Economy is designed as a multiregional, multi-industrial disequilibrium structure with several built-in adjustment mechanisms. It is regionalized to the extent permitted by the available information. The subsystems, constructed around a national input-output matrix, consists of a number of interconnected blocks that serve the purpose of generating current values of the following variables: final and over-all demand, value added and output, imports, stocks, enterprise savings, investment, personal incomes, taxes and contributions to social-service funds, all by industry of each region. Also generated within the subsystem are personal savings by region.

Sectoral levels of demand and supply are determined endogenously to a large extent. On the demand side, four categories of final demand are distinguished: consumer, investment, social-services plus exports. Levels of final demand are determined by a number of behavioural functions: household consumption functions by commodity-service groups; investment functions by industry of origin; and exports plus social-service consumption functions by industry and social-service activity, respectively. On the supply side, sectoral levels of the value added depend upon the availability of capital and human resource endowments by sector, and on the sectoral production functions. Complementary imports are linked to sectoral output levels. Sectoral levels of over-all demand and supply are obtained from sectoral levels of final demand and value added, respectively, and the input-output matrix.

The adjustment mechanisms ensure consistency within the subsystem whenever specific constraints become binding. Forcing consistency within any given part of the subsystem entails modification of values of endogenous variables initially determined only via behavioural and/or technological relationships according to the rules of the appropriate adjustment mechanism. The mechanism includes: adjustment of imports to foreign exchange constraint, adjustment of desired demand for investment to the over-all saving constraint, clearing of commodity and service markets across regions and the like.

Enterprise savings, personal incomes, taxes and contributions to social services are to a large extent determined exogenously via policy variables in a way which is compatible with the present institutional framework of the Yugoslav economy. The distributive rules and guidelines, shaped through legislation and a number of "social agreements", determine the distribution of enterprise value added, on the one hand, and the distribution of personal incomes among various educational categories of labour, on the other.

A number of variables generated within Economy affect population either directly within Population, or indirectly through Labour allocation, Social services and Education. Similarly, demographic variables affect Economy both directly and indirectly. The direct effects are limited to those felt through determination of personal savings and consumer demand for various commodity-service groups. Thus, young-age dependency, average educational attainment of adults and the like appear as independent variables in personal savings and various consumption functions. Indirect effects operate through Social services, Education and Labour allocation.

Social services

This subsystem covers determination of demand for social services expressed in terms of resources needed to finance their provision, revenues collected to meet the demand and consumption of services. It also covers the distribution of expenditures among various uses (material costs, personal incomes, savings etc.) and fixed-asset formation, all by alternative social-service activities. The activities are: three levels of schooling (primary, secondary and tertiary), medical care, public housing, old-age security, other miscellaneous services, regional and federal government.

Revenues are determined by setting aside exogenously specified proportions of value added of Economy, expenditures of Social services and gross personal incomes generated in both subsystems. The way demand for services is determined varies among activity. In educational and medical care activities demand is obtained as a product of appropriate service costs per user and the number of users: students by level of schooling and total population, generated in Education and Population, respectively. Average costs are endogenously determined in the present subsystem via respective average-cost equations. Independent variables of the medical care equation include a few demographic variables: young- and old-age dependency, proportion of population in Agriculture and population density. Average costs of educational activities are not directly linked to demographic variables; however, they are indirectly affected, particularly at the primary level, by population growth through increase in the number of students. Demand for old-age security, public housing, other miscellaneous and government services is determined by multiplying the total gross domestic product by the proportion of each of those sectors in the gross domestic product. The proportion is endogenously determined and depends on population density and proportion of population in Agriculture, among others.

Revenues may equal, exceed or fall short of resources needed to meet the demand by activity. Whenever the resources and the demand are out of balance, adjustments based on specified rules take place and the disequilibrium is removed either partially or completely. Consumption of services equals resources actually spent in order to supply the services.

Population

This subsystem models vital and migratory processes as well as the resultant changes in the size and composition of the population. It focuses on population of Yugoslavia residing within national boundaries and treats population residing abroad to the extent required for modelling the domestic portion of the population. Disaggregation of the subsystem along the two principal dimensions makes the national population consist of 16 region-sector-unit subpopulations, each of which is broken down into a number of age-sex-educational groups. The size and composition of each subpopulation is traced over time, and this is done by explicit modelling of fertility, nuptiality, mortality, internal and external migration.

Two types of fertility are distinguished in the subsystem: marital and extramarital. The former is treated endogenously, the latter exogenously. The distinction between the two is introduced since illegitimate childbearing is sufficiently widespread within certain age groups in some regions of Yugoslavia to deserve a separate treatment, and because factors affecting marital fertility are probably quite different from those influencing extramarital fertility. Marital fertility is determined via a couple of simultaneous marital fertility equations for each sector. Dependent variables of the equations are Coale's indices M and r, denoting respectively, a relative level of marital fertility in the age group 20–24, and an index of fertility control at age 25 and beyond.[13] The equations are used to determine M and r of every region-sector unit for each simulation interval. Given M and r, the period schedule of marital fertility of the unit is reached by a procedure proposed by Coale. Age pattern of illegitimate fertility prevailing in the base year within each particular region stays fixed over the time and is applied to both sectors of the region equally. Period age schedule of illegitimate

[13] A. J. Coale, "Age patterns of marriage", *Population Studies*, vol. XXV, No. 2 (1971), pp. 193–214.

fertility for the given region-sector unit is reached by combining the age pattern of illegitimate fertility for the region with the exogenously determined level of total illegitimate fertility.

Female nuptiality is split into first marriage, on the one hand, and widowhood, divorce and remarriage combined, on the other. The former is treated endogenously, the latter exogenously. The modelling of the former generates the female schedule of proportions ever-married, while the treatment of the latter yields female age schedule of proportions currently widowed and divorced. The first marriage is covered with a triple of simultaneous first-marriage equations for each sector. Dependent variables of the equations are Coale's indices a_o, k and C, which respectively stand for the earliest age of first marriage, average speed at which women enter the first marriage by age and the ultimate proportion of ever-married. The equations are used to determine Coale's first-marriage indices for specific region-sectors for each simulation interval. The indices are in turn employed to generate for each region-sector unit a schedule of proportions ever married by the Coale's procedure. Generating the schedule amounts to transforming a particular standard age schedule of proportions ever married into the schedule underlined by the values of the indices.[14] Age schedule of proportions widowed and divorced for each unit is generated as a product of the base-year Yugoslav schedule of proportions currently widowed and divorced chosen as a standard, and an index representing the ratio of the derived schedule to the standard schedule. The value of the index is determined exogenously. To conform with the age schedule of fertility, the two age schedules of nuptiality are period- rather than cohort-specific.

The schedules discussed so far are used to derive an age schedule of over-all fertility for each unit. The schedules of proportions ever-married, as well as those of proportions widowed and divorced, are first converted into age schedules of proportions currently married and single. Then, the schedule of over-all fertility is reached as a weighted average of appropriate marital and illegitimate fertility schedules, with the weights being age proportions currently married and single, respectively.

Mortality is split by age and sex, and thus variations in age-sex patterns of mortality are explicitly allowed. Two different types of mortality equations are built into the subsystem. Dependent variables of the equations are indices of child and adult mortality-probability of dying before exact age two, $_2q_o$, and life expectancy at age five, e^o_5. The equations are employed to generate region-specific $_2q_o$ and e^o_5 by sex for each simulation interval. These indices are in turn used to generate for each region-sector units so-called "split" model life tables by sex using Coale-Demeny model life tables.[15]

In the model, population moves across three types of boundaries: sectoral, regional and national. Mobility across sectoral and regional boundaries is defined as internal migration, that across national boundaries as external migration. The former is treated endogenously, the latter exogenously. Two sets of equations are built into the model in order to handle internal migration. One set consists of equations with dependent variables defined as age-sex-education specific rates of migration from one region into either sector of another region. The other set consists of equations with dependent variables defined as age-sex specific rates of net migration of population belonging to Agriculture of the region. The equations are used to generate respective rates for each simulation interval. External migration is modelled in a much cruder manner. Distinction is made between permanent emigration, temporary emigration and return migration of temporary emigrants. Over-all proportions of population of each region-sector unit emigrating both permanently and temporarily, and the distributions of the emigrants are all set exogenously. Also exogenously determined are the proportions of population of every unit staying temporarily abroad which returns, and the distribution of return emigrants.

Fertility rates, life tables, internal migration rates and proportions and distributions of external migrants of the given yearly simulation interval are all used to arrive at size and composition of population of every unit at the end of the interval. Fertility and mortality are first used in a standard fashion to reach population unaffected by migration. Next, internal migration rates are employed to determine net changes due to internal migration and then to reach population affected by internal migration at the end of the interval. At a final stage, population of every unit is modified to account for external migration for the interval.

There are numerous linkages within Population, on the one hand, and between this subsystem and the rest of the model, on the other. Most of the linkages within the subsystem are embodied in the behavioural equations; many variables of the subsystem appear both as dependent variables in some equations and as independent variables in the others. Thus, for example, in the marital fertility equations, child mortality and proportion of ever-married women currently widowed and divorced appear as independent variables. Furthermore, r appears as an independent variable in the M equation, and vice versa. Specifications of the child mortality equations include: levels of over-all fertility proportion of illegitimate fertility and proportion of births occurring to young and older mothers. Several demographic variables appear as explanatory variables in the first-marriage equations. Those appearing in the equation covering the earliest age of marriage are: sex ratio at the beginning of the childbearing period, level of marital fertility, average speed at which first marriages are contracted and the rate of illegitimate fertility at age 15–19. Marital fertility, sex ratios of appropriate age groups and the earliest age of marriage are explanatory variables in two other first-marriage equations. Average educational attainment of men or women of appropriate age groups appear in nearly all of the above equations. In migration equations of certain age-sex-educational groups, independent variables

[14] *Ibid.*

[15] A. J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations* (Princeton, New Jersey, Princeton University Press, 1966).

include proportions single and average numbers of surviving children.

Linkages between Population and the rest of the model are of two types. First, population size and structure generated within Population are inputs into other subsystems, namely Education and Labour allocation. Secondly, variables generated in Population appear as explanatory variables in behavioural equations of all other subsystems, while in turn variables generated within the latter appear as explanatory variables in the equations of Population. Examples of non-demographic variables appearing in the equations of Population are: labour force participation rates of woman in marital fertility, migration and first-marriage equations; proportions attending schools at various levels in fertility and marriage equations; average personal income in marital fertility, migration and mortality equations; levels of supply of family planning and health services in marital fertility and mortality equations, respectively; employment growth and unemployment rate in migration equations; capacity of educational institutions relative to eligible persons in migration equations etc.

Education

This subsystem treats the process of acquiring new skills and knowledge through formal education; it does not model on-the-job training and other informal schemes. The subsystem is disaggregated along two principal dimensions, and among four levels of schooling: lower primary, higher primary, secondary and tertiary. Each level takes four years to complete. The secondary level is subdivided into two categories of schooling: general secondary and other secondary (technical and vocational). The subsystem generates students, graduates and drop-outs, classified by age, sex and grade, and helps shape the educational structure of the population of every region-sector unit at each simulation date.

The educational process is treated largely endogenously. Three classes of behavioural equations exist in the subsystem: enrolment and over-all drop-out equations at lower and higher primary levels, and attendance (in specific grades) equations at secondary and tertiary levels. Dependent variables of the equations are rates of enrolment, over-all drop-out and attendance. All equations are sex-sector specific. The equations are used to generate respective rates which, together with exogenous variables of the subsystem (single-grade relative drop-out rates on all four levels, and over-all drop-out rates on the secondary and tertiary levels), are converted into enrolment and single-grade drop-out rates for each level. These rates are applied to distributions of students and graduates, as well as to children eligible for entry into lower-primary level at the beginning of the given simulation interval. The results are numbers of students, graduates and drop-outs at the end of the interval.

Independent variables of the equations of the subsystem are generated throughout the model. It is impossible to list all of them here but some will be mentioned, particularly those generated in Population. Thus, young-age dependency appears in enrolment and drop-out equations, while proportions of females age 15–19 currently married appear in female secondary level attendance equations. Educational attainment of adults of appropriate age intervals appear in all enrolment, drop-out and attendance equations. In addition to the demographic variables, average number of hectares and labour force participation rate at age 10–14 in Agriculture appear both in enrolment and in drop-out equations of Agriculture. Various indicators of educational composition of labour force in Non-agriculture appear in equations at all four levels of schooling of the sector. Furthermore, relative wages, unemployment rates of various educational categories of labour etc. appear in attendance equations.

Labour allocation

Supply of and demand for labour as well as employment and unemployment are modelled in a subsystem which like Population and Education, is fully disaggregated among region-sector units. The treatment of labour allocation differs from one sector to another, irrespective of region. In Agriculture, labour allocation is handled in a rather rudimentary way. It is assumed that all labour supplied to this sector is employed by the sector itself, of course at varying degrees of utilization. All labour of the sector belongs to the lowest educational category. In Non-agriculture three educational categories of labour are distinguished, and supply, demand, employment and unemployment of each category is determined.

On the supply side, size and structure of active population by age, sex and education of every region-sector unit for each simulation interval are jointly determined by the population size and distribution, generated in Population, and by age-sex-education specific labour force participation rates generated in the present subsystem via labour force participation equations. To obtain the labour supply by education, active population is aggregated across age-sex groups. Dependent variables of the equations are the respective labour force participation rate. Specifications of the equations vary across age-sex groups. Some of the independent variables are common to many equations, while others appear only in the equations of some, mostly marginal, groups. Independent variables are generated throughout the model. Demographic variables appearing as independent ones are: proportions of females currently married, over-all fertility rates and average numbers of living children, all by age of women in various young- and prime-age female equations; average educational attainment by age in various female and male equations in Non-agriculture; and an age index of active male population of Agriculture in old-age male equations of the sector. The list of non-demographic explanatory variables includes among others: level of supply of child-care services, average personal income and rates of unemployment in prime-age female equations in Non-agriculture; proportion of adolescents attending school in prime and old-age female, as well as in some old-age male equations in Agriculture and others.

On the demand side, industry and activity-specific levels of labour demand by educational category are determined by using the respective employment functions. Over-all demand of each category is simply an aggregate of industry and activity labour demand levels. Independent variables of employment functions are generated in Economy, Social services and the present subsystem.

An equilibrium between the supply of and demand for labour by educational category in Non-agriculture is not ensured. Instead, in every region in each simulation interval the supply of each category may operate as a constraint, be fully absorbed or go partially unused. Consequently, unemployment of some educational groups may arise simply as an excess supply of labour. Being determined largely within the given institutional framework, salaries do not play a role in the adjustment process. Supply may vary over time as a result of changes in the size and structure of the population (largely determined by migration, in the short run), as well as variations of the labour force participation rates.

Concluding remarks

While there is abundant experience with regard to application of comprehensive demographic projections to development planning, we know very little about the utilization of economic-demographic models for planning purposes. In fact, a first experiment with the BACHUE-Yugoslavia is to be performed in 1978, in the course of plan preparations for the first half of the 1980s. In considering experience acquired with the BACHUE-Philippines, it is hoped that the Yugoslav model would work and prove useful, although perhaps after some adaptation in parts of its present structure. In that case, it would be possible to examine alternative development strategy for the 1981–1985 period in the light of its long-range effects, which is one of essential requirements set up by the competent authority.

Assuming that the working of the model would prove satisfactory, there would be two sets of demographic and other projections available for planning; one produced by the conventional models, the other generated in the BACHUE model. Consequently, the following questions may arise: Would it be appropriate to proceed along the two lines? Why could not the BACHUE model substitute for demographic and other projections that are currently in use? And, in the final analysis, are further development projections worth the efforts and resources involved? The answers would indeed depend very much on the judgement of planners but as far as we are concerned, there seem to be strong reasons for continuing projection work for the purposes of economic-demographic modelling.

First, modelling the growth and structures of population and their relevant relationships with economic and social development is still in its infancy and is thus currently a rather uncertain undertaking. The same is even more true for demographic projections whose exogeneity already creates serious problems. It therefore makes sense to produce independently two series of data on future prospects in order to provide for comparisons and evaluation of the procedures used and the results obtained. Secondly, there are situations to which comprehensive models can hardly be applied, e.g., in planning for development of small regions or cities, for which either data is lacking or the relations with the rest of the country are so complex that modelling would prove prohibitively expensive. Demographic projections that are flexible and sufficiently simple appear to better suit such situations, at least in the present stage of modelling technology. Thirdly, comprehensive demographic projections of the kind developed so far by the United Nations system can hardly be replaced at the international level by any other system. Construction of global projections requires well standardized national projections for each country that could be aggregated in different fashion to suit a variety of national and international purposes. We could, therefore, foresee a parallel development of the projecting and modelling work and look forward to further improvements in both.

FINE-TUNING BRASS-TYPE MORTALITY ESTIMATES WITH DATA ON AGES OF SURVIVING CHILDREN

*Samuel H. Preston and Alberto Palloni**

William Brass (1975; Brass and others, 1968) has developed an ingenious technique for estimating child mortality rates that prevailed in the recent past from women's reports on the total number of children that they have borne and the number of those children who survived to the date of interview. Sullivan (1972) and Trussell (1975) modified the Brass technique in a manner that is expected to increase the precision of estimates if a certain set of conditions pertain. The present paper develops and evaluates a related technique for converting women's reports into child mortality estimates. The basic idea, as first described by Ansley Coale to Lee-Jay Cho (1973), involves back-projecting surviving children by age until one has reproduced the reported number of children ever-born. The approach was reinvented by the authors when faced with a concrete estimation problem. The proposed technique offers some advantages for estimation of mortality level among social classes or other permeable subgroups; when fertility trends are present in the population under investigation; when the prevailing fertility pattern deviates markedly from normal patterns; and in certain other circumstances. It also permits a more exact identification of the ages of children to which the estimated mortality level pertains. An elaboration of the technique is developed to permit an estimation of mortality trends.

The Brass approach is based on the following identity:

$$\frac{D}{B} = \int_0^{\alpha} \frac{B(a)q(a)da}{B} = \int_0^{\alpha} c(a)q(a)da, \text{ where} \qquad (1)$$

D = total number of children who have died of those ever-born to reporting women

B = total number of children ever-born to reporting women

$B(a)$ = total number of children born a years ago to reporting women

$c(a)$ = proportion of children ever-born to reporting women who were born a years ago

$q(a)$ = proportion of children born a years ago who have died

α = years since birth of the first child born to reporting women

If a census or survey produces information on D and B, equation (1) contains two unknown functions, $c(a)$ and $q(a)$. Brass proposed a clever means to approximate $c(a)$: compare the cumulative fertility rates of women in different age categories in order to infer the shape of the fertility function, which was assumed to apply in the past to women of a certain current age. The observed cumulative fertility rates could then be used in conjunction with adjustment multipliers derived by simulation in order to estimate $q(a)$.

An alternative approach is the following. Let

S = total number of children who have survived of those ever-born to reporting women ($S = B - D$)

$S(a)$ = total number of births to reporting women a years ago who have survived to the present

$p(a)$ = proportion of births that occurred a years ago who have survived to the present ($p(a) = 1 - q(a) = \frac{S(a)}{B(a)}$)

$c_s(a)$ = proportion of surviving children of reporting women who are now age a ($c_s(a) = \frac{S(a)}{S}$).

Then

$$\frac{B}{S} = \frac{\int_0^{\alpha} B(a)da}{S} = \frac{\int_0^{\alpha} \frac{S(a)}{p(a)}da}{S}, \text{ and}$$

$$\frac{B}{S} = \int_0^{\alpha} \frac{c_s(a)}{p(a)}da. \qquad (2)$$

The potential advantage of equation (2) in comparison with equation (1) is immediately obvious. If the census or survey that provided information on births and survivors also provided information on the ages of surviving children, then the only unknown in the equation is the $p(a)$ function. In effect, the age distribution of surviving children maps out the fertility history of reporting women. More precisely, knowledge of B/S and the age

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distribution of surviving children enables one to solve simultaneously for fertility and child mortality histories. If reproductive histories of reporting women are available—in particular, the dates of all of their births—then the $c(a)$ function can also be estimated directly and more precise Brass-type estimates made with equation (1). Our basic point, which will be illustrated throughout with reference to equation (2) but is also applicable to (1), is that mortality estimates from Brass-type questions need not inevitably rely upon approximations that are based upon violable assumptions. Women's reports on their fertility histories or on ages of surviving children will usually allow greater precision in estimating mortality level and also, as we will show, in specifying the ages of children to which survival is estimated most accurately.

Using equation (2) to estimate mortality levels is a simple matter. If one assumes that the correct $p(a)$ function is a member of a one-parameter system of model life tables, then only one level of mortality in that system will be compatible with B/S and the $c_s(a)$ function. As trial mortality levels improve, $p(a)$ will rise at all ages and the right-hand side of equation (2) will fall monotonically, crossing the observed B/S value only once. Much of this paper is devoted to identifying the childhood ages to which mortality estimates are least sensitive to the choice of model mortality family and to the assumption of constancy of mortality within that family.

Advantages and disadvantages of the surviving children approach

The major advantage of incorporating information on ages of surviving children is that it should provide a more precise indication of the fertility history of reporting women than is provided by Brass-type procedures. As noted, these latter procedures utilize cumulative fertility rates of women, usually grouped into five-year age or marital-duration categories, to index the shape of the age-specific or marital-duration specific fertility function for reporting women. A particular index, typically the ratio of cumulative fertility rates in two successive five-year age groups, is then used to provide adjustment factors for converting D/B into estimates of $q(a)$. The equations that convert fertility indices into adjustment factors have been produced by simulating in one way or another mortality and fertility histories and by computing the adjustment factors that would minimize errors in estimating $q(a)$. The conventional approach is therefore subject to the following sources of error that are not present when the surviving children approach is used:

(*a*) Fertility trends. If fertility has been declining at all ages, the reporting women who are aged 20–24 would have had higher cumulative fertility when they were age 15–19 than women who are currently 15–19. Use of the latter group's fertility to infer the fertility level at age 15–19 of women now aged 20–24 will produce an incorrect index of that cohort's fertility history. In effect, the children of women now 20–24 will be assumed to have been born too recently, on average. A given D/B will thus translate into too high an estimated mortality level ($q(a)$). In contrast, under the surviving children approach, any trends in fertility will be reflected in $c_s(a)$.

Annex I by Coale and Trussell describes another means of dealing with fertility trends that can be applied when two censuses or surveys are available.

(*b*) Unusual fertility patterns. Many different fertility histories can produce the same cumulative fertility rates in two successive age groups. The cumulative fertility indices should perform well if the fertility history that produced them is close to the average of those used in the reproductive régimes that produced the adjustment factors. However, unusual patterns by definition will not be accurately represented by these averages and thus will cause distortions in adjustment factors. These problems are particularly acute towards the beginning of reproduction, when the pattern of fertility is not reflected with great precision by five-year aggregated rates. For this reason, Brass-type estimates are less reliable for young ages of women than they are for most older ages (Trussell, 1975). Again, whatever fertility history has prevailed among reporting women is reflected in the $c_s(a)$ function, which has the additional advantage of providing information by single-year ages of childbearing rather than by five-year age groups.

(*c*) Flows of women among social categories. Inference of fertility histories from comparisons of cumulative fertility among successive cohorts faces particular problems for population subgroups that are not closed to "migration". For example, it would clearly be wrong in most cases to assume that professional-class wives aged 25–29 had the same average fertility when they were 15–19 as professional-class wives who are now 15–19. Many of the former group were certainly unmarried at 15–19 and others belonged to different classes. Managers, farm labourers and the highly educated are other social groups whose membership typically changes in a major and a systematic way with age. The most serious source of distortion is encountered when child mortality estimates are to be made according to fathers' characteristics but reporting is done by mothers. In this case, fertility histories must be limited to married women. But younger married women will almost always have achieved higher fertility than the older married women had at a comparable age. This latter problem is largely averted if fertility indices are specific to marital-duration, as recommended by Sullivan (1972), rather than to age. In this case, the only potentially serious problem is a pattern of social mobility or of marital disruption that is correlated with achieved fertility. Differential mortality of women by parity is also a problem, but a very minor one in most instances. Marriage, social mobility and differential mortality by parity are prevented from distorting surviving children estimates, since women's characteristics are recorded at the time of census and they are reporting on their own childbearing histories. One must, however, be careful to describe results as pertaining to children born to women now in a particular class, rather than to children born into that class.

It should be noted that the first two sources of error are also expected to be less serious for Sullivan's marital-duration approach than for an approach based on age-by-age comparisons of cumulative fertility. Fertility trends should distort mortality estimates less because an important source of trend in age-specific rates, changes in ages of marriage, is generally not an important disturbance for marital-duration-specific fertility. In addition, duration patterns of fertility are probably more regular and predictable than are age-patterns, although this assertion needs documentation. In all three cases, the comparative advantage of the surviving-children approach seems to be greater with respect to estimates based on age-specific than on duration-specific rates.

An added advantage of the surviving-children approach is its flexibility with regard to the age groups of women considered. Equation (2) pertains regardless of the ages of reporting women, as does equation (1). But current methods of implementing equation (1) are based upon adjustment factors specific to five-year age or duration groups of women. Each group begins at an age or duration that is some integer multiple of 5. Age misreporting of women, especially preference towards digits that are some multiple of 5, can distort inferred fertility patterns under conventional techniques. The estimates for equation (2) could be readily based on age groups centred on ages exhibiting the greatest digit preference. Perhaps more important is the potential in applications of system (2) for combining age groups of women. The stability of estimates gained thereby can be a major advantage when dealing with small samples or subsamples (but see also foot-note 1).

The surviving-children technique is flexible with respect not only to age groups of women but also to the grouping criterion itself. The technique is applied as readily to marital duration groups as to age. However, marital duration loses its advantages associated with superior identification of fertility histories but retains its disadvantage related to remarriage. Parity is a grouping criterion that deserves but has not received attention. It has the advantage over marital duration in that backward movement from state to state is impossible, as well as some possible advantages over age in that child mortality may co-vary less with the status itself and in that the numbers of events observed in the various reporting classes may be more precisely equal. In most populations, there will be more cumulative births to one-parity women aged 15–35 than there will be births to women 15–19. Furthermore, those births will be distributed more evenly over ages of mother (whereas births to women 15–19 will still be very highly concentrated at the first parity). Both factors should allow a superior identification of infant mortality rates on the basis of one-parity women than on the basis of 15–19 year-old women. An even better approach for estimating infant mortality may be to ask about survivorship of the last birth alone and to back project the surviving youngest children by age; that is, apply equation (2) only to last births. This procedure provides recent evidence on mortality, it is less subject to recall error and omission of distant-born dead children, and the distribution of last births should be much more representative of all births (with respect to factors associated with mortality) in a given period than would be births to women of a particular parity or age group. Despite these attractive alternatives, we will use age of women as the sole grouping criterion in the rest of this paper.

The surviving children approach also has disadvantages relative to conventional techniques. First, it requires more labour to prepare the requisite tabulations and estimates, usually including a special processing of a computer tape. Secondly, unlike system (1), it is sensitive to omission and misreporting of ages of children. This topic will be treated below. At this point, we note only that the system should not be applied to ages of women whose children are likely to be leaving the household permanently, unless the ages of these children are recorded.

Applying the surviving-children approach

Most of the remainder of this paper is addressed to the question of how the surviving-children technique can be used to provide mortality estimates of maximum reliability. The best procedure will of course depend upon the information available to the investigator. In particular, we distinguish among the following situations: model mortality pattern known, no mortality trend suspected; model mortality pattern postulated or unknown, no trend suspected; and mortality trends suspected.

Model mortality pattern known, no mortality trend suspected

Application of the approach under this condition is simple and straightforward. In discrete notation, equation (2) can be written

$$\frac{B}{S} = \sum_{a=0}^{\alpha-1} \frac{1^{c}a}{1^{L}a} \qquad (3)$$

where $1^{c}a$ is the proportion of surviving children who are between ages a and $a+1$ and $1^{L}a$ is the ratio of the life table population aged a to $a+1$ to the radix. B, S, and the $1^{c}a$ function are provided by the survey. One and only one set of $1^{L}a$ values in a one-parameter model life table system will satisfy equation (3). One may solve for that set via trial and error with a desk or hand calculator or through a computer program (such as one that has been adapted for this purpose by Roger Avery of Cornell University). Coale and Demeny (1966) provide $p(a)$ values for each model at single years up to five. The United Nations model life tables (1955) are abridged but the results they would yield must be very similar to those yielded by model West. A new set of United Nations model life tables is currently under preparation.

The procedure for identifying mortality level is even simpler if Brass' model life table system is employed. In Brass' system, the logit of $p(a)$ is a linear transformation of the logit of $p_s(a)$, where $p_s(a)$ is the probability of surviving to age a in the standard life table pertaining to and representative of that family:

$$\text{logit } p(a) = \alpha_0 + \beta_0 \text{ logit } p_s(a)$$

α_0 is conventionally termed the "level" of mortality and β_0 is the "slope" of mortality. More precisely, within an existing system of model life tables, $p_s(a)$ can be quite accurately transformed into $p(a)$ at any mortality level through the choice of β_0 that is close to 1.00 in value and that shows no systematic trend with mortality level (Brass *et al.*, 1968). On the other hand, α_0 rises monotonically with mortality level.

Supposing that we have chosen a standard $p_s(a)$ schedule from the appropriate model system which is sufficiently close to the correct mortality level so that variation in β_0 about 1.00 can be neglected, then equation (2) needs only to be solved for α_0. In effect, Brass' two-parameter system is converted by this assumption into a one-parameter system. It can be shown that one implication of the Brass linear-logit system is that

$$\frac{1}{p(a)} = e^{2\alpha_0}\left[\frac{1}{p_s(a)} - 1\right]^{\beta_0} + 1.$$

Substituting this expression for $1/p(a)$ into (2) and allowing β_0 to equal unity gives

$$\frac{B}{S} = e^{2\alpha_0}\int_0^{\alpha}\frac{c_s(a)}{p_s(a)}da - e^{2\alpha_0} + 1.$$

Rearranging and simplifying, we have

$$\alpha_0 = [1nD - 1nS - 1n(F-1)]/2$$

where F is the trial sum of $\int_0^{\alpha}\frac{c_s(a)}{p_s(a)}da$

that is obtained by using the "standard" $p_s(a)$ function. Since D and S are provided by the survey, no iteration whatsoever is required in this case; the level of mortality, α_0, can be solved for directly after one computation of the trial sum. Very conveniently, Carrier and Hobcraft (1971: appendix 1) provide tabulations of the $1^{L}a$ functions for a one-parameter set of model life tables based upon Brass' African-Asian standard.

Regression equations for estimating mortality based upon age structures of surviving children

Sullivan (1972) and Trussell (1975) have estimated a series of regression equations that relate the ratio, $\frac{q(a)}{D/B}$, to variables representing the age- or marital-duration sequence of average cumulative parities (designated P_i). We have used this same approach but related the ratio to indices of the age structure of surviving children. The resulting equations can be readily used to give a first approximation to mortality level or, indeed, a final estimate, if one is prepared to sacrifice a small amount of accuracy. The regression equations may in some instances produce estimates with smaller expected errors than those produced by application of the "exact" equation (3), since this application requires the use of discrete ages. For younger women in particular, making discrete the continuous fertility and child mortality process can introduce distortions.

A separate set of equations was estimated for each of the West, North, East, and South model mortality patterns of Coale and Demeny (1966). For each model, a set of simulated fertility-child mortality histories were produced. Mortality varied in single-level increments from level 5 (female life expectancy at birth of 30 years) to level 16 (female life expectancy at birth of 60 years). Each of these child mortality histories was combined with each of 61 model fertility histories provided by Coale and Trussell (1974). These 61 were selected from a larger set in such a way as to retain variability in age patterns of fertility but also to emphasize those patterns likely to be encountered in less developed countries. More detail on fertility selection can be found in annex II. For each model mortality pattern, then, we have $61 \times 12 = 732$ simulated fertility and child mortality histories, and in each of these the histories of women in seven age groups (15–19 . . . 45–49) are distinguished.

Each mortality/fertility history for a particular age group of women supplied values of D, B, and indices of the age structure of surviving children. The "true" values of $q(a)$ were of course known since they were used to produce the simulated results. Table 1 shows the regression equations that relate $\frac{q(a)}{D/B}$ to two indices of the age structure of survivors for all of the simulated mortality/fertility histories within a particular model mortality pattern for women in a certain age group. These equations retain the correspondences used by Brass between the ages of reporting women and the ages of children whose mortality is estimated on the basis of these women's reports. In subsequent sections we will re-examine those correspondences.

In place of Brass' indices of fertility (ratios of cumulative average parity of consecutive cohorts) we have used two indices of the age structure of surviving children: A_s, their mean age last birthday, and $C(2)$, the proportion of surviving children who are aged 0, 1 or 2 last birthday. We expected that this combination would perform well because A_s serves to identify the mean duration of exposure of children to mortality and $C(2)$ to distinguish between children in their early years, when cumulative mortality risks rise rapidly, and children who have passed through this stage. We experimented with other combinations of indices but none performed better when all ages are considered. It is clear from table 1 that information on $C(2)$ becomes less valuable for older women, most of whose children have passed through their early years.

It should be stressed that the age structural indices are much more sensitive to fertility than to mortality histories.

TABLE 1. EQUATIONS FOR CONVERTING PROPORTIONS DEAD AMONG CHILDREN EVER-BORN TO WOMEN, BY AGE, INTO ESTIMATES OF CHILD MORTALITY.[a]
EQUATIONS BASED ON 732 SIMULATED FERTILITY AND CHILD MORTALITY HISTORIES

Age Group of women	Age of child for which equation pertains (i)	Model mortality pattern															
		West				East				North				South			
		α	β	σ	R^2	α	β	σ	R^2	α	β	σ	R^2	α	β	σ	R^2
15–19...	(1)	3.5438	−0.70289	−2.0859	0.990	2.9771	−0.55725	−1.5884	0.984	3.5756	−0.73404	−2.1209	0.991	3.834	−0.79906	−2.3833	0.938
20–24[b]..	(2)	−1.1959	0.36026	2.3504	0.985	−0.7588	0.29003	1.8970	0.986	−1.5087	0.39801	2.6439	0.985	−1.8450	0.47040	2.9955	0.978
25–29...	(3)	0.8731	−0.00494	0.4348	0.993	0.9031	−0.00415	0.3545	0.991	0.8580	−0.01581	0.4785	0.991	0.8468	−0.00222	0.5135	0.982
30–34...	(5)	1.0320	−0.01265	0.3164	0.995	1.0165	−0.00911	0.2722	0.997	1.0454	−0.01957	0.3748	0.996	1.0191	−0.01053	0.3637	0.993
35–39...	(10)	1.1416	−0.01451	0.2222	0.993	1.1003	−0.1000	0.2181	0.992	1.1805	−0.01784	0.3263	0.989	1.1041	−0.01061	0.3124	0.995
40–44...	(15)	1.2341	−0.01645		0.988	1.1763	−0.0122		0.983	1.2864	−0.01920		0.979	1.2016	−0.01382		0.988
45–49...	(20)	1.2815	−0.1526		0.982	1.2054	−0.0111		0.978	1.2919	−0.01548		0.980	1.2187	−0.01181		0.995

[a] The table presents coefficients of the following equation:

$$\frac{q(i)}{D/B} = \alpha + \beta \cdot A_S + \sigma \cdot c(2), \text{ where}$$

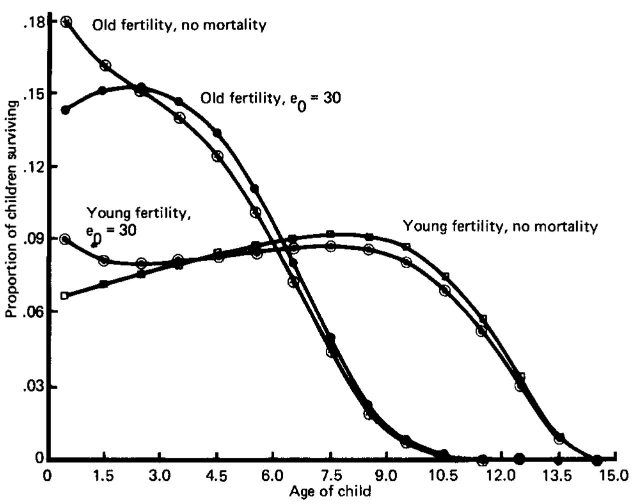
$q(i)$ = probability that a child born i years ago has died
D/B = ratio of dead children to children ever-born to reporting women
A_S = mean age last birthday of surviving children of reporting women
$c(2)$ = proportion of surviving children of reporting women who are aged 0, 1 or 2 last birthday

[b] Because of the extremely high multicollinearity between A_s and $c(2)$ for 20–24 year-old women ($r > 0.995$), the regression coefficients are very unstable for this group. Although the regression plane fits the data well, as indicated by the values of R^2, the equation may produce large errors when applied to other data sets. It is therefore recommended that the following equations be used for this age group, where σ is now the coefficient of $c(3)$, the proportion who are aged 0, 1, 2 or 3 last birthday:

		West				East				North				South			
20–24...	(2)	3.2890	−0.43775	−1.6874	0.972	2.6856	−.32694	−1.2101	0.970	3.5941	−.50886	−1.9441	0.975	3.8364	−0.53950	−2.1258	0.964

For example, with mortality fixed at its mean (level 11), the simulated variation in fertility causes A_s to vary among women 25–29 from 2.51 (youngest fertility schedule) to 5.48 (oldest). With P_1/P_2 fixed at its mean value for these women, variation in mortality from level 5 to level 16 causes A_s to vary only from 3.30 to 3.52. Figure I displays four age distributions of surviving children among women aged 25–29, which combine the oldest and youngest of our fertility schedules (as indexed by P_1/P_2) with high mortality (life expectancy of 30 in the West) and no mortality. Although mortality helps to sculpt the distributions, the dominant influence is clearly fertility (see Palloni, 1977, for more detail on these relations).

Figure I. Age distribution of surviving children among women aged 25–29 under various assumptions about fertility and mortality



The relative insensitivity of age structure to mortality variation results from the heavy concentration of mortality in the first year of life. If all child deaths occurred at the moment of birth, then the age structure of surviving children would be completely insensitive to mortality variation. Since the indices of age structure basically function as indicators of fertility history, they operate very effectively to translate proportions dead into mortality levels. Comparison of table 1 with Trussell's equations (1975, table 2) for the same ages will show a considerable gain in the accuracy of prediction (as gauged by R^2s) for equations of table 1 at ages 15–19 and, increasingly, with ages over 29, despite the reduced number of variables in the equations of table 1. The relative superiority of prediction for equations in table 1 would of course increase if the assumptions of constant fertility, regular age-patterns of fertility, and closed reporting groups are violated.

If the conditions assumed in this section actually pertain, then there is no reason not to aggregate reporting women into one large age category, a procedure that would reduce random or sampling variation in mortality estimates. The equations in table 1 could still be used to provide initial levels for iterative mortality estimation or to check the accuracy of assumptions. Regression equations for combined age groups of women could be readily constructed by appropriate weighting of the coefficients in table 1.[1]

Model mortality pattern postulated, no trend suspected

It is rare that one can be absolutely certain that a particular model mortality pattern pertains. In most instances there will be *a priori* reasons to prefer one pattern to another but without one's having complete confidence in the selection. An appropriate strategy in such a case is to use the preferred pattern to estimate cumulative mortality rates for ages whose mortality will be least sensitive to the choice of pattern. Brass provides one set of such ages, which are reflected in table 1. The information available through the surviving-children approach enables these ages to be identified somewhat more precisely, although in general the Brass ages are found to work quite well.

Let us define $P_T(a)$ as the true probability of survival function for children born to reporting women and $P_M(a)$ as the function that is identified by solving equation (2) under the assumption that mortality belongs to a particular model mortality pattern, M. Then it must be the case that

$$\frac{B}{S} = \int_0^\alpha \frac{c_s(a)}{P_T(a)} da = \int_0^\alpha \frac{c_s(a)}{P_M(a)} da.$$

[1] In particular, the equations should be weighted by the proportion of child deaths that have occurred to the various groups of reporting women to yield an estimate of $q(a^*)$ at an age a^* that is the *birth*-weighted mean of the ages of children that correspond to the ages of women. This procedure amounts to linear interpolation and gives exactly correct results, if the $q(a)$ function is linear between the ages of children considered. The need for death-weighting can be shown in the following way. Suppose that we are attempting to combine data for women aged 15–19 and 20–24. Designate D, B and the regression coefficients of the first group with a subscript 1, the second with a 2, and the combination with a "t". If we attempt to estimate mortality for some age a^* which is the birth-weighted mean of ages 1 and 2, then by the linearity assumption

$$q(a^*) = \frac{B_1 q(1) + B_2 q(2)}{B}, \text{ where}$$

$$a^* = \frac{B_1 \cdot 1 + B_2 \cdot 2}{B}.$$

By the regression formulas,

$$B_1 q(1) = D_1(\alpha_1 + B_1 A_s(1) + \sigma_1 C_1(2))$$

$$B_2 q(2) = D_2(\alpha_2 + B_2 A_s(2) + \sigma_2 C_2(2)).$$

Substituting, we have

$$q(a^*) = \frac{D_1(\alpha_1 + \ldots) + D_2(\alpha_2 + \ldots)}{B}, \text{ or}$$

$$\frac{q(a^*)}{D/B} = \frac{D_1}{D}(\alpha_1 + \ldots) + \frac{D_2}{D}(\alpha_2 + \ldots).$$

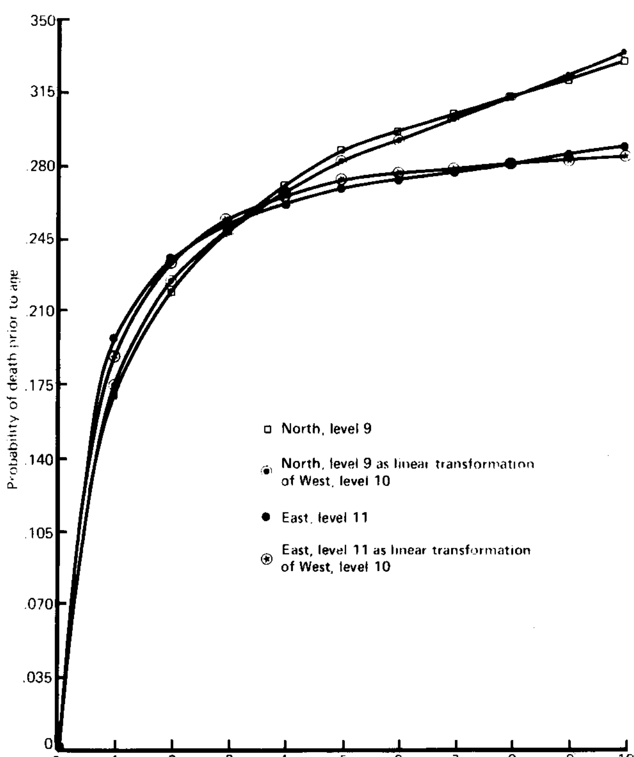
Therefore, weighting the regression equations by the number of child deaths in the respective groups of reporting women will provide the correct adjustment factor to convert D/B into an estimate of mortality for age a^*.

This same approach can also be applied to conventional Brass adjustment factors to provide, for example, more robust estimators of $q(a)$ by basing estimation on women 15–29.

It is obvious from this last expression that, at some age (call it A) between O and α, $P_T(A) = P_M(A)$. If $P_T(a)$ exceeded $P_M(a)$ at all ages between O and α, the two integrals could not possibly both equal B/S. Likewise, they could not be equal if $P_M(a)$ exceeded $P_T(a)$ at all ages. Therefore, the mortality function identified by application of the model must cross the true mortality function at least once. The true mortality level will be correctly identified at this age of crossing even if the model mortality function that is actually applied is incorrect.

Figure II shows the $q(a)$ curve for representatives of the two models of Coale and Demeny that are most extreme with respect to age patterns of child mortality. Level 9 of the North, the oldest pattern, intersects with level 11 of the East, the youngest, around age 3. Supposing that these are the levels in the respective patterns that satisfy equation (2), then we produce the same estimate of $q(3)$ regardless of which model is used. On the other hand, the solution yields estimates of $q(1)$ that vary by 27/1,000, or 16 per cent, and estimates of $q(a)$ for ages over 7 that differ by more than 30/1,000, or 10 per cent.

Figure II. Cumulative probability of death by age for level 9 in model North and level 11 in model East



If the $p(a)$ functions from one mortality pattern closely parallel those of another (intersect with them at a slight angle), then their ages of intersection will be highly variable. This variability is not problematic; it simply means that the two patterns will yield similar mortality estimates for a wide range of ages, hence that the unique age of intersection is not so important to identify. Because the West is the "average" pattern, one would expect it to show the most variability in its ages of intersection with other patterns, and the least error in its estimates when other patterns are true. This latter expectation is confirmed in table 2. Table 2 was developed by applying estimation equations developed for each region to foreign data: data that were actually generated by other model mortality patterns. Using the simulated fertility/mortality histories that were described earlier, there are $732 \times 3 = 2{,}196$ "foreign" histories for each model. The table displays the sum of squared errors that would be made if a particular model mortality pattern were applied to these 2, 196 simulated histories generated by other models. Rather than iterating to an exact solution, the estimation involves the application of a series of regression equations of the form shown in table 1. These regression equations were computed separately for each model and for each combination of ages of children and ages of women shown in table 2.

The series of connected circles shows the ages of children for which mortality estimates are subject to least error as the age of reporting women advances. As expected, the older the women, the older the children whose mortality is best identified. The age profiles of minimum errors are quite similar among the models. The conventional Brass correspondences are retained for the first two ages. That is, 15–19 year-old women best identify cumulative mortality to age 1, and 20–24 year-old women best identify mortality to age 2. But 25–29 year-olds best identify $q(4)$ ($q(5)$ in the South) rather than $q(3)$. The additional error in estimating $q(3)$ rather than $q(4$ or $5)$ from reports of 25–29 year-old women is relatively small in the South and West but is rather large in the East, which tends to cut equivalent-level patterns from other families at a sharp angle. A sum of squared errors of 0.28 implies a standard deviation of 0.011, whereas the sum of errors of 0.09 committed at age 4 implies a standard deviation of 0.006.

Likewise, women aged 30–34 best identify cumulative child mortality to age 6 or 7 (rather than 5), women 35–39 child mortality to age 9 (rather than 10), and except for the West, women 40–44, age 12–14 (rather than 15). However, the differences in errors at the "best" ages compared to the Brass ages for these older women are very small.

The starred entries in table 2 show the age of women-model mortality pattern combination that results in the best identification of mortality for children of a particular age. At ages 2–9 (except for a small disadvantage relative to the East at age 4), the West model provides the least error estimates, probably because it is the "average" pattern. The clear implication is that, if there is no basis for choice other than insensitivity to error, the West should be chosen for estimations based on women aged 20–39. For older women and children, where these techniques will probably, seldom be applied, the South works best but errors in all patterns are very small. For infant mortality, the West also provides least-error estimates except for women aged 15–19, where the North works best. That the North should successfully estimate infant mortality in this interval is not surprising, since the pertinent age pattern of mortality for this age group of women is dominated by relations between mortality in the

TABLE 2. ERRORS COMMITTED WHEN USING INCORRECT MODEL MORTALITY PATTERN, BY AGE OF WOMAN AND AGE OF CHILD.
Sum of squared errors[a] in q(a) when:

Age of child for which mortality is estimated (a)	*East is used*							*North is used*						
	Women aged							*Women aged*						
	15–19	*20–24*	*25–29*	*30–34*	*35–39*	*40–44*	*45–49*	*15–19*	*20–24*	*25–29*	*30–34*	*35–39*	*40–44*	*45–49*
1	0.10	0.86	2.37	3.01	3.80			0.07[b]	0.46	1.14	1.93	2.63		
2	0.80	0.09	0.62	1.17	1.84			0.41	0.15	0.75	1.77	2.79		
3	2.24	0.42	0.11	0.42	0.88			1.30	0.21	0.28	1.04	1.96		
4	3.49	0.93	0.12	0.14	0.41			2.76	0.65	0.09	0.43	1.12		
5		1.40	0.15	0.05	0.18	0.41			1.37	0.22	0.12	0.55	1.12	
6			0.24	0.04	0.11	0.30				0.41	0.06	0.32	0.79	
7				0.06	0.06	0.20					0.07	0.16	0.52	
8				0.10	0.03	0.13					0.16	0.07	0.31	
9				0.17	0.02	0.08					0.32	0.04	0.16	
10				0.26	0.04	0.04	0.17				0.56	0.08	0.07	0.29
11					0.05	0.03	0.13					0.11	0.05	0.22
12					0.07	0.02	0.10					0.16	0.04	0.16
13					0.10	0.02	0.07					0.23	0.03	0.11
14					0.13	0.02	0.05					0.30	0.04	0.08
15					0.17	0.03	0.04					0.39	0.07	0.05
16						0.04	0.03						0.09	0.04
17						0.05	0.02						0.11	0.03
18						0.07	0.01						0.14	0.02
19						0.08	0.01						0.18	0.02

	South is used							*West is used*						
1	0.11	0.71	1.22	1.54	1.73			0.11	0.45	0.90	1.24	1.49		
2	1.04	0.11	0.21	0.50	2.50			0.18	0.08[b]	0.28	0.59	0.87		
3	2.52	0.48	0.17	0.32	0.58			0.65	0.19	0.09[b]	0.27	0.49		
4	3.28	0.70	0.17	0.19	0.38			1.07	0.39	0.06[b]	0.11	0.26		
5		0.80	0.15	0.07	0.18	0.35			0.57	0.09	0.03[b]	0.12	0.28	
6			0.18	0.05	0.11	0.25				0.14	0.02[b]	0.07	0.21	
7			0.23	0.04	0.07	0.18				0.20	0.03[b]	0.04	0.16	
8			0.30	0.05	0.03	0.12					0.05	0.02[b]	0.12	
9				0.08	0.02[b]	0.07					0.08	0.02[b]	0.10	
10				0.13	0.03[b]	0.04	0.14				0.14	0.04	0.10	0.31
11					0.03[b]	0.03	0.11					0.04	0.07	0.27
12					0.04	0.03[b]	0.09					0.04	0.06	0.22
13					0.06	0.02[b]	0.07					0.05	0.04	0.19
14					0.08	0.02[b]	0.05					0.07	0.03	0.16
15					0.10	0.02[b]	0.04					0.09	0.03	0.13
16						0.03	0.03[b]						0.03	0.09
17						0.03	0.02[b]						0.03	0.06
18						0.04	0.02[b]						0.05	0.04
19						0.06	0.01[b]						0.07	0.03

[a] The values in the table are based upon simulations that combine 61 fertility schedules with 12 different mortality schedules (levels 5–16) for each model mortality pattern. This procedure generates 732 simulated fertility-child mortality histories for each model. There are thus 2,196 incorrect fertility/mortality histories for each model, 732 produced by each of the three other models. The table presents the sum of squared errors that would be committed by using a particular model on these 2,196 incorrect histories.

Separate regression equations were computed for every model, every age of woman, and every age of child shown in the table.

The equations were always of the form $\frac{q(a)}{D/B} = \alpha + \beta A_s + \sigma c(2)$. Thus, a particular value in the table is

$$\text{S.S.E.}(M, a, A) = \sum_{i=1}^{2196} (\hat{q}_M(a, A) - q_{-M}(a))^2$$

where S.S.E. (M, a, A) = sum of squared errors produced by using model M for women aged A to estimate mortality for children aged a when applied to mortality-fertility histories produced by other models

$\hat{q}_M(a, A)$ = predicted mortality for children aged a based on the form

$q_M(a, A) = \alpha_M(a, A) + \beta_M(a, A) \cdot A_s + \sigma_M(a, A) \cdot c(2)$

$q_{-M}(a)$ = actual mortality for children aged a in a particular simulated history that uses a mortality model other than M.

[b] Circled entries represent ages of children for which mortality estimation is subject to least error for a given age of woman in a particular model.

Other[b] entries represent the age of woman-model combination that provides least-error estimates of the mortality of children of a particular age.

first and second years of life. In these relations, the North pattern lies about half-way between the East (high ${}_1q_0$) and the South (high ${}_1q_1$). However, the West is also intermediate and has nearly the same age pattern prior to age 2 as the North. We have no explanation for the relatively poor performance of the West regression equation for ${}_1q_0$ on the basis of women aged 15–19 but we note that Trussell (1975, table 4) reveals the same phenomenon for conventional Brass-type estimates.

Table 3 presents new, supplementary regression equations that reflect the improved correspondences established in table 2. These equations do not necessarily represent improvements over the regression equations of table 1 for estimating mortality when the model mortality pattern is known but the results of using the equations are somewhat less sensitive to error in the choice of pattern.

This table also presents an additional pair of equations for women aged 35–39. If ages of surviving children must be inferred from ages of children in the household, then older women's inferred age structures of surviving children will probably be distorted by permanent child out-migration. Thus, it is preferable to base estimates only on the age structure of surviving children who are below age 15, where out-migration begins to become a substantial risk in most societies. Our hope was that the age structure of children below age 15 would provide useful clues regarding the number of older children by discriminating between "old" and "young" fertility patterns. R^2 for each of the new equations at 35–39 is much lower than those reported in table 1 but they exceed those obtained by the traditional Brass approaches (Trussell, 1975, table 2). For older ages (not shown), however, the age structure of children under 15 conveys less and less information and results are inferior (at least when Brass assumptions are not violated) to conventional Brass approaches.

Identifying the ages for best estimation with the aid of data on ages of surviving children

Using the West pattern for circled or starred combinations in table 2 results in small errors even if other models had generated the data. Nevertheless, the estimation technique used in the table made no attempt to identify the age of intersection between true and model functions by incorporating data on the age structure of surviving children. It is reasonable to expect the introduction of such information to improve the accuracy of estimation. For example, reports of women whose children are age two, on average, should do an equally effective job in identifying the mortality of children prior to age two, regardless of whether the women are themselves aged 15–19, 20–24 or 25–29. The age structure of surviving children, by helping to locate fertility histories on a time scale, can not only provide improved adjustment factors but also can indicate the ages of children whose mortality is estimated most robustly.

The age of intersection of two $p(a)$ sequences satisfying equation (2) can obviously be solved for directly. For example, one could solve equation (2) with the North and solve it again with the East and plot the $p(a)$ solutions to determine their age at intersection. This age cannot be determined under conventional Brass-type estimates, for which applications at successive ages will provide two, often parallel, sequences of mortality estimates for two different mortality patterns. With two model mortality patterns whose representatives cut each other at a sharp angle, such as the North and East, it will be important to identify this age of intersection as accurately as possible. Relatively small errors in assumed ages of intersection can introduce relatively large variability into mortality estimates.

A fairly precise notion of the factors that determine the age of intersection can be gained by the following example. Suppose that the true mortality function (designated by T) is some transformation of the model mortality function that satisfies equation (1) (designated by M). In particular, suppose that the ratio of the true mortality function to the model is a linear function of age. Figure II demonstrates that both of the North and East specimens are quite accurately assumed to be linear transformations of the West, an intermediate pattern. The variance in $q(a)$ in the true model "explained" by the predicted function in both cases is 0.9998.[2] Then

$$q_T(a) = [K + ma]q_M(a). \quad (4)$$

By assumption, then,

$$\frac{D}{B} = \int_0^\alpha c(a)q_M(a)da = \int_0^\alpha c(a)q_T(a)da = \int_0^\alpha c(a)[K+ma]q_M(a)da$$

or

$$\int_0^\alpha c(a)q_M(a)da = K\int_0^\alpha c(a)q_M(a)da + m\int_0^\alpha c(a)q_M(a)a\,da.$$

Dividing both sides by the left-hand side, we have

$$1 = K + mA_D$$

where

$$A_D = \frac{\int_0^\alpha c(a)q_M(a)a\,da}{\int_0^\alpha c(a)q_M(a)}. \quad (5)$$

[2] For example, the predicted value of $q(a)$ for the North pattern, based on a linear transformation of the West, was developed by fitting an ordinary least-squares-regression equation of the form

$$q_N(a) = [K + ma]q_W(a)$$

to observations on ages 0, 1, . . . 10, where $q_N(a)$, $q_W(a)$ = cumulative probability of dying prior to age a in the North, level 9, and West, level 10, respectively.

TABLE 3. SUPPLEMENTARY REGRESSION EQUATIONS FOR ESTIMATING CHILD MORTALITY

Coefficients of regression equations of form[a]

$$\frac{q(a)}{(D/B)} = \alpha + \beta \cdot A_s + \sigma \cdot C(2)$$

Age group of women reporting	West					East					North					South				
	Age of child (a)	α	β	σ	R^2	Age of child (a)	α	β	σ	R^2	Age of child (a)	α	β	σ	R^2	Age of child (a)	α	β	σ	R^2
25–29.......	4	0.9147	−0.00469	0.4624	0.992	4	0.9351	−0.00382	0.3735	0.992	4	0.9299	−0.01680	0.5241	0.990	5	0.8670	0.00502	0.6322	0.989
30–34.......	6	1.0543	−0.01333	0.3155	0.995	6	1.0340	−0.00954	.2695	0.996	6	1.0842	−0.002083	0.3709	0.993	7	1.0449	−0.01030	0.3865	0.994
35–39.......	9	1.1213	−0.01410	0.2275	0.993	9	1.0839	−0.00974	0.2211	0.992	9	1.1458	−0.01710	0.3304	0.992	9	1.0899	−0.01056	0.3029	0.997
40–44.......	14	1.2213	−0.01632	–	0.986	13	1.1605	−0.01210	–	0.972	13	1.2556	−0.01879	–	0.974	14	1.1928	−0.01373	–	0.988

Coefficients of regression equations of form[a]

$$\frac{q(a)}{(D/B)} = \pi + \lambda \cdot C'(0\text{–}4) + \Delta \cdot C'(5\text{–}9)$$

Age group of women reporting	West					East					North					South				
	Age of child (a)	π	λ	Δ	R^2	Age of child (a)	π	λ	Δ	R^2	Age of child (a)	π	λ	Δ	R^2	Age of child (a)	π	λ	Δ	R^2
35–39.......	9	0.7521	0.3380	0.6066	0.888	9	0.8215	0.2724	0.4366	0.896	9	0.6850	0.4534	0.7666	0.900	9	0.7981	0.3405	0.4870	0.904
35–39.......	10	0.7626	0.3408	0.6239	0.889	10	0.8312	0.2744	0.4478	0.897	10	0.7008	0.4618	0.7988	0.899	10	0.8101	0.3469	0.4895	0.902

[a] Definitions:

$q(a)$ = probability that child born a years ago has died
A_s = mean age last birthday of surviving children
$C(2)$ = proportion of children whose age last birthday was 0, 1 or 2
$C'(0\text{–}4)$ = proportion of surviving children under age 15 who are below age 5
$C'(5\text{–}9)$ = proportion of surviving children under age 15 who are aged 5–9 last birthday

A_D is the average length of time since the birth of the children who have died, if exposed to the model mortality pattern that satisfies equation (2). According to equation (4), $q_T(a) = q_M(a)$ at the age where $[K + ma]$ equals unity. We have just shown this to be the case at A_D. Therefore, the incorrect model pattern will provide the correct estimate of mortality level at age A_D.

It is clear from equation (4) what A_D depends upon. The more recently childbirth has taken place (the higher the value of $c(a)$ at low ages), the lower will be the age of intersection. Young children's mortality will in general be best identified by young women's reports.

Furthermore, given a particular fertility history, the older the mortality pattern (the higher the $q(a)$ at an older age relative to $q(a)$ at a younger age), the higher will be the age of intersection. Therefore, we expect the age of intersection to vary with the model mortality pattern used. The North should produce a higher age of intersection, for example, than the East. However, since empirical variation in fertility histories is much greater than variation in the shape of model mortality patterns, one should expect fertility history to be the dominant factor determining the age of intersection. Since fertility history is well indexed by the distribution of ages of surviving children, it should be possible to use data on this distribution to identify the age of intersection.

An even better assumption than the one just examined is that

$$p_T(a) = p_M(a) \cdot \frac{k}{1 - ja}.$$

In this case the ratio, $p_T(a)/p_M(a)$, is relatively large in absolute value in infancy and changes in the ratio become smaller and smaller with age. This transformation represents more accurately relations pertaining among Coale-Demeny model mortality patterns, as reflected in R^2s for relations equivalent to those displayed in Figure II of 0.99999 (with age zero omitted from the calculated relations). It can readily be shown by manipulations of the sort that produced equation (5) that, if this new transformation is correct, the true mortality function will always intersect with the model function at age A_B, where

$$A_B = \frac{\int_0^\alpha \frac{c_s(a)}{P_M(a)} a\, da}{\int_0^\alpha \frac{c_s(a)}{P_M(a)} da} = \frac{\int_0^\alpha \frac{c_s(a)}{P_M(a)} a}{\frac{B}{S}}$$

Thus, A_B is simply the average length of time since the birth of all children to reporting women, as determined by back-projecting surviving children by the level of the model mortality pattern that solves equation (2). Not only does A_B provide a more accurate estimate of the age of intersection, as will be further demonstrated below but, unlike A_D, it can also be directly and exactly computed from information on surviving children.[3]

Table 4 is designed to test the proposition that errors using the West model on foreign data can be reduced when mortality estimates are made for ages A_B or $\hat{A}_D$, rather than for pre-designated ages that are fixed for a certain age of women. Ages A_B and $\hat{A}_D$ were estimated for each of the 2 196 simulated histories foreign to the West, and the West model life tables were then applied to estimate $q(a)$ at that age. Results were then compared to the true $q(a)$ at that age. Since the age in question was rarely an integer, the $q(a)$ functions were linearly interpolated between integer ages. Because linearity is a very poor assumption in infancy, no estimates were attempted for women aged 15–19.

Table 4 shows that assignment of the West-solution mortality level to ages A_B or A_D does in fact tend to reduce errors in estimates. The sum of squared errors of estimate at these ages are shown for the 2 196 simulated histories, so that results are directly comparable to those in table 2. The gain in making estimates for $\hat{A}_D$ is rather small but errors in estimating $q(A_B)$ for women 20–34 are reduced by 50 per cent or more over the least-error estimates of table 2. The basic reason for the superior performance of A_B is undoubtedly that the assumed relation between the true and the model mortality function is more accurate

[3] Unfortunately, to identify A_D exactly, it is necessary to know the $c(a)$ function, whereas only the $c_s(a)$ function is assumed to be observed. But the $c(a)$ function can be estimated in the following manner from $c_s(a)$, together with the $P_W(a)$ function (where W denotes the West model solution) that solves equation (2). By definition,

$$A_D = \frac{\int_0^\alpha c(a) q_W(a) a\, da}{\int_0^\alpha c(a) q_W(a)} = \frac{\int_0^\alpha \frac{c_s(a)}{p(a)} q_W(a) a\, da}{\int_0^\alpha \frac{c_s(a)}{p(a)} q_W(a)\, da}.$$

Now if we substitute for the true $p(a)$ function the $p_W(a)$ function that solves equation (2), we have

$$\hat{A}_D = \frac{\int_0^\alpha c_s(a) \frac{q_W(a)}{P_W(a)} a\, da}{\int_0^\alpha c_s(a) \frac{q_W(a)}{P_W(a)} da} = \frac{\int_0^\alpha c_s(a) \left[\frac{1 - P_W(a)}{P_W(a)}\right] a\, da}{\int_0^\alpha c_s(a) \left[\frac{1 - P_W(a)}{P_W(a)}\right] da}$$

$$= \int_0^\alpha \frac{\frac{c_s(a)}{P_W(a)} a - A_s^*}{\frac{B}{S} - 1} = \frac{S}{D}\left[\int_0^\alpha \frac{c_s(a)}{P_W(a)} a\, da - A_s^*\right].$$

This latter expression is simple to calculate. S and D are given, A_s^* (the mean age of surviving children) can be readily calculated, and the $c_s(a)/P_W(a)$ sequence has already been computed in the solution to equation (2). Note, however, that A_s^* is the actual mean exact age of surviving children, which exceeds (by about one half year) A_s, their mean age last birthday. $\hat{A}_D$ is not necessarily the true A_D but is rather the A_D that is estimated by assuming that the population that generated the data belonged to the West pattern.

TABLE 4. ERRORS COMMITTED WHEN USING WEST MODEL MORTALITY PATTERN TO ESTIMATE $q(A_B)$ AND $q(\hat{A}_D)$ WHEN OTHER PATTERNS ARE TRUE (2 196 CASES)

	Age group of women			
	20–24	25–29	30–34	35–39
Sum of squared errors in estimating $q(A_B)$	0.03	0.03	0.01	0.02
Sum of squared errors in estimating $q(\hat{A}_D)$	0.06	0.05	0.02	0.03
Lowest West error from table 2	0.08	0.06	0.02	0.02

A_B = average length of time since birth of all children born to reporting women, when survivors are back-projected by the West model.

$\hat{A}_D$ = estimated average length of time since birth of dead children born to reporting women, when survivors are back-projected by the West model.

than that which leads to the identification of A_D as the age of intersection. A probable contributing factor to the disparity is that A_B can be estimated exactly and A_D only approximately.

We are finally able to identify a simple "best" procedure for dealing with uncertainty about the choice of model mortality pattern:

(*a*) Use the model considered most appropriate. If in doubt, use the West, which works very well even when "incorrect".

(*b*) Identify in that model the level of mortality which solves equation (2).

(*c*) Use that estimated level to identify A_B simply by back-projecting surviving children to estimate the average interval since the birth of all children.

(*d*) Assume that the estimated mortality level is correct for age A_B.

(*e*) Perform such calculations for each age group of women except 15–19, which yields estimates of infant mortality. If there is no reason to prefer one model to another, use the North for women 15–19. If the assumption of constancy of mortality is correct and the true model is chosen, then all of the estimates should identify the same level of mortality in the model or at least deviations from the average level should be uncorrelated with age. In this case, all mortality functions, including $q(a)$ at integer ages, can simply be read from the model pattern at the average level identified. An age trend in estimated levels may be indicative of an inappropriate choice of model, a trend in mortality or omission and misreporting. Disturbances from the first two sources can be minimized by fitting a polynomial directly to the $q(a)$ estimates, which are not sensitive to errors from these sources.[4]

*Mortality trends suspected**

Our treatment of possible errors in estimation introduced by mortality trends will be very similar to the treatment of errors in choice of mortality model. The similarity is deliberate, in order to provide the user with a single technique that is adaptable to both types of uncertainty. The only type of trend considered in this section is a linear one.

Existing Brass-type techniques are based on the very accurate assumption (unnecessary until the present section in the surviving-children approach) that, within a model mortality family, each $q(a)$ function can be expressed as some multiple of any other $q(a)$ function. We will apply this assumption to cohorts, with the additional proviso that the multiplying factor changes at a constant rate from cohort to cohort. In this sense, the mortality change is linear in cohorts.

As before, designate as $q_M(a)$ the $q(a)$ function that solves equation (1) or (2) under the assumption of constant mortality within model M. By assumption, all cohort $q(a)$ functions within a model are constant multiples of this $q_M(a)$, and the constant of multiplication for a particular cohort varies linearly with its date of birth. Therefore, for the cohort aged a in year T, the time of the census or survey,

$$q(a, T) = q_M(a)[K + r(T-a)] \quad 0 \leq T \leq \alpha$$

where K and r, the annual rate of change in the cohort multiplier, are the parameters of the linear mortality trend. Since

$$\frac{D}{B} = \int_0^\alpha c(a)q(a, T)da = \int_0^\alpha c(a)q_M(a)\,[K + r(T-a)]da$$

$$= \int_0^\alpha c(a)q_M(a)da,$$

then

$$(K+rT)\int_0^\alpha c(a)q_M(a)da - r\int_0^\alpha c(a)q_M(a)a$$

$$= \int_0^\alpha c(a)q_M(a)da.$$

Dividing both sides by the right-hand side, we have

$$K + rT - rA_D = 1 \text{ or}$$
$$K + r(T - A_D) = 1$$

Thus, for the cohort born A_D years before the census, the multiplier of $q_M(a)$ is unity and $q(A_D, T) = q_M(A_D)$. That is, the solution of equation (1) under the assumption of constancy produces the correct mortality estimate for the cohort born A_D years before the census, even though mortality is changing from cohort to cohort.

Another way to state this result is to say that all trends in mortality that are linear in cohorts and are consistent in a particular model with D/B must intersect for the cohort

[4] The next section provides some documentation in the case of trends.

* This section is a short summary of material to be found in Palloni (1977). It was strongly influenced by Sullivan and Udofia (1977).

born A_D years before the census. It is not necessary to specify how rapidly mortality is changing in order to estimate accurately its level for this one cohort. Mortality can be falling rapidly or rising slowly; so long as the changes are linear in cohorts, the same cumulative mortality must pertain to the cohort born A_D years before the census. One consistent linear trend in mortality that will therefore pass through A_D is that in which mortality is unchanging ($r = 0$). The existence of such an age is undoubtedly related to Feeney's (1975) empirical result that all consistent linear trends in period mortality tend to identify the same level of infant mortality at a certain point in time prior to the census.

With little loss of precision, A_D can be estimated from regression equations supplied in table 5. These are developed using the West model life tables in conjunction with the simulated fertility histories. A_D, the dependent variable in these regressions, is calculated as the actual point of intersection between the true cohort mortality functions, which contain linear changes from cohort to cohort in the level of mortality, and the level that would be identified assuming that mortality had been constant.[5] This point of intersection is then estimated as a linear function of the mean age last birthday of surviving children. $C(2)$ was added to the equations with relatively little gain in explanatory power.

TABLE 5. EQUATIONS FOR PREDICTING A_D — THE YEARS SINCE BIRTH OF THE COHORT WHOSE MORTALITY IS CORRECTLY IDENTIFIED WHEN MORTALITY CHANGES ARE LINEAR IN COHORTS — FROM DATA ON AGES OF SURVIVING CHILDREN

Age group of reporting women	*Prediction equations*	R^2
15–19	$0.6147 + 1.380\ A_s$	0.986
20–24	$0.9104 + 1.1056\ A_s$	0.9990
25–29	$1.1726 + 1.0287\ A_s$	0.987
30–34	$1.4417 + 0.9982\ A_s$	0.979
35–39	$1.9284 + 0.9675\ A_s$	0.966
40–44	$2.6470 + 0.9367\ A_s$	0.953

A_s = mean age last birthday of surviving children

The mortality trend assumed to prevail can be termed "sectionally linear" because it need apply only to children of reporting women. If the actual mortality trend is non-linear, it may still be the case that linearity provides a reasonably good assumption for the restricted range of ages of the children of women in a particular age interval.

[5] By level of mortality in this instance we mean the true level in the Coale-Demeny system which goes from 1 to 24, rather than the constant of proportionality. The annual rate of change in cohort level varied from 0.0000 to −0.0300 of the final level at intervals of 0.0030. Terminal levels (at the time of census) ranged from 10 to 18 in single-step increments. Thus, there are 99 simulated mortality histories. Each of these was combined with each of the 61 fertility histories to generate the data on which table 5 is based. The age of intersection thus identified is very similar to A_D as estimated through the discrete approximation version of the equation found in foot-note 3. The square roots of the mean square difference between the two series at ages 15–19 . . . 40–44 are: 0.105, 0.141, 0.165, 0.190, 0.213 and 0.219. That is, the average difference between the two is between a tenth and a fifth of a year.

But the best-fitting linear trend among children born to young women could be quite different from the best-fitting linear trend among children born to older women. The estimation technique should allow the non-linearities to be identified in the form of an estimated $q(a)$ sequence that diverges from linearity in mortality level.

The outline of a proposed technique to deal with mortality trends should now be obvious:

(*a*) Use the preferred mortality model to estimate child mortality on the basis of reports of women in different groups (e.g., of age), assuming constancy in mortality.

(*b*) Calculate A_D for each of the groups of women providing estimates, based on the preferred model pattern and using the equation (see foot-note 3).

$$A_D = \frac{S}{D}\left[\int_0^{\alpha} \frac{c_s(a)}{p(a)} a\, da - A_S^*\right] \cong \frac{S}{D}\left[\sum_0^{\alpha} \frac{{}_1c_s(a)}{{}_1L_a} a - A_S^*\right].$$

Alternatively, use regression equations for A_D presented in table 5.

(*c*) Assume that the mortality level estimated on the basis of women in group i is exactly correct for children born $\hat{A}_D(i)$ years earlier, where $\hat{A}_D(i)$ is the value of $\hat{A}_D$ estimated from reports of women in group i.

(*d*) To link the various estimates in order to create a continuous child mortality history (e.g., for purposes of back-projecting surviving children to reproduce fertility histories), use a polynomial fitting procedure to the pairs $(q_i(A_D), A_D(i))$ or to the pairs $(1_i, A_D(i))$, where 1_i is the level of mortality in the model pattern estimated for group i. This latter procedure will by slight extrapolation also yield an estimate of mortality level at the time of census.

The procedure for dealing with trends is thus virtually identical to that for dealing with uncertainty about the appropriate model, with the exception that estimates using the preferred model and assuming constancy are to be assumed applicable to $\hat{A}_D$ rather than to A_B. A_B is always slightly lower than $\hat{A}_D$. It is obvious from table 4 that use of $\hat{A}_D$ also gives reliable estimates when the selected model is incorrect, so that as a general procedure for dealing with uncertainty both about model and trend, it is probably best to use $\hat{A}_D$. A pattern of accelerating rather than linear mortality decline, however, would normally produce more reliable estimates for A_B than for $\hat{A}_D$.

Annex III provides a brief illustrative example of the application of the approach.

There will be many instances where information is sought on the period of time, rather than the cohort, to which estimates most accurately apply. Coale and Trussell in annex I use an approach quite similar to the present one, but assuming the availability of conventional Brass-type information, to provide estimates of this date. Work is continuing on this issue for the surviving-children approach.

Sensitivity of estimates to omission and to age-misreporting

Unlike conventional techniques, the surviving-children approach is sensitive to systematic misreporting of ages of children or to differential omission of children by age. Any factor that distorts the reported $c_s(a)$ relative to the true $c_s(a)$ is liable to introduce error into the mortality estimate. If $c_s(a)$ is inferred from the ages of children present in the women's households, then differential rates of in- and out-migration by age of child are an additional source of distortion. It is important to note that migration of children is not a problem if migration flows occur within the age groups of reporting women, since $c_s(a)$ would be unaltered. This consideration reinforces the suggestion that age groups should be broadly constructed where possible. If migration flows are believed to be horizontal with age of women, one should include all children in the households of these women and not exclude cases in which children in the household are more numerous than children reported to be surviving. Vertical flows are a problem only if the flows are differentially intense by age of child, which is likely to occur in most societies only for older women whose older children are beginning to leave the household. Generally, the oldest age of women for which the technique will yield reliable estimates is 35–39 if marriage is late or 30–34 if it is not. Marital duration is probably a better selection criterion than age in this respect. Restriction of reporting women to those in the first 15 years of marriage, and to children under age 15 for these women, should provide the best control over the child migration problem.

In this section we examine the sensitivity of mortality estimates to two types of errors in $c_s(a)$: differential omission of infants; and systematic overstatement of age. In both cases we simulate the effect of errors on the basis of two fertility schedules, a late and an early one ($P_1/P_2 = 0.0088$ and 0.2659) and an average mortality schedule (West, female $e_0^\circ = 45$). Since the regression equations of table 1 predict mortality levels so accurately, we use them rather than an exact solution to simulate the effects of errors (employing the alternative equations for ages 20–24 that are based on the cumulative proportions below age 4).

Table 6, column (1) shows the correct adjustment factors produced by the assumed combination of mortality and fertility. Column (2) shows the adjustment factors that would have been produced if the true $c_s(a)$ function were distorted by the omission of one quarter of the infants of reporting women. As one might expect, the omission of infants has the largest effect on estimates of $q(1)$. However, the errors of 2.3 per cent and 5.4 per cent are not as large as might be expected. Part of the reason why it is so low for estimates of $q(1)$ is that the large majority of these women's children remain infants even though one quarter of these are omitted. For the "old" fertility schedule, virtually all are infants and the omission of a quarter of these has very little effect on the reported age distribution.

After age 20, the omission of one quarter of infants modifies the estimated $q(a)$ by less than 1.2 per cent. Estimates of $q(a)$ will be too low because the children born to reporting women will be assumed to have been born longer ago (i.e., to have passed through higher cumulative mortality risks) than they actually were. Hence, a particular D/B implies a lower level of mortality than has actually pertained.

The second type of error simulated in table 6 is one in which all children's ages are rounded to the nearest birthday, rather than reported as their age last birthday. Thus, for approximately half the children, age will be overestimated by one year. (However, the calculation recognizes the actual age last month of infants, who for

Table 6. Simulation of errors in mortality estimates produced by infant omission and by age misreporting

Age group of Reporting women	*Age of child to which cumulative mortality is being estimated (a)*	*Correct adjustment factor to convert D/B into q(a)** (1)	*Adjustment factor produced if one quarter of infants are omitted* (2)	*Percentage error if one quarter of infants are omitted* (3) $\left(\frac{(1)-(2)}{(1)}\cdot 100\right)$	*Adjustment factor produced if all children's ages are rounded to closest birthday* (4)	*Percentage error if children's ages are rounded* (5) $\left(\frac{(1)-(4)}{(1)}\right)$
			Late fertility ($P_1/P_2 = 0.0088$)			
15–19	1	1.340	1.308	2.3	1.301	2.9
20–24	2	1.247	1.258	0.9	1.164	6.7
25–29	3	1.104	1.093	1.1	1.066	3.5
30–34	5	1.046	1.040	0.6	1.026	1.9
35–39	10	1.036	1.034	0.2	1.025	1.1
			Early fertility ($P_1/P_2 = 0.2659$)			
15–19	1	0.984	0.930	5.4	0.958	2.5
20–24	2	0.989	0.982	0.8	0.958	3.1
25–29	3	0.953	0.946	0.8	0.933	2.1
30–34	5	0.968	0.963	0.4	0.954	1.3
35–39	10	0.984	0.981	0.2	0.974	1.0

younger women will disproportionately consist of children born in the last half year.) Column (5) shows that this type of reporting error produces estimates of $q(a)$ that differ from the true $q(a)$ by between 1.0 per cent and 6.7 per cent. The average error is somewhat greater than that induced by the specified rate of infant omission. Once again, errors are largest for young ages of children and women because the $q(a)$ function changes with age more rapidly in the younger ages, so that age misreporting is more critical in this range. It makes relatively little difference for mortality estimates at older ages if children are reported as averaging, say, 9 years of age instead of 8.5, since mortality in this interval is relatively slight.

The errors presented in table 5 are roughly equivalent to those that would be produced by a 1 per cent annual decline in fertility from cohort to cohort in the traditional Brass approach. Coefficients of P_2/P_3 as derived by Sullivan (1972, table 3) cluster around 0.45, and total adjustment factors or multipliers average about 1.0. A 1 per cent decline in fertility will produce a 5 per cent error in measured P_2/P_3 relative to true cohort P_2/P_3, so that the error in estimated $q(a)$s will be about 0.05(0.45) = 2.3 per cent. A relatively modest fertility decline will thus produce the same error as the rather extreme types of omission and misreporting simulated in table 5.

Errors induced by differential omission and systematic (directional) age misreporting can obviously be reduced if independent information is available on age misreporting patterns that could form the basis of adjustment factors. Usually, analytic graduation procedures will reduce the error. The fact that the errors tend to be largest for younger women may be an additional reason to group women into larger reporting aggregates.

Extensions of the surviving-children approach to other kinship relations

Hill and Trussell (1976) summarize a variety of approaches to estimating adult mortality on the basis of reports of surviving kin. Like conventional Brass approaches to childhood mortality estimation, these techniques require that the shape of the fertility schedule be inferred from comparisons of cumulative fertility rates. However, if the age distribution of surviving kin be known, this source of error can be eliminated. For example, if individuals report on the number of their siblings and surviving siblings and if the age distribution of surviving siblings is known, then the level of mortality of siblings can be solved by the following equation:

$$\frac{\textit{reported siblings}}{\textit{reported surviving siblings}} = \int_0^\infty \frac{c_{si}(a)}{p(a)} da,$$

where $c_{si}(a)$ is the proportion of surviving siblings who are age a. Using the previous reasoning, the estimated level of mortality should be very nearly correct (barring reporting errors) for persons born T years before the survey, where T is the average time since birth of all siblings, found by back-projecting survivors.

Likewise, for mortality among surviving parents of a particular sex, it is necessary to solve the following equation:

$$\frac{\textit{reported parents}}{\textit{reported surviving parents}} = \int_0^\infty \int_0^\infty \frac{c_s.par.\,(a, x)}{{}_xp_{a-x}} dadx,$$

where $c_s$par. (a, x) is the proportion of surviving parents who are currently age a and whose reporting child is age x, and ${}_xp_{a-x}$ is the probability of surviving from age a–x to age x in the life table for the appropriate sex. For spouses from the first marriage, it is necessary to solve

$$\frac{\textit{reported spouses}}{\textit{reported surviving spouses}} = \int_0^\infty \int_0^\infty \frac{c_{s\cdot spo}(a, x)}{{}_xp_{a-x}} dadx,$$

where $c_{s\,spo}(a, x)$ is the proportion of surviving first-marriage spouses who are currently aged a and whose first-marriage occurred x years earlier.

The relative advantage of exploiting these additional relationships in mortality estimation would appear to be even greater than in the case of children, because the events of birth and death extend over a much longer period of time. Current parity distributions can be assumed to provide a less instructive guide to the distant than to the recent past.

Summary

Brass-type approaches have revolutionized procedures for estimating mortality (and, by reflection, fertility) in populations with poor vital registration. Undoubtedly the major source of error in applications of Brass procedures is incomplete and inaccurate reporting of the numbers of dead and surviving children. Improved methods of data collection are required for reducing these errors.

Certain additional sources of error, however, can be neutralized by improved techniques of analysis. These include errors in estimated mortality levels introduced by fertility trends, lack of closure of groups of reporting women, misstatement of women's ages, small size of reporting groups, uncertainty about the appropriate model mortality pattern and mortality trends. The present paper has outlined a method of reducing errors from these sources when data are available on the ages of surviving children born to reporting women. Each of the recommendations is applicable and readily adaptable to the situation in which data on the date of each birth are available instead. The error reductions are effected by improving the identification of fertility histories, adding flexibility in the grouping of reporting women and identifying more accurately the ages of children for which estimated mortality levels are most robust to error or trend. Although errors of many other types are reduced by the recommended approach, a new one, resulting from omission or misreporting of ages of children, is introduced. A sensitivity analysis shows that such misreporting, when it assumes extreme forms, can be a moderately important source of error for young women. Whether or not this error will exceed those from sources brought under better control by the technique is a question for which no general answer can be provided.

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Annex I

ESTIMATING THE TIME TO WHICH BRASS ESTIMATES APPLY

Ansley J. Coale and James Trussell*

The purpose of this annex is to provide some information that supplements the third section of the text. In particular, it will guide the user in determining the period of time (rather than the cohort) whose mortality is correctly identified by estimates conducted under Brass-type procedures. Our method differs from that described in the third section in that we assume period, rather than cohort, mortality to decline linearly. That is,

$q_p(a, T) = q_s(a)[K + rT]$, where
$q_p(a, T)$ = cumulative probability of death prior to age a in the life table prevailing at time T
$q_s(a)$ = standard $q(a)$ function in the model mortality pattern
K, r = parameters of the linear period mortality decline.

The postulated pattern of decline retains the assumption that each $q(a)$ function is a constant multiple of the standard $q(a)$ function but applies this assumption to periods. Cohort mortality is derived by appropriately chaining together period levels.

Analogous to the case of linear cohort declines, there must be some point in time t^* years before the census for which the mortality level estimated under the assumption of constancy is exactly correct. t^* must lie between zero and the length of time since the earliest birth to reporting women. Unlike the decline that is linear in cohorts, however, there is no single reference point at which all linear trends must intersect. Given a certain level of D, B and a schedule of $c(a)$, the time whose mortality level is correctly identified by the assumption of constancy varies with the actual speed of decline. However, extensive trial calculations show that even among women aged 35–39, varying r from 0.01 to 0.06 affects t^* by no more than 0.14 years (out of an average of 10.2 years). We have therefore simulated mortality declines with $r = .03$ in all cases. The fertility schedules used in the simulation employed values of $a_\sigma = 13, 14, 15$; $m = 0, 0.2, 0.4, 0.6, 0.8, 1.0$; and a singulate mean age at marriage (*SMAM*) of 18, 19, 20 and 21. We have indexed fertility in the classical way, using average cumulative parities in successive age intervals (P_is). The equations for predicting t^* are displayed in tables 7 and 8, the latter including *SMAM* as an explanatory variable.

As noted above, when age-specific fertility is changing, the $c(a)$ schedule will not be properly indexed by ratios of cumulative parities of different cohorts. One way around the problem is to use the age structure of surviving children. Another way is to observe the same cohort at different times and to utilize the cohort P_is as input into the adjustment factors. Existing systems of regression equations to be used for producing adjustment factors do not normally allow for this possibility

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TABLE 7. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]
$t^*_i = a_i + b_i PAR1 + c_i PAR2 + e_i$

Age group	Identity number	a_i	b_i	c_i	Mean of t^*_i	Largest absolute error	R^2
15–19	1	1.1026	5.5934	−2.0133	0.9161	0.059	0.947
20–24	2	1.3187	5.6158	0.2645	2.1707	0.013	0.999
25–29	3	1.5413	2.6451	4.8783	4.1040	0.007	1.000
30–34	4	1.9978	−2.4053	10.5208	6.4679	0.204	0.956
35–39	5	2.8052	−8.5119	16.2550	9.0868	0.576	0.813

[a] All coefficients significant at the 0.01 level.

TABLE 8. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$$t^*_i = a_i + b_i PAR1 + c_i PAR2 + d_i SMAM + e_i$$

Age group	a_i	b_i	c_i	d_i	Mean of t^*_i	Largest absolute error	R^2
15–19	−0.5579	5.1881	−0.4990	0.0526	0.9161	0.019	0.994
20–24	1.2961	5.6103	0.2851	0.0007[a]	2.1707	0.013	0.999
25–29	1.6649	2.6753	4.7655	−0.0039	4.1040	0.008	1.000
30–34	−2.5818	−3.5231	14.6972	0.1449	6.4679	0.096	0.987
35–39	−11.0285	−11.8887	28.8708	0.4378	9.0868	0.250	0.956

[a] Not significant; all other coefficients significant at 0.01 level.

because they are inflexible with respect to the P_is required or they demand more than two of them. Therefore, table 9 presents regression coefficients designed to convert cohort P_is observed in two successive censuses into adjustment factors. Allowance is made for the possibility that the censuses are separated by five years or, for ages 25–29 and above at the second census, by 10 years. Values of a_o used in these simulations are 13, 13.5, 14, 14.5 and 15; m varies from 0 to 0.9 in steps of 0.1, and $SMAM$ varies from 18 to 22 in steps of 0.5. The methodology underlying the calculations is described in detail in Trussell (1975) and does not need to be repeated here.

Table 10 displays the companion regression equations for estimating t^* when such cohort information is used. Naturally, the fit is not as good as in table 8 where more explanatory variables are incorporated but it is reasonably good nonetheless.

Finally, we will consider the case where grouping of women is done on the basis of marital duration rather than of age. Table 11 presents equations for estimating t^* on the basis of information from a single census where information specific to marital duration is available. Note that the P_is now refer to average cumulative parities for women in different marital duration groups.

Table 12 presents equations for estimating $q(x)$ when it is suspected that fertility trends are present and when data classified by marital duration are available from two successive censuses. Table 13 completes the presentation by showing companion regression equations for predicting t^*.

It will be noted that equations in tables 11–13 embody a considerably greater degree of precision (as measured by R^2s) than do equivalent equations of tables 7–10. When tabulations based on marital duration and age are equally accurate, marital duration produces more reliable estimates than does age. Its superiority reflects the control achieved over an important source of disturbance in age-specific fertility rates, variations in age patterns of marriage.

TABLE 9. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$$\frac{q_x}{D_j} = a_i + b_i(P_i/P_j) + e_i$$

Age group	q_x/D_j	P_i/P_j	a_i	b_i	R^2
20–24	q_2/D_2	P_1/P_2	1.838	−0.8901	0.943
25–29	q_3/D_3	P_2/P_3	1.1776	−0.3828	0.993
	q_3/D_3	P_1/P_3	1.0579	−0.8796	0.842
30–34	q_5/D_4	P_3/P_4	1.2757	−0.3939	9.998
	q_5/D_4	P_2/P_4	1.1054	−0.3139	0.941
35–39	q_{10}/D_5	P_4/P_5	1.4017	−0.4662	0.977
	q_{10}/D_5	P_3/P_5	1.1914	−0.3043	0.996

[a]Each regression based on 450 observations; all coefficients significant at the 0.001 level.

TABLE 10. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$$t_i = a_i + b_i(P_j/P_i) + e_i$$

Age group	P_j/P_i	a_i	b_i	Mean of t^*_i	Largest absolute error	R^2
20–24	P_1/P_2	1.3999	5.9156	2.1707	0.020	0.998
25–29	P_2/P_3	1.1637	6.4668	4.1040	0.094	0.972
	P_1/P_3	3.2474	14.2086	4.1040	0.174	0.924
30–34	P_3/P_4	−0.4262[a]	10.1371	6.4679	0.281	0.908
	P_2/P_4	3.6914	8.9412	6.4679	0.055	0.996
35–39	P_4/P_5	−2.7596	14.6371	9.0868	0.410	0.891
	P_3/P_5	3.4605	10.1997	9.0868	0.192	0.977

[a] Not significant; all other coefficients significant at the 0.01 level.

TABLE 11. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$t^*_i = a_i + b_i PAR1 + c_i PAR2 + e_i$

Duration group	Identity number	a_i	b_i	c_i	Mean of t^*_i	Largest absolute error	R^2
0–4	1	1.0377	1.3660	−0.3416	1.2861	0.002	0.990
5–9	2	1.6814	4.5904	0.0024[a]	3.2649	0.001	1.000
10–14	3	1.2222	3.4424	5.1120	5.7367	0.001	1.000
15–19	4	−0.5423	−1.7579	14.7431	8.4503	0.024	0.999

[a] Not significant; all other coefficients significant at 0.01 level.

TABLE 12. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$q_x/D_j = a_i + b_i(P_i/P_j) + e_i$

Duration group	q_x/D_j	P_i/P_j	a_i	b_i	R^2
5–9	q_3/D_2	P_1/P_2	1.1882	−0.4803	0.994
10–14	q_5/D_3	P_2/P_3	1.2455	−0.3499	1.000
	q_5/D_3	P_1/P_3	1.1394	−0.5401	0.985
15–19	q_{10}/D_4	P_3/P_4	1.3408	−0.3857	0.999
	q_{10}/D_4	P_2/P_4	1.1883	−0.2978	0.999

[a] Each regression based on 450 observations; all coefficients significant at the 0.001 level.

TABLE 13. ESTIMATED COEFFICIENTS AND MEASURES OF GOODNESS OF FIT OF THE REGRESSIONS:[a]

$t^*_i = a_i + b_i(P_j/P_i) + e_i$

Duration group	P_j/P_i	a_i	b_i	Mean of t^*_i	Largest absolute error	R^2
5–9	P_1/P_2	1.6812	4.5954	3.2649	0.001	1.000
10–14	P_2/P_3	1.5051	6.4997	5.7367	0.035	0.992
	P_1/P_3	3.3781	10.5019	5.7367	0.038	0.991
15–19	P_3/P_4	−0.4116	11.1290	8.4503	0.064	0.995
	P_2/P_4	3.9324	8.7033	8.4503	0.016	1.000

[a] All coefficients significant at the 0.01 level.

Annex II

FERTILITY SCHEDULES USED IN SIMULATION

The fertility histories used in the simulations were obtained from a set of fertility patterns generated by Coale and Trussell.[a] These fertility patterns depend on three parameters. The first parameter, M, measures the extent to which married couples practice birth control, which varies from a low level of 0.0 (natural fertility) to a value as high as 3.9. The second parameter, a_o, measures the minimum age of entrance to marital union and was allowed to vary from 12.5 up to 18 years. Finally, the parameter K, measuring the pace at which marriage proceeds with respect to a standard nuptiality schedule (Sweden, nineteenth century) varies from a value of 0.20 (a pace equivalent to five times that of the Swedish schedule) to a value of 1.7 (slow progression of marriage with age). By combining different values of these parameters, Coale and Trussell identified 1 568 schedules of fertility. For our purposes, the consideration of these 1 568 patterns would have been an excessively demanding enterprise. Instead, we selected among those schedules a smaller number representing in an approximate way the variability required for our results to be capable of being generalised. In the first place, we tried to select disproportionately those fertility schedules that are most likely to prevail in underdeveloped countries; they should have medium-low values in the parameter a_o and low-medium values in the parameter M. Secondly, inasmuch as it was possible we tried to maintain some balance in the selection process by combining fertility patterns having a high value on one of the parameters with those having low or medium values on the others. In this way, we attempted to represent most of the range of schedules generated by Coale and Trussell, while giving less weight to all intermediate cases.

[a] Coale, A. and J. Trussell, "Model fertility schedules: variations in the age structure of childbearing in human populations", *Population Index*, vol. 40, No. 2, April 1974, pp. 185–258.

The following one-way frequency table summarizes the main characteristics of the 61 patterns:

Frequency distribution for values of K	number	percentage
0.200	10	0.16
0.350	10	0.16
0.500	11	0.18
0.750	12	0.20
1.000	11	0.18
1.250	4	0.07
1.500	3	0.05

Frequency distribution for values of M	number	percentage
0.0–0.500	9	0.15
0.500–1.000	14	0.23
1.000–1.500	17	0.28
1.500–2.000	9	0.15
2.000–2.500	9	0.15
2.500–3.000	3	0.05
3.000+	0	

Frequency distribution for values of A_0	number	percentage
12.0–13.5	12	0.20
13.5–15.0	15	0.25
15.0–16.5	17	0.28
16.5–18.0	17	0.28

In order to compare these selected fertility histories with those selected by Sullivan (Sullivan, 1972), it is sufficient to note that they span values of P_1/P_2, the ratio of the average number of children ever-born to women 15–19 to the average number of children ever-born to women 20–24 from 0.0088 to 0.2700.

Annex III

APPLICATION OF THE SURVIVING CHILDREN APPROACH TO DATA FROM THE UNITED STATES CENSUS OF 1900

One of the authors has drawn a sample of manuscript records from the 1900 United States Census of Population for purposes of studying fertility and mortality variation during this period. These records may be exploited to demonstrate the potential of the approach described in the text for estimating mortality. The records were drawn by systematic sampling from 11 geographic areas, distributed as follows:

	Total	Rural	Urban (4000 +)	Black	Foreign-born
Alabama	986	890	96	417	5
Arizona	370	370	0	0	15
Baltimore	481	0	481	27	82
Brooklyn	892	0	892	6	227
California	748	414	334	4	99
Chicago	909	0	909	0	373
Connecticut	1 213	770	443	5	208
Georgia	605	605	0	310	1
Indiana	1 329	1 114	215	0	373
Louisiana	602	602	0	208	13
Massachusetts	423	24	399	3	129
TOTAL	9 052	4 789	4 263	982	1 475
Percentage	100	52.9	47.1	10.8	16.4
United States population percentage	100	62.7	37.3	11.6	13.6

TABLE 14. EXAMPLE OF COMPUTATIONAL STEPS IN APPLYING THE MORTALITY ESTIMATION TECHNIQUE

Steps	Age group of women 15–23	24–29	30–34
1. Children ever-born	227	637	821
2. Children alive	190	532	650
3. Children in household	191	520	649
4. Children in household with ages reported	191	520	649
5. Children in household with ages reported in permissible range (C^* children)[a]	183	512	644
6. (Births/survivors) multiplied by children with permissible ages = ((step 1 divided by step 2) multiplied by step 5). This is the target number to be achieved by back-projecting C^*	218.64	613.05	813.42
7. Estimated births by back-projecting C^*, children by age with West level 11 life table	226.54	–	840.98
8. Back-projecting C^*, children by age with West level 13 life table	216.40	620.29	793.20
9. Back-projecting C^*, children by age with West level 15 life table	–	592.29	–
10. Interpolated mortality level	12.56	13.52	12.15
11. $\bar{A}_D$–mean time since birth of dead children	3.09	5.45	7.90
12. A_B–mean time since birth of all children	2.71	4.90	7.25

[a] Permissible ages for children are: 0–9 for reporting women aged 15–23; 0–14 for reporting women aged 24–29; and 0–19 for reporting women aged 30–34.

In addition to these comparative frequencies, other salient comparisons between the census and the sample can be made in terms of the percentage of males (51.1 versus 49.6), percentage of the population under age 15 (34.5 versus 36.2), and percentage of those aged 65 and over (4.2 versus 4.0). For the purpose of this exercise, the data from Arizona, consisting primarily of reservation Indians, have been excluded.

The 1900 census asked questions about children ever-born and children surviving, although no tabulations based on these questions were presented in the census itself and the results have never been used to estimate child mortality. Table 14 lays out the format for estimating child mortality by the recommended procedures. Unconventional age groups of women are used in order to make them more equal in terms of numbers of births; there were only 17 children ever-born to 15–19 year-old women in the sample.

The three age groups of women yield estimates of child mortality that imply quite similar levels in the West mortality pattern, with a range of only 1.37 levels. No age trend is obvious in the estimated levels. The age structure of surviving children is such that estimated mortality levels are most robust to errors in assumed mortality pattern or trend at ages around 3, 5 and 7.5. However, since there is no age trend in estimated levels, there is no reason not to group women into one large reporting category and produce a single mortality estimate that is less sensitive to random error. At the same time, we have estimated mortality according to characteristics of the mother and father to produce the first national estimates of mortality by social class available for the United States at the turn of the century. Results are shown in table 15. The women's reports are used to identify the probability of survival to age 5, and the level of life expectancy implied by the level of child mortality is indicated. It should be noted that all ages of children in the household are employed to produce the figures in table 15. The result of this procedure produces a life expectancy at birth for all females that differs by about one year from the one which would have been produced by the previously described procedure.

Estimates from the two sources shown in table 15 agree closely. The major discrepancy relates to black mortality. Blacks in the death registration states were predominantly urban, whereas blacks in the nation as a whole were predominantly rural. The major protective advantages of rural areas are evident in table 15, and the results here suggest that mortality for the black population as a whole was much lower than indicated by official figures. Further data-gathering activities that are now under way will provide a more conclusive test of this proposition.

TABLE 15. ESTIMATES OF CHILD MORTALITY AND IMPLIED LIFE EXPECTANCY IN THE UNITED STATES, 1895–1900

Group	*Estimated probability of surviving from Birth to age 5 (p(5)) for children of:*	*Implied life expectancy at birth, West model*	*Number of births (N)*
Total sample	0.813 (0.818)[a]	49.01 (49.24)[a]	1685
Urban areas (4000 +population)	0.792 (.793 Whites, 8000+)[a]	46.76 (45.89W)[a]	773
Rural areas (< 4000 population)	0.833 (.860 Whites, < 8000)[a]	51.20 (54.70W)[a]	912
White women	0.822 (0.821)[a]	50.05 (49.62)[a]	1453
Non-white women	0.767 (0.662)[a]	44.15 (33.76)[a]	232
Native-born women (second generation children)	0.818	49.63	1224
Foreign-born women (first generation children)	0.801	47.71	461
Women with native-born mothers (third generation children)	0.817	49.53	991
Women with foreign-born mothers	0.805	48.08	649
White-collar wives	0.843	52.36	221
Blue-collar wives	0.767	44.04	653
Farmers' wives	0.848	52.95	505
Wives of men fully employed, 1899	0.819	49.74	1187
Wives of men with 1 + months unemployed, 1899	0.787	45.48	306
Special groups			
Hopi Indians[b]	0.490	21.49	569
Navaho Indians[b]	0.818	49.55	415
Pennsylvania coal-mining regions (Haines)[c]	0.790	46.5	2393

[a] Life tables for original death registration states, 1900–02, from James W. Glover, *United States Life Tables, 1890, 1901, 1910, and 1901–1910,* United States Department of Commerce, Bureau of the Census, (Washington, DC Government Printing Office, 1910). The areas are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Indiana, Michigan and the District of Columbia.

[b] Ages 14–37.

[c] Ages 20–34. From Michael Haines, "Mortality in nineteenth century America: estimates from New York and Pennsylvania census data, 1865 and 1900". Ithaca, New York, Cornell University Department of Economics (unpublished manuscript).

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