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Foreword

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. In accordance with the endorsement and recommendation of the Population Commission at its eighteenth session, the *Bulletin* has been reinstated as a United Nations publication, beginning with the publication of *Bulletin* No. 8 in 1977. As in the past, the *Bulletin* will be prepared by the Population Division.

It is expected that most of the articles to be published in 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.

Annual rates of growth or change, unless otherwise stated, refer to annual compound rates.

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

POPULATION POLICIES IN EUROPE AND NORTH AMERICA

*Dirk J. van de Kaa**

Introduction

When Glass, in 1940, published his now-classic book on population policies and movements in a number of Western European countries, he remarked in his preface, "To many readers the book will appear overlong. Yet it can scarcely do more than describe the broad structure of the subject, for it attempts to cover, in five hundred pages, problems which would need many large volumes for satisfactory discussion. Because of this inevitable superficiality I have included a fairly wide documentation . . .".[1]

There are indications in many other publications that the policy aspects of population development in a large region of the world do, as Glass suggested, defy condensation in a brief paper. The recent volume on population policies in developed countries edited by Berelson[2] numbers almost 800 pages and a report[3] describing population law in one particular European country, Romania, amounts to nearly 335 pages. Indeed, what most impresses the student of population policies in the States members of the Economic Commission for Europe (ECE) is the enormous volume of relevant material that has become available in the last few years.

The area of responsibility of the Economic Commission for Europe covers 39 countries, of which five are members of one or more specialized agencies but not of the United Nations.[4] Almost 30 of these countries replied to the Second Inquiry on Population and Development; a summary exposition of their answers is given in E/CONF.60/CBP/32. In addition, 22 ECE countries submitted a summary country statement of population change and development to the World Population Conference (E/CONF.60/CBP/33 and addenda). In the book edited by Berelson a separate chapter is devoted to 20 countries, while a country report on legislation directly or indirectly influencing fertility has, as a result of a project jointly sponsored by the International Union for the Scientific Study of Population and the European Centre for Co-ordination of Research and Documentation in Social Sciences, become available for 21 countries.[5] If one further takes into account the activities in this field of the various national population commissions and of such organizations as the International Planned Parenthood Federation and the Fletcher School of Law and Diplomacy of Tufts University,[6] one reaches the conclusion that, during the past four years or so, probably about a million words were written in reports that contain basic information pertinent to the study of population policies in Europe and North America.

The time seems ripe for a thorough analysis of this material and for a study that digests the wealth of detail to uncover the main trends and to draw conclusions from them. Some attempts to do this have, in fact, already been made.[7] Several of the resulting papers and drafts do, however, show signs that, like the present paper, they have been written for a specific occasion, within a short period of time and with an eye on a too-rapidly approaching deadline. They must have given the authors, as well as a sense of achievement, a sense of regret that they could not devote more time to analysis and reflection.

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* Director of the Netherlands Interuniversity Demographic Institute, the Netherlands. An earlier version of this paper was presented to the United Nations/UNFPA Post-World Population Conference Consultation among Countries of the ECE Region, Geneva, July 1975.

[1] D. V. Glass, *Population Policies and Movements in Europe* (London, Clarendon Press, 1940; reprinted 1967).

[2] B. Berelson, ed., *Population Policy in Developed Countries* (New York, McGraw-Hill Book Co., 1974).

[3] I. Ceterchi, *et al.*, *Le Droit et la croissance de la population en Roumanie* (Bucharest, 1974).

[4] These countries are: Albania, Austria, Belgium, Bulgaria, Byelorussian Soviet Socialist Republic, Canada, Cyprus, Czechoslovakia, Denmark, Finland, France, German Democratic Republic, Federal Republic of Germany, Greece, Holy See[a], Hungary, Iceland, Ireland, Israel, Italy, Liechtenstein[a], Luxembourg, Malta, Monaco[a], Netherlands, Norway, Poland, Portugal, Romania, San Marino[a], Spain, Sweden, Switzerland[a], Turkey, Ukrainian Soviet Socialist Republic, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland, United States of America, Yugoslavia.

[a] Not Members of the United Nations.

[5] M. Kirk, M. Livi-Bacci and E. Szabady, eds., *Law and Fertility in Europe* (Delhain-Belgium, Ordina Editions, 1975).

[6] International Planned Parenthood Foundation Europe, *A Survey of the Legal Status of Contraception, Sterilization and Abortion in European Countries*, March 1973; the results of the Law and Population Programme of the Fletcher School are published in a continuing series, the *Law and Monograph Series*, 1972- (Medford, Mass.).

[7] The country reports on legislation directly or indirectly influencing fertility have, as far as the Western European countries are concerned, been analysed by M. Livi-Bacci, "Population policy in Western Europe", *Population Studies* (Cambridge, England), vol. 28, No. 2 (1974), pp. 191-204. A draft chapter dealing with the Eastern European countries was prepared by E. Szabady, while summary chapters on groups of topics were written by M. Kirk, P. Paillat, H. Schubnell and V. Trebici. An unpublished set of technical comparative tables has been compiled by G. Ferrari. B. Berelson has summarized the results of the survey of policies in developed countries in B. Berelson, "Summary", in B. Berelson, ed., *op. cit.*, pp. 771-789. A perceptive analysis of the policies in Eastern European countries can be found in M. Macura, "Politiques de population dans les pays socialistes d'Europe", *Population et famille* (Brussels), vol. 32, No. 2 (1974), pp. 29-52.

The techniques available for analysing a large quantity of material of a mainly qualitative and descriptive character are limited in number; they have all, in varying degrees, been used in the previous attempts mentioned. These techniques consist essentially of compiling lists or comparative tables and of scanning them for specific patterns; these will then yield interrelated regional or other groupings or will indicate similarities and differences in the ways in which specific situations are treated and in the solutions found for common problems. There is usually a certain amount of synthesis, and the conclusions are usually reached by placing the findings in a broader historical, cultural or socio-economic perspective.

Since the present paper draws on original sources as well as on these earlier efforts, and since it aims to present an overview of the most important findings and the main issues involved, the approach is not different. After a brief discussion of the concept and purposes of a population policy, there follows a section dealing with national objectives, socio-economic correlates and the demographic situation in the countries concerned. The Governments' perceptions of the current levels of population growth, fertility and migration are then discussed briefly as an introduction to a consideration of what relationships can be observed between these perceptions and changes in population policy. There follows a brief review of present patterns and directions of change in a few specific areas of policy change, and the paper concludes with a brief note on possible future developments.

THE CONCEPT AND PURPOSES OF A POPULATION POLICY

In discussions of population policy,[8] one usually encounters a reference to a perpetual dilemma posed by the use of the term "population policy". The problem is to decide whether the term should be narrowly interpreted, to mean "a settled course adopted and followed by a Government" to influence demographic developments, or whether, on the contrary, "population policy" should be regarded as comprising "all those aspects of national law that affect demographic trends".[9]

The choice between these two meanings has significant consequences. While the first interpretation is easy to understand and apply, it tends to disregard important steps and decisions taken by Governments. On the other hand, while the second interpretation avoids this shortcoming, it is difficult to apply, since the broader interpretation of the term "policy" could conceivably include nearly all governmental activity. A good case for using the narrow instead of the broad interpretation is frequently made—in particular on the grounds that effects can be evaluated only if they can be compared with stated purposes. In practice, however, the ultimate choice is usually in favour of the broader definition. This can be expressed in a series of approximate synonyms and antonyms. In describing actual situations, the broad concept is generally preferred to the narrow. In principle then, "population policy" includes the implicit as well as the explicit, the accidental as well as the intentional or planned, the inferred as well as the stated, the indirect as well as the direct and the passive as well as the active.

However, too broad a definition is as unsatisfactory as one that is too narrow. Therefore Berelson,[10] expressing ideas not unlike those expressed earlier by Doublet,[11] recently distinguished three types of government policies that can usefully be considered in discussions of population policy in its broader meaning: policies that are directly intended to affect demographic events; policies that are taken primarily for other reasons but take demographic factors into account to some extent; and policies taken without explicit demographic intent but with non-trivial demographic consequences, actual or perceived. We will adhere to that approach in the present paper.

Population policies, even those of the first type, cannot be considered to be goals in themselves. They must be expected to serve other purposes and to be means to other ends and objectives, presumably the same national objectives that are served by other governmental policies. Those national objectives are rarely formulated explicitly.[12] They may have a strong ideological, religious or theoretical basis and they tend to be fairly abstract. In many countries the selection of a particular population policy will be the result of the interplay of contending forces and will reflect the material and immaterial goals and desires of different sections of the population. Such a policy, inevitably, is likely to be neither constant nor fully consistent.

Societal changes, in particular, will lead to a revision of national objectives. The revision may occur only in an implicit way—for example, by changing the emphasis to different aspects of given policies or by strengthening certain policies and weakening others. Social and demographic changes are interrelated, and demographic changes will, at any rate, draw attention to the significance of demographic developments in relation to national objectives. Thus one may expect that changes in population policy, and changes in their distribution by type, will be triggered by demographic change, socio-economic change, change in national objectives or by some combination of these.

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[8] J. J. Spengler, "Socio-economic theory and population policy", in J. J. Spengler and O. D. Duncan, eds., *Population Theory and Policy; Selected Readings* (Glencoe, Ill., Free Press, 1956), pp. 456-461; B. Berelson, "Population policy: personal notes", *Population Studies* (Cambridge, England), vol. 25, No. 2 (1971), pp. 173-182.

[9] Hope T. Eldridge, *Population Policies: A Survey of Recent Developments* (Washington, D.C., International Union for the Scientific Study of Population, 1954), pp. 173-182.

[10] B. Berelson, "Introduction", in B. Berelson, ed., *op. cit.*, pp. 6-7.

[11] J. Doublet, "Des lois dans leur rapport avec la Population", *Population* (Paris), vol. 4, No. 1 (1949), pp. 39-56.

[12] In the Netherlands a special working group of public servants recently tried to compile a list of the main objectives of the national Governments. After considerable difficulty they formulated 15 objectives, which could be divided into five groups and which had explicitly or implicitly been used.

One may likewise expect that existing demographic policies will reflect differences and similarities in national objectives, in social, cultural and economic conditions and in the demographic situation of the country. Before considering policies, a few remarks should therefore be made with regard to these points and, more particularly, with regard to recent demographic developments.

NATIONAL OBJECTIVES, SOCIO-ECONOMIC CORRELATES AND DEMOGRAPHIC SITUATION

The two most fundamental objectives of a national Government are probably to maintain the territorial integrity and national sovereignty of the State and to improve, for the population it represents, the quality of life, in both its material and its intangible aspects.

In the countries in the area of responsibility of the ECE these basic aims are pursued through a variety of political and economic systems, which view the population factor in different ways. The most important difference in this respect is probably that between the socialist countries of Eastern Europe and the other countries, which may be considered to follow variants of the capitalistic system.

In this recent paper, Macura[13] has made a number of interesting observations on the ideological and theoretical considerations underlying the general attitude of socialist Governments towards demographic events and phenomena—that is, population size and growth, mortality, fertility, international migration, population distribution and population structure. As regards population growth and fertility, Macura remarks that the optimism characteristic of socialism tends to lead to policies favourable towards maintaining a relatively high level of fertility and natural growth. He notes that Lenin's statement regarding the freedom of medical propaganda and the democratic rights of citizens has probably influenced the underlying attitude towards abortion and (one might add) contraception. He further points out that, whereas, the concepts of internationalism and proletarian solidarity would appear to favour international migration, it is in the nature of socialist societies to provide work within the country for all those who seek it.

The other ECE countries do not appear to share, at least consciously, any common ideological or theoretical base that might determine their basic attitudes towards population questions, although it may be argued that there is a common philosophy, reflected in the strong tendency, in these countries, not to interfere with the processes that determine natural growth and to accept the demographic trends as given. The non-socialist countries also differ in type of governments; they are quite heterogeneous, for example, in cultural heritage and in the degree to which religious considerations are taken into account when deciding questions involving individual human rights.

[13] M. Macura, *loc. cit.*, pp. 34-39.

From a socio-economic point of view the countries of Europe and North America also present a picture of considerable diversity. They range in *per capita* income from less than $US 1,000 to over $US 5,000; there are, similarly, large differences in the proportion of the population engaged in agriculture, in female labour participation rates, in degree of urbanization, in system of education and the like.

Probably at least as important as these differences, however, is the fact that in trying to improve the quality of life of their populations, all countries have striven to develop, particularly since 1945, some form of social security system, which aims to protect individuals and families from undue hardship and, in general, to improve social justice.

The Netherlands might be considered as a case in point. In that country four general insurance schemes have been enacted since 1957: the General Act on Special Medical Benefits (1968); the General Old-age Act (1957); the General Widows and Orphans Act (1959); and the General Child Endowment Act (1963). Five insurance schemes for employees have similarly been enacted since 1951, including the Unemployment Act of 1952 and the Disabled Persons Act of 1967. As a result of these measures, people can be reasonably sure that under almost all foreseeable circumstances their children will not have to suffer from want.

Short-term economic fluctuations or recessions no longer seem to exert a significant influence on procreative behavior,[14] and we may be witnessing a relatively new and important feature of fertility decisions in developed countries: that the long-term economic costs and benefits of children can now be assessed against a "guaranteed" long-term earning capacity and a predictable level of services. At the same time, other motivations for parenthood can be assessed in the knowledge that there is at least some margin of safety before the continuing need to provide for the basic family necessities imposes a definite limit on family growth.

It is not clearly established that increased social security and the associated prospect of a higher material standard of living have been significant factors in the recent declines in fertility in Europe and North America. But it is clear that the combined effect on fertility of different elements of social security legislation may exceed the effect that might be predicted were each element to operate in isolation; that the enactment of basic social security measures may increase the level of aspirations; and that families can best achieve a higher standard of living by reducing expenditure for housing, clothing, food and so on, and thus by reducing family size.

Since the areas of population concern in individual countries and groups of countries have been closely

[14] K. G. Basavarajappa, "The influence of fluctuations in economic conditions on fertility and marriage rates, Australia, 1920-1921 to 1937-1938 and 1946-1947 to 1966-1967", *Population Studies* (Cambridge, England), vol. 25, No. 1 (1971), pp. 39-53.

related in each case to the actual demographic situation, it will be useful to review briefly the recent demographic developments in Europe and North America.

Mortality

With a few exceptions, the mortality rate in the countries of the ECE varies from 8 to 12 per cent. Among the socialist countries, which have experienced a substantial mortality decline in the past half century or so, the German Democratic Republic, Hungary and Czechoslovakia top the list, while values between 8 and 9 can be observed in Poland and the USSR. Amongst the countries of Western Europe and North America age structural effects are clearly visible in the high rates for Belgium, Sweden, France, the United Kingdom and the Federal Republic of Germany, when compared with the much lower rates for Canada, the Netherlands or Greece. Changes in mortality pattern, leading to an excess mortality of males in adult age groups and an increased difference in life expectancy at birth between males and females, are a recent phenomenon and a cause for concern, especially in several of the Western European countries. Classified by life expectancy at birth, 31 of the ECE countries belong to the category 70 years and over, 7 to the category 60-69 years, and only 1 to the group 50-59 years.

Fertility

With the exceptions of Albania, Ireland, Iceland and Turkey, the countries in the area of responsibility of ECE are characterized by a low level of fertility, with most birth rates falling in the range of 11 to 17 per 1,000 population. A recent fertility decline seems to be the pattern in almost all countries; the pattern of decline differs, however, from subregion to subregion.

Up-to-date fertility measures of a more satisfactory character than the crude birth rate are difficult to assemble, even for ECE countries, but graphs displaying the changes in the total fertility rate between 1945 and 1973 in most of the countries concerned have been published by Westoff.[15] Leaving aside certain countries (e.g. Albania, Ireland, Israel and Turkey) that display trends of a special character, five different patterns of fertility decline can be discerned.

The first is characteristic of North America. It shows a substantial increase in total fertility rate (TFR) until the early 1960s and a decline from about 3.5-4.0 to about 2.0 thereafter.

The Scandinavian countries form the second group, although the differences between them are not negligible. With the exception of Sweden, they experienced total fertility rates of between 2.5 and 3.0 during the period 1955-1965 and a subsequent fairly rapid decline to near or below replacement level.

The third pattern is characteristic of the Western and Central European countries. After a post-war surge in fertility, which lasted only a few years, fertility tended to rise fairly slowly until the early to mid-1960s. At that time the TFR typically had a value of between 2.5 and 3.0. After 1964-1965 a decline became apparent, which seems to have received new impetus after about 1971. The Central European countries, particularly the German Democratic Republic and the Federal Republic of Germany, now have fertility levels that are well below replacement, while some of the Western European countries (Belgium, the Netherlands) tend towards a similar position.

In the fourth group, formed by the Southern European countries, Portugal, Spain, Italy and Greece, fertility change has remained limited and the level relatively high, particularly in Spain and Portugal.

The socialist countries of Eastern Europe constitute the last group. In those countries fertility has generally declined since the early or mid-1950s. In some cases (Bulgaria, Hungary) fertility has been below replacement level for some time. In fact, Schubnell[16] has reported a net reproduction rate of between 0.8 and 0.9 for Hungary during each of the years 1961 to 1966.

International migration

Except for Yugoslavia and the German Democratic Republic, international migration does not play a significant role in the demographic development of the socialist countries of Europe. The population of the German Democratic Republic declined by 9 per cent between 1950 and 1970, largely as a result of emigration. The migration situation in Yugoslavia is similar to that of several other Mediterranean countries, notably Spain, Italy, Malta and Greece, as well as to that of Portugal, Turkey and certain countries in North Africa. Large numbers of workers from those countries migrate to Central and Western Europe, where the demand for specific types of labour far exceeds the supply. These streams of foreign workers and their families have grown in magnitude to a point where international migration has become an area of concern for both the countries of origin and those of destination. In 1971 the total foreign-born population in the main countries of immigration amounted to approximately 3.5 million in both France and the Federal Republic of Germany, more than 2.25 million in the United Kingdom, nearly 1 million in Switzerland, 0.7 million in Belgium and 0.4 million in Sweden. The significance of international migration for population growth can be assessed from table 1, which was presented by Linke[17] in a recent working document for the Council of Europe; the figures just mentioned are quoted from that document with permission of the author.

The effect of migration on population growth is also apparent from other data. Linke has calculated, for

[15] C. F. Westoff, "The population of the developed countries", *Scientific American* (New York), September 1974, pp. 109-123.

[16] H. Schubnell, "Law affecting contraception, abortion, and sterilization", in M. Kirk, M. Livi-Bacci and E. Szabady, eds., *op. cit.*, p. 61.

[17] W. Linke, "The demographic characteristics and the marriage and fertility patterns of migrant populations, an assessment of their role in the future demographic development of countries of origin and destination" (Strasbourg, April 1975).

example, that in 1972 the proportion of live births with foreign nationality amongst total live births amounted to 13 per cent in the Federal Republic of Germany, 12.4 per cent in Belgium and 30.6 per cent in Switzerland. It may finally be recalled that amongst the ECE countries those in North America and Israel have traditionally been countries of immigration.

By way of summary it may be concluded that recent demographic developments in the countries in the area of responsibility of ECE have been such that in a majority of cases fertility is hovering around replacement level and that, depending on each country's demographic history, the end of an era of substantial natural growth either has arrived or has come in sight.

No guarantee can be given that all countries will converge to replacement-level fertility or that this reduction in total fertility rates will be a permanent development. Nevertheless, Governments will undoubtedly have to consider whether they must expect a future characterized by a stationary or declining population and whether, if such a future does not please them, there are any alternatives to this. We may note that further decline in mortality can be expected in only a minority of cases and that, in the long run, extensive international migration pleases neither the Governments in the countries of origin nor those in the countries of destination. Thus attempts to manipulate the level of fertility through deliberate policy measures may well result from the present situation.

TABLE 1. ESTIMATES OF NET MIGRATION AND ITS RELATION TO TOTAL POPULATION SIZE AND NATURAL INCREASE IN SELECTED COUNTRIES OF EUROPE, 1950-1970

Region and country	Net migration[a] (thousands) Total 1950-1970	Total 1950-1960	Total 1960-1970	Average annual net migration, 1950-1970 (as percentage of 1960 population)	Ratio of net migration to natural increase, 1950-1970 (percentage)
Western Europe	+8 748	+3 882	+4 866	+0.3	+ 51
Austria	− 103	− 141	+ 38	−0.1	− 17
Belgium	+ 211	+ 59	+ 152	+0.1	+ 27
Federal Republic of Germany	+4 780	+2 723	+2 057	+0.4	+ 81
France	+3 258	+1 080	+2 178	+0.4	+ 55
Luxembourg	+ 22	+ 7	+ 15	+0.4	+105
Netherlands	− 50	− 142	+ 92	−0.02	− 2
Switzerland	+ 630	+ 296	+ 334	+0.6	+ 72
Southern Europe	−7 301	−3 475	−3 826	−0.3	− 29
Cyprus	− 100	...	...	−0.9	− 50
Greece	− 651	− 195	− 455	−0.4	− 36
Italy	−1 958	−1 166	− 792	−0.2	− 23
Malta	− 81	− 43	− 38	−1.2	− 89
Portugal	−1 952	− 662	−1 290	−1.1	− 90
Spain	−1 377	− 826	− 551	−0.2	− 19
Yugoslavia	−1 282	− 582	− 700	−0.3	− 26
Northern Europe	− 698	− 501	− 197	−0.05	− 8
Denmark	− 32	− 52	+ 20	−0.03	− 5
Finland	− 214	− 73	− 141	−0.2	− 26
Ireland	− 558	− 397	− 161	−1.0	−101
Norway	− 10	− 14	+ 4	−0.01	− 2
Sweden	+ 297	+ 93	+ 204	+0.2	+ 41
United Kingdom	− 181	− 58	− 123[b]	−0.02	− 5

SOURCES: "International migration trends, 1950-1970" (E/CONF.60/CBP/18).

[a] Unless otherwise indicated, the estimates of net migration have been derived by subtracting natural increase from population growth during the specified periods, which run from mid-year to mid-year.

[b] Adjusted estimates.

THE GOVERNMENTS' PERCEPTION OF THE PRESENT LEVELS OF POPULATION GROWTH, FERTILITY AND MIGRATION

An indication of the ways in which the Governments perceive the present levels or trends of population growth and selected components of change can be obtained from table 2, which was compiled from information contained in a document presented to the World Population Conference.

The figures presented in the table obviously imply that in some instances complex statements have been reduced to a single term. But since the basic documents were primarily official statements of Governments, almost all of which "have been published, or confirmed, or transmitted to the Secretary-General of the United Nations within the last year" (E/CONF.60/CBP/21, p. 8), the resulting broad picture of the regional situation is likely to be valid.

Perhaps the most striking feature of the table is that, while most countries consider their growth and fertility rates "acceptable", about a quarter consider the present rates deficient and consider intervention desirable to stimulate fertility (E/CONF.60/CBP/21, p. 41). In fact, all Governments that consider their growth rates "deficient" have "actually formulated policies either to stimulate fertility, or to encourage net immigration, or both" (E/CONF.60/CBP/21, p. 14). The countries that belong in this category include Bulgaria, Hungary, Romania, the German Democratic Republic and Czechoslovakia amongst the socialist countries, and Greece, Luxembourg and France amongst the others.

With regard to international migration, it is apparent that few countries seek to reduce their population growth by implementing measures that directly or indirectly stimulate people to emigrate, on either a permanent or a temporary basis. Moreover, assisted passages and other assistance are usually offered largely for non-demographic reasons. A comparatively large number of countries (28-33 per cent) discourage emigration, through direct administrative control or through socio-economic measures; all the socialist countries except Yugoslavia tend to follow this policy.

Immigration, either temporary or permanent, is encouraged by a surprisingly large proportion (45-46 per cent) of the ECE countries. Such countries frequently assist or arrange for transportation to the country of destination or facilitate the process of resettlement and integration. This category includes Israel and Canada and, as noted earlier, several Western European countries. All countries not classified in table 2 under the heading "encouraged" are classified as "restricted"; thus no great significance can be attached to the latter term.

If all countries that "stimulate" fertility, "permit" or "discourage" emigration and "restrict" or "encourage" immigration are considered to have policies that have the potential effects of promoting growth rates, 25 countries (64 per cent) can be so classified. Of the other countries, only five (13 per cent) can be considered to have policies that could potentially have the effect of reducing population growth; the remaining nine (23 per cent) can be considered to follow a policy of "no intervention" (E/CONF.60/CBP/21, p. 37).

TABLE 2. ECE GOVERNMENTS' PERCEPTIONS OF PRESENT LEVELS AND TRENDS OF POPULATION GROWTH, AND POLICIES WITH REGARD TO INTERNATIONAL MIGRATION

	Perception of growth and fertility rates			
	"Deficient"	*"Acceptable"*	*"Excessive"*	*Total*
Growth rates	9	29	1	39
Fertility rates	10	27	2	39
	Policy with regard to international emigration			
	"Discouraged"	*"Permitted"*	*"Encouraged"*	
Permanent emigration	13	23	3	39
Temporary emigration	11	23	5	39
	Policy with regard to international immigration			
	"Encouraged"	*"Restricted"*		
Permanent immigration	17	22		39
Temporary immigration	18	21		39

SOURCE: *"Population policies and programmes"* (E/CONF.60/CBP/21).

SUMMARY OF THE ECE GOVERNMENTS' PERCEPTION OF DEMOGRAPHIC LEVELS OR TRENDS IN RELATION TO CHANGES IN POPULATION POLICY

Demographers have long practised the art of preparing population projections, and Governments, in principle, clearly have had the opportunity of changing population policies in anticipation of demographic changes. Nevertheless it is probably fair to expect that policy changes will usually occur *ex post facto,*[18] not least because fertility changes (the phenomena most likely to trigger policy changes) tend to surprise demographers as much as they do policy-makers. We are immediately confronted, therefore, with the most basic question: is it possible to discern or establish *any* clear relationship between changes in a Government's population policy and that Government's perception of demographic levels and trends? In population studies, as in any field, many questions are asked and relatively few answered. There is no cause for immediate despair, then, if we fail to find answers to many demographic questions about the ECE countries. However, it must be realized at the same time that the odds are very heavily against finding more than a partial answer to our question.

The reasons for this are obvious. There is, first of all, the problem of time lag; many months, if not years, may elapse between the time when the need for a new policy is recognized and the time the new policy becomes effective. Additional problems are posed by the tremendous width of the field of action covered under the concept of "population policy". There is often great difficulty, too, in obtaining accurate and detailed material for each country concerned. Finally, special problems arise in attempting to evaluate demographic material properly for a large number of countries.

[18] M. Macura, *loc. cit.*, p. 40.

It seems desirable to illustrate the problems involved briefly by again using the Netherlands as an example, although the question of time lag will thereby only be touched upon in passing.

The field of population policy can be subdivided into four main sections, as follows:

(*a*) *Marriage and family formation* (minimum legal age at marriage; other marriage regulations; separation; divorce; marriage grants; housing loans; benefits upon childbirth and during the pre-natal and post-natal period; maternity leave and other relevant laws and regulations);

(*b*) *Procreation and contraception* (availability of means of contraception, sterilization and abortion; sex education);

(*c*) *Social and economic aid to families* (assistance in obtaining and maintaining housing; assistance to working wives; provision of nurseries and care centres; family allowances; child endowments; tax benefits and the like); and

(*d*) *Migration and mobility* (regulations dealing with arrival and departure; assistance to different types of migrants; investment policies; creation of new towns; administrative decentralization; support to disadvantaged areas and the like).

An inventory of changes in legislation and jurisprudence in the Netherlands since about 1970 that affect social measures and collective services, indicates that there have been at least 10 changes that are all more anti-natalist than pro-natalist in character. These range from the enactment of new legislation on divorce to a decision that contraception requiring medical supervision should be available as a medical benefit. Since the Government has also long recognized the need for more liberal legislation on abortion and is now contemplating action in this respect, we might conclude that the policies are a response to the relatively high rate of population growth in the Netherlands and that they follow from the Government's perception that the very high population density and the congestion and pollution associated with it are not conducive to the well-being of the people.

Such a conclusion could, moreover, be supported by pointing out that during the same period many attempts were made by the Government to improve the distribution of the population through physical planning, administrative decentralization and the like.

Nevertheless, this conclusion would, at best, be only partly correct. For although it is undoubtedly true that within the Government there is an awareness of the problems that would be caused by continued population growth, the Government's measures dealing with procreation and family formation would almost certainly also have been taken even had the population density been only half of what it is now. And since even the most thinly populated countries in Europe appear to have adopted redistribution policies, it is also quite likely that the redistribution policies in the Netherlands would not have been very different in the event of lower population density.[19]

This example suggests quite strongly that in discussing population policy changes, it is dangerous to overlook the humanitarian, ideological, economic, social and other factors that Governments consider when taking policy decisions. As Glass stated in 1954, "We may take it as axiomatic that social policy is never single-minded and rarely fully consistent".[20]

We can thus offer a partial answer to the question posed in the opening paragraph of this section: There is a certain amount of evidence that in about 1965 at least some of the socialist countries of Eastern Europe started to react to a prolonged period of fertility decline, which dated from about 1955 and which had brought fertility down to below replacement level. The material upon which this conclusion is based relates to Romania, Bulgaria, Hungary, Czechoslovakia and Poland, and for the most part has been assembled and presented by Macura.[21] No similar movement has been reported in other countries, although there have been substantial increases recently in child endowment payments in Austria and France. It may be that the difference in the starting date of fertility decline plays a role here, or that other ECE countries, because they make use of the free, or almost free, movement of labour across national boundaries, do have a different appreciation of the significance of natural population growth. Their policy response so far might thus be considered to have consisted mainly of encouraging immigration or emigration, particularly on a temporary basis.

It is interesting to observe how, at the same time that some socialist countries of Eastern Europe tighten their traditionally liberal legislation with respect to marriage, divorce, contraception and abortion, and stimulate and assist family formation, the other ECE countries are moving in the direction of greater liberalization and reduced social pressure to conform to a given pattern of fertility behaviour. Will the influence of continued fertility decline cause this process of liberalization to be interrupted before it has run its full course? Or are the forces that have led to the secularization of the societies concerned—and to a situation in which great emphasis is being put on extending individual human rights and social justice—strong enough that they can withstand one or two decades of fertility below replacement level? Livi-Bacci[22] considers the tendency in Western European countries to extend and protect individual rights to be "irreversible"; this may, however, prove to be a case where the wish is the father of the thought.

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19 H. ter Heide, "Goals and objectives of population redistribution policies with special reference to Western Europe", International Union for the Scientific Study of Population, *International Population Conference*, Liège, vol. 3 (1974), pp. 373-388.

20 D. Glass, in H. Eldridge, *op. cit.*, p. iv.

21 M. Macura, *loc. cit.*, p. 42.

22 M. Livi-Bacci, *loc. cit.*, p. 192.

A final remark must be made at this level of generalization. It is frequently possible to link the position of a country on a given item of population policy to an area of concern that is typical, sometimes unique, to that country. Prime examples of this are concern with population density and its possible consequence (in the Netherlands), concern about environmental pollution in large industrialized countries (United States, United Kingdom, Federal Republic of Germany), concern over differential growth between ethnic or language groups (Belgium, Canada) and concern with survival in a region considered to be at least potentially hostile (Israel). In such cases a perception of "too much" or "too little" growth, "too high" or "too low" fertility, will have an increased intensity, and will more likely lead to attempts to change the problem or to deal with the consequences.

PRESENT PATTERNS AND DIRECTIONS OF CHANGE

Since it is impossible to discuss in detail the population policy situation in a large number of countries, the following discussion will focus on two basic concerns: changes that may affect fertility; and the direction of change in each case. Three fields will be considered specifically: marriage and family formation; procreation and contraception; and social and economic aid to families.

Marriage and family formation

Marriage is universal in the States in the area of responsibility of ECE: nearly 95 per cent of all men and women marry during their lifetime and they frequently marry young. The legal systems share a common definition of marriage as a social contract and stipulate the conditions that must be fulfilled before a marriage can be concluded. These conditions always include a precise minimum age or ages for the intending marriage partners.

Since age at marriage is, or can be, a determinant of fertility, differences and changes in the minimum legal age of marriage may be considered relevant in a discussion of population policy. The minimum legal age of marriage for men ranges from 21 (Federal Republic of Germany, Poland) to 16 (United Kingdom); 18 is the mode.[23] For women, the upper and lower limits are 18 years (in quite a few countries) and 14 years (Greece). The minima are nearly always reducible, particularly in the case of pregnancy, and the minimum legal age is usually higher for men than for women.

In analysing the IUSSP/Vienna Centre country reports for Europe, Kirk *et al*[24] came to the conclusion that, after many decades of raising the minimum age at marriage, the current trend was to reduce the age of adult competence to marry. These changes are mainly a reflection of the increased social status of the young, in particular their improved earning capacity. The lowered legal age for marriage should thus be regarded as part of a tendency to amplify individual human rights, rather than as a result of demographic considerations.

However, a few countries (Poland, Romania) are reported to be contemplating formal steps in the opposite direction, because early marriages are considered to carry an increased risk of divorce, at least in societies where the termination of a marriage is relatively easy.

A marriage implies the public recognition of a relationship between a woman and a man. Because of its fundamental character and because of the different functions it fulfils, marriage used to be considered permanent in the countries of Europe and North America, and was terminable only through the death of one of the partners. In some countries where the influence of canon law is very strong marriage legislation still reflects this position; other countries already have considerable experience in permitting divorce by mutual agreement.

Kirk has observed that the process of secularization is continuing and that the shift from "no divorce allowed" to "divorce by agreement" has led to striking dissimilarities in legislation between the countries of Europe and North America. Although each grouping is soon outdated, and although there are many differences in detail and interpretation, it would appear that the countries of Europe can be divided into four groups, according to their legislation with respect to divorce. In the first group (Ireland and some Catholic countries of Southern Europe) divorce is impossible; in the second group (France, Greece, Italy, Turkey) divorce is possible only on certain grounds, mainly matrimonial offences; in the third group (e.g. Belgium, Finland, Federal Republic of Germany) the "breakdown of the marriage" is admitted as an alternative ground; while in the fourth group (the socialist countries of Eastern Europe, the Netherlands, the United Kingdom and most of the Scandinavian countries) the joint submission of the partners that the marriage is lastingly disrupted is admitted as the essential or only ground for divorce.

Two further remarks must now be made. The first is that, while the tendency to move towards "breakdown of marriage" as the basic ground for divorce will probably become even stronger in future years, it is also quite likely that in a number of countries it will become more difficult than it is now to obtain divorce by consent, because of the high costs of divorce to society, because of the consequences of divorce for children and for demographic reasons. For example, certain tightening has already taken place in Romania.

The second is that, with norms and values changing, there is likely to be an increased demand for social contracts of various types, rather than marriage contracts, between partners who do not want to marry (for example, because of pension rights) or who cannot marry

[23] See tables prepared by G. Ferrari, mentioned in footnote 7.

[24] M. Kirk, "Law and marriage in Europe", in M. Kirk, M. Livi-Bacci and E. Szabady, eds., *op. cit.*, pp. 1-30.

(for example, because they are of the same sex). Action groups are already active in several countries in Western Europe and North America; they have already proposed a number of such contracts, for example to provide for cases where property is owned and the laws of inheritance are not applicable or to facilitate obtaining mortgages.

The direct demographic effect of possible changes in this respect will undoubtedly be trivial. Their indirect effects, though, may be considerable, since such changes would to some extent de-emphasize the position of the family in society and thereby reduce the frequently subtle pressures upon young adults to marry and have children. It may be noted in this connexion that a recent international instrument (the World Population Plan of Action) describes the family as "the basic unit of society" and recommends that it be protected "without discrimination, as to other members of society", and that earlier instruments reflect the concept of the family as "the natural and fundamental unit of society".

Many more topics could be discussed in relation to marriage and family formation, and could throw further light on some of the tendencies indicated here. Among these are the treatment of one-parent families, the status and treatment of illegitimate children, rules regarding alimony and others. Their consideration, however, properly lies outside the scope of the present paper.

Procreation and contraception

It is fair to say that all or nearly all countries in the ECE region subscribe to the principle that persons have the basic human right to decide freely and responsibly on the number and spacing of their children, and that they should have the means and knowledge to do so. However, there does not appear to be a single country where a codification of that right has taken place and where citizens can go to court if the right is impaired. Moreover, the term "persons" is not always interpreted as "all persons independent of age or marital status"; neither can it be said that there are no restrictions with regard to the means that may be used to exercise such a right. In particular, the idea that the number of children might be zero is not usually accepted explicitly.

The trend towards formal recognition and implementation of individual human rights has been almost completed in what Livi-Bacci[25] has termed the liberal-reformist group of countries in Western and Northern Europe and in North America. Governments in these countries usually play an important role in the family-planning field by financing advisory centres (Denmark, United Kingdom) or by subsidizing private clinics (Federal Republic of Germany, Netherlands). Generally speaking, contraceptives may be manufactured, imported and advertised without restriction and disseminated through a variety of outlets (including, for example, vending machines for condoms). In many instances contraceptive advice, services and means requiring medical supervision are provided as a medical benefit and without discrimination as to age or marital status of the prospective client.

There has been a considerable shift in the same direction in a number of other countries (Austria, Belgium, France, Italy, several states in the United States of America). Some restrictions remain in force, however, particularly with regard to the advertising of services and means. The sale of condoms through vending machines outdoors is almost invariably not allowed. Perhaps of greater importance, there are in such societies strong forces opposed to certain means of family planning; thus the Governments are not prepared to accept an active role.

In a further group, which comprises Ireland, Spain, Portugal and, in some respects, Malta, individual rights in the field of family planning cannot be exercised effectively. Either the manufacture of contraceptives is not permitted, their import in bulk or for personal use is not possible and/or their distribution is not free. Moreover, the advertising of contraceptive advice, services and devices is prohibited.

In the socialist countries of Eastern Europe, finally, family-planning consultation is generally provided through advisory centres that are entirely State-supported; these are related to the national health programmes. Restrictions have been tightened in most instances on the import of contraceptives and on their sale through outlets other than pharmacies. This is particularly true in Romania.

In no field of legislation relevant to population questions in the ECE countries is there such a variation in basic provisions and, at the same time, such a discrepancy between theory and practice as in that of abortion. As with the other topics discussed here, it is possible to classify countries by type of practice, on a scale ranging from complete prohibition to complete freedom. There are, in fact, strong parallels in this respect if the resulting list is compared with those on contraception and sterilization.

Abortion, even for medical or eugenic reasons, is not permitted in Ireland, Malta, Portugal or Spain. The formal situation in Belgium and Italy is similar, but more exceptions are possible. For example, abortion may be performed not only if the life of the mother is endangered but also if her health is in jeopardy. In a further group of countries rape is also a ground to allow abortion (Austria, Federal Republic of Germany, Greece). A further cluster shows countries where the grounds for abortion have been broadened to include those of a medico-social, social or humanitarian nature (Bulgaria, Czechoslovakia, Denmark, Hungary, Sweden, United Kingdom, Yugoslavia). Although in such countries abortion is not available "on request" as it is for example in the United States, the USSR and the German Democratic Republic, the practical situation may not be too different, since the term "on request" is a misnomer. Even where abortion up

[25] M. Livi-Bacci, *loc. cit.*, p. 195.

to a certain duration of the pregnancy can be performed as a matter of routine, specific formalities and procedures must invariably be observed.

Recent legislative changes in France and Norway, and the activities and plans reported for other countries, lead one to expect that the tendency will continue towards greater liberalization of abortion laws. However, in countries where there is strong opposition to legalized abortion on ethical and moral grounds, the period required before new legislation comes into force may be very protracted. It is not unusual to see opposing factions in Parliament holding each other very nearly in balance, as in the Federal Republic of Germany, the Netherlands and Norway, while public opinion appears to be more favourably disposed than legislative bodies towards liberalization.

It must also be noted that restrictions can easily be reintroduced if the Governments deem this necessary; developments in three socialist countries demonstrate this clearly.[26]

The final remarks under this subheading relate to sterilization. The various reports show that sterilization for medical or eugenic reasons is, with the exception of Italy and Spain, allowed in all countries under discussion. The picture is different if sterilization on other grounds or upon request is considered. In that case the situation encountered in the ECE region is as diverse as it was found to be with regard to divorce and contraception.

Schubnell[27] has argued that four basic patterns can be distinguished. In the first there is no special law on sterilization, and operations can be performed as part of normal medical practice (France, Netherlands, Poland); in the second there are no special laws on sterilization, but it is punishable as an act of grievous bodily harm or mutilation if it does not take place on medical indication (Austria, Belgium, Czechoslovakia, Greece, Romania, Sweden, United Kingdom, Yugoslavia); the third pattern is to have special but broadly formulated rules governing sterilization, allowing a great deal of flexibility (Denmark, German Democratic Republic); and finally there may be strict regulations but with violations seldom prosecuted (Italy, Turkey).

Social and economic aid to families

Governments assist and protect families in many ways. It is generally acknowledged that the assistance thus given leads to greater social justice and contributes to the welfare of society. The two types of assistance that will be briefly considered here are family allowances and tax benefits.

The origin of modern family allowances goes back a long time. Their actual introduction in France occurred in November 1916, at a time when rising prices were making it very difficult for workers with children to maintain their standard of life.[28] However, family-allowance policies did not become part of a pro-natalist policy until the 1930s.

Family-allowance policies now serve a dual function in many ECE countries: on the one hand they improve social justice, by preventing a decline in the standard of living as a result of the birth of children and by providing equal opportunities to all children; on the other hand they stimulate the birth rate through the provision of material incentives. It is difficult to decide whether a particular system of family allowances is essentially meant to improve social justice or whether it is pro-natalist in intention.

It has been argued that these systems are neutral so long as the allowance is the same for each child. In such a case the progression in payments would, for the first five children, follow the series: 33, 67, 100, 133 and 167, if the amount payable to a family of three children is given the index value of 100.[29] Since the costs of children may not rise in proportion to their number, there is reason to doubt whether this scale is fully appropriate. It may, moreover, be important to consider such questions as whether the allowances are subject to income tax, whether a premium must be paid on the basis of total taxable income and whether special allowances are due to older children who attend school, before coming to definite conclusions in this respect.

But if it is accepted that the amount of progression is indicative of the intent of the measures, then the system in many countries (for example, Belgium, Czechoslovakia, Finland, France, the Federal Republic of Germany, Greece, the Netherlands, Romania and the United Kingdom) would appear to be pro-natalist. The systems in force in Denmark, Hungary, Italy and Sweden would then be described as neutral, while non-progressive systems would appear to exist in parts of Bulgaria and Yugoslavia, for example.

Obviously, the amount of money paid may largely determine the power of family allowances as a pro-natalist incentive. Figures expressing the amounts payable as a proportion of the minimum wage and the total amount paid as a proportion of the national budget would be very valuable, but no such figures seem to be available. Evidence from scattered sources, however, makes it quite apparent that the differences in this respect are very marked.

Just as family allowances can be used for the dual purpose of improving social justice and promoting natality, so the fiscal system of a country can be applied as a multi-purpose instrument. It can be used as a means of stimulating marriage, by imposing an additional tax burden on the unmarried; equally, it can be used to stimulate fertility, by allowing tax reductions on the basis of the number of dependent children in

[26] M. Macura, *loc. cit.*, p. 49.
[27] H. Schubnell, *op. cit.*, pp. 31-66.

[28] D. V. Glass, *op. cit.*, p. 101.
[29] P. Paillat, "Economic and social assistance to families", in M. Kirk, M. Livi-Bacci and E. Szabady, eds., *op. cit.*, p. 67.

the family, by penalizing the childless and by taking the household rather than the individual person as the basic unit of taxation. The fiscal system, of course, also can be and is used as an essential instrument in the redistribution of incomes, through the provision of financial assistance to the aged and the underprivileged, to incomplete families and illegitimate children and through the provision of collective services. Since a population's appreciation of its own welfare may largely depend on the ways in which these redistributive functions are fulfilled, the use of the tax system for these purposes may also well be its most important function in terms of demographic consequences.

Since the question of direct as opposed to indirect taxation must also be considered, it is not at all easy to decide whether a given fiscal system is pro-natalist or not. All that can be said is that within the ECE region some countries use the household as the basic unit of taxation, some allow a deduction in taxable income depending on family size, others permit a tax reduction depending on family size and several impose additional taxes on the unmarried and the childless. There are also a few ECE countries which do all four.

Whether family allowances and fiscal measures have a more than trivial effect on fertility has not been established; there is, however, an *a priori* case that societies that provide generous assistance to families over a broad range of activities provide an environment more favourable to high fertility than those that do not. Although a clear insight into the most recent changes has not been obtained, it appears that some socialist countries are acting on this assumption in their efforts to reach the objective of maintaining fertility at least at replacement level.

CONCLUSION

For the most part, the Governments in the area of responsibility of ECE perceive current trends in population growth and fertility as either "acceptable" or "deficient". The latter is especially true for the Eastern European Countries, where fertility decline started early and international migration is usually not an important determinant of population growth.

No more than a partial answer is possible to our central question, "Does the perception of current trends relate to policy changes?" There are, however, indications that this perception does indeed influence the content of population policies. In Western and Southern Europe the movement of labour is "encouraged". In Eastern Europe attempts are made to stimulate fertility, partly by increasing social and economic aid to families and partly through restrictions of various types.

Since population policies are seldom formulated with a single purpose in mind, and since the area they cover is extremely wide and each country must confront its own particular problems, many changes are made in population policy that do not appear to be inspired by demographic levels and trends. Such changes are particularly important in the countries of North America and in Western and Northern Europe. In these areas there have been a series of policy changes that have resulted from a greater recognition of individual human rights, a new emphasis upon promoting social justice and an increased secularization of society. These changes are all more likely to have the effect of reducing fertility and natural growth than of increasing them. It must be expected that further such changes will take place, and that they will also occur in the Southern European countries.

If this is indeed the case, and if fertility converges to replacement level and stays there, the region may be on its way to a stationary situation. Since there is a growing consensus as to the acceptability of such a development, it will probably be welcomed by many Governments. There is, however, the distinct possibility that a prolonged period of below-replacement-level fertility in some countries may result in the maintenance —or reintroduction—of the substantially diverse rules and legislation which exist at present.

EFFECTS OF ECONOMIC, SOCIAL AND DEMOGRAPHIC FACTORS ON FERTILITY AND MORTALITY LEVELS: INTERCOUNTRY STUDIES

Ranjan K. Som*

INTRODUCTION

The Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (hereinafter referred to as the "the Population Division") recently initiated two exploratory intercountry studies to assess the joint and residual effects of selected economic, social and demographic variables on recent fertility levels, changes in fertility levels and recent mortality levels. The two studies were carried out in connexion with the Population Division's on-going monitoring of world-wide population trends, which is being undertaken following the recommendations of the World Population Plan of Action and the Population Commission. The same methodology, hierarchical multiple regression, was adopted for both of these studies.

Some of the preliminary results of the studies were reported in a document presented to the nineteenth session of the United Nations Population Commission.[1] The present report gives the results of the final analysis and also discusses the methodological issues involved. It is divided into two parts. The first deals with fertility levels and their changes and the second deals with mortality levels; a summary is provided at the end.

FERTILITY LEVELS AND CHANGE

The study on fertility was aimed at identifying, among selected economic, social, demographic and family-planning programme indicators, a few key elements, which could be considered statistically significant in their effects on recent fertility levels and changes in the developing countries of the world. One may note in this connexion a few intercountry studies of a similar nature, particularly those undertaken at the Population Council by R. J. Lapham and W. P. Mauldin,[2] R. Freedman and B. Berelson,[3] and K. S. Srikantan,[4] (the latter a recently completed analytical study). The Population Division itself has an on-going study covering 99 countries, of which 74 are developing, focusing on the relationships between demographic and socio-economic factors in the context of development.

In their study, Lapham and Mauldin considered 20 countries with national family-planning programmes. When grouped according to three levels of contraceptive use and by the mean values of each of the 16 selected social, economic and health criteria, the data suggested that in countries with national family-planning programmes, social, economic and health conditions seemed to bear some relationships to levels of contraceptive use. Calculated bivariate zero-order product-moment correlation coefficients between the crude birth rates and four selected economic, health and social criteria also suggested that economic, health and social factors probably did exert some influence, perhaps a major influence, on fertility trends.

The study by Freedman and Berelson covered 46 countries with national family-planning programmes. They adopted a social-setting classification based on three variables: gross domestic product per capita; proportion of elementary-school- and secondary-school-age girls enrolled in school; and infant mortality rate. A programme effort index was based on programme strength and institutional setting. They concluded that both social setting and programme effort had strong positive correlations with programme acceptance, with a somewhat greater correlation for programme effort. Their cross-tabulation of social setting and programme effort also led them to the conclusion that programme effort had a significant relation to acceptance rates, independent of the social setting.

The study by Srikantan covers 75 countries, including 50 developing countries. The study attempts to determine the socio-economic thresholds for fertility decline; 20 countries are also covered in a comparative study of the national family-planning programmes and associated socio-economic infrastructural factors and their impact on fertility. The 20-country study indicated that socio-economic factors had a direct (i.e., a demand-generating) effect on fertility, and that in addition they provided the infrastructure for programme implementation; the programme outputs had a substantial direct effect, independent of the socio-demographic factors.

The present study starts with a number of selected economic, social and demographic variables as well as family-planning programme inputs and outputs, and

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[1] See *Official Records of the Economic and Social Council, Sixty-second Session, Supplement No. 4* (E/5913).

[2] R. J. Lapham and W. P. Mauldin, "An assessment of national family planning programmes" in *An Assessment of Family Planning Programs* (Paris, Organization for Economic Co-operation and Development, 1972), pp. 7-184.

[3] R. Freedman and B. Berelson, "The record of family planning programs", *Studies in Family Planning*, vol. 7, No. 1 (1976), pp. 1-40.

[4] K. S. Srikantan, *The Family Planning Program in the Socio-economic Context* (New York, Population Council, 1977).

then seeks to relate these, in a specified framework, both with the 1970 and 1975 fertility levels and with the proportional change in fertility during the period. By its very nature, an intercountry study is different from a time-series study in individual countries or from a cohort or longitudinal study of the same group of people.

Data base

Table 1 lists the variables included in the study. Generally, one variable was selected from each group relating to demographic, social and economic factors. These were: married women (including consensually married women) of reproductive age (reckoned as 15 to 44 years), as a proportion of the total population; the infant mortality rate; the proportion of the population living in cities with populations of 100,000 and over; the proportion of females among salaried employees and wage earners; the number of radio receivers per person; the proportion of physicians in the population; and the gross domestic product per economically active person. Variables pertaining to family-planning programmes included the budget *per capita* (from all sources, internal and external) for family planning and the respective proportions among married women of reproductive age of (first-time) acceptors and (current) users of family planning. The fertility indicators used were the gross reproduction rates in 1970 and 1975 and the proportional decline during the period. Except for these last two items, the data related to the years around 1970. Some of the data came from the study by the Population Division of the relationships between demographic and socio-economic factors in the context of development; most of the infant mortality rates were taken from estimates supplied by the World Health Organization for the monitoring of population trends; and some data were from documents and publications of the Population Council, the Organization for Economic Co-operation and Development, the World Bank, the World Health Organization, the International Labour Organisation, the United Nations Fund for Population Activities and the United Nations Educational, Scientific and Cultural Organization. All other figures are based on data and estimates prepared by the Population Division.

TABLE 1. VARIABLES USED IN THE FERTILITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

Sector or grouping	*Variable*
Demographic (other than fertility)	Married women of reproductive age (15-44 years), as a proportion of total population
	Infant mortality rate
Urbanization	Proportion of population living in cities of 100,000 or more inhabitants
Literacy	Literacy rate among adult females
Labour Force	Proportion of females among salaried employees and wage earners
Communication	Number of radio receivers per person
Health infrastructure	Proportion of physicians in population
Income	Gross domestic product per person in the labour force
Family-planning programmes	Annual *per capita* budget (from all sources) for family planning programmes
	Proportion of family planning (first-time) acceptors among married women of reproductive age
	Proportion of family planning (current) users among married women of reproductive age
Fertility	Gross reproduction rate, 1970
	Gross reproduction rate, 1975
	Proportional decline in gross reproduction rate, 1970 to 1975

Of the family-planning programme inputs, it would have been desirable to include actual cost per acceptor of family planning rather than the budget *per capita* but the cost data were not available for a large number of countries. It thus was necessary to settle for using the budget data, with all their consequent limitations.

Table 2 lists the 25 countries included in the study; these were the countries with national family-planning

TABLE 2. COUNTRIES INCLUDED IN THE FERTILITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

Region	*Subregion*	*Country*
Africa	Eastern Africa	Kenya
		Mauritius
	Northern Africa	Egypt
		Morocco
		Tunisia
	Western Africa	Ghana
Latin America	Caribbean	Dominican Republic
	Central America	Costa Rica
		El Salvador
		Guatemala
	Tropical South America	Colombia
Asia	East Asia	Hong Kong
		Republic of Korea
	Eastern South Asia	Indonesia
		Peninsular Malaysia
		Philippines
		Singapore
		Thailand
	Middle South Asia	Bangladesh
		India
		Iran
		Nepal
		Pakistan
		Sri Lanka
	Western South Asia	Turkey

TABLE 3. BI-VARIATE PRODUCT-MOMENT CORRELATION COEFFICIENTS, INTERCOUNTRY FERTILITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

	Infant mortality rate	*Urban population*[a]	*Literacy rates adult females*	*Radio receivers per person*	*Physicians*[a]	*Gross domestic product*[b]	*Family planning budget*[c]	*Family planning acceptors*[d]	*Family planning users*[d]	*Gross reproduction rate (GRR), 1970*	*Gross reproduction rate (GRR), 1975*	*Proportional decline in GRR, 1970-1975*
Married women of reproductive age[a]	0.54[e]	−0.52[e]	−0.64[e]	−0.55[e]	−0.50[e]	−0.57[e]	−0.26	−0.56[e]	−0.43[f]	−0.43[f]	0.44[f]	−0.51[e]
Infant mortality rate		−0.57[e]	−0.79[e]	−0.43[f]	−0.62[e]	−0.61[e]	−0.21	−0.70[e]	−0.73[e]	0.78[e]	0.79[e]	−0.82[e]
Urban population[a]			0.27[g]	0.72[e]	0.69[e]	0.78[e]		0.51[e]	0.79[e]	−0.69[e]	−0.70[e]	0.79[e]
Literacy rate, adult females				0.28[g]	0.53[e]	0.32[g]	0.31[g]	0.61[e]	0.53[e]	−0.51[e]	−0.53[e]	0.56[e]
Radio receivers per person					0.50[e]	0.53[e]	0.06	0.38[f]	0.56[e]	−0.49[e]	−0.52[e]	0.61[e]
Physicians[a]						0.76[e]	0.41[f]	0.65[e]	0.66[e]	−0.54[e]	−0.57[e]	0.67[e]
Gross domestic product[b]							0.44[f]	0.64[e]	0.60[e]	−0.52[e]	−0.55[e]	0.70[e]
Family planning budget[c]								0.64[e]	0.33[g]	−0.16	−0.20	0.33[g]
Family planning acceptors[d]											−0.62[e]	0.68[e]
Family planning users[d]											−0.80[e]	0.83[e]
Gross reproduction rate (GRR), 1970											0.99[e]	−0.87[e]
Gross reproduction rate (GRR), 1975												−0.91[e]

SOURCE: Prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat.

[a] As a proportion of total population.

[b] Per economically active person.

[c] *Per capita.*

[d] As a proportion of married women of reproductive age.

[e] Significant at the 1 per cent level of probability.

[f] Significant at the 5 per cent level of probability.

[g] Significant at the 10 per cent level of probability.

programmes for which data and estimates of reasonable accuracy were available. Together, the countries listed in table 2 had a total population of 1,254 million persons in 1975, comprising 31.6 per cent of total world population and 44.2 per cent of the population of all the developing countries.

Analytical methods and discussion of results

Analysis began with a calculation of Pearsonian zero-order correlation coefficients among the variables. The variable "proportion of females among salaried employees and wage earners" did not show any significant correlation with the other variables at the 10 per cent probability level; therefore this variable was eliminated from further consideration. The other correlation coefficients are shown in table 3 with their associated levels of probability, as measured by the t-statistic. A probability level of 10 per cent was adopted, less stringent than would be used in statistical testing of controlled experiments in the natural sciences, but not an uncommon practice in social and economic studies. The paired relationships that emerge conform, in general, to the expectations. By their nature, however, these correlation coefficients do not indicate the joint and residual effects of the variables on fertility levels and change.

The next step in the analysis was to calculate separately the multiple-regression coefficients of the ten independent (but obviously interdependent) variables on the three dependent variables: the fertility levels in 1970 and 1975 and the proportional decline in fertility between 1970 and 1975. The three multiple regressions were all significant at either the 5 per cent or the 1 per cent probability level.

A subsequent test was undertaken to determine the additional contribution of each of the ten independent variables when the other nine had already been included in the multiple regression. None of these was statistically significant. This simply meant that when any nine variables had been included in a multiple regression, the tenth variable did not have any significant additional contribution to the regression.

An exhaustive approach would have been to compute the multiple regression on every subset of the ten independent variables (that is, on each variable singly, on every pair of variables, on every triplet, on every quadruplet, and so on), and then to select that subset which gave the smallest mean square for deviation from regression. This approach, however, would have required the computation of $2^{10}-1$ ($=1{,}023$) multiple regressions. With electronic computers, this task would be feasible, but it would scarcely be meaningful. Another approach would have been to compute (forward) a stepwise multiple regression, including only those independent variables that met specified statistical criteria, the order of inclusion to be determined by the respective contribution of each of the independent variables to the explained variance.

These regression methods would not have provided any understanding of the data, nor would they have allowed the study to follow any conceptualized approach. Therefore a decision was made to adopt the hierarchical method of regression analysis. In this method the variables are added in a multiple regression equation, in an order predetermined by the implicit conceptual approach. That is, instead of determining the marginal contribution of each variable by assuming that it was added last, the hierarchical method requires that the order of inclusion of the variables be specified before computation.

Two orders of inclusion were adopted for the hierarchical decomposition method. The first started with the indicators of social and economic development, the programmatic variables being added last; the second started with the programmatic variables, with the economic and social variables being placed at the end.

Multiple regressions were computed by adding one variable after another in the specified sequence. The statistical significance of the change in R^2 (R being the multiple correlation coefficient) was tested by the F-statistic, the ratio

$$\frac{\textit{Incremental change in squared multiple correlation}^1}{\dfrac{1-R^2}{N-k-1}}$$

having an F-distribution with $(1, N-k-1)$ degrees of freedom, where N is the number of observations and k the number of independent variables.[5]

TABLE 4. FERTILITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: TEST OF SIGNIFICANCE OF THE INCREMENTAL PROPORTION OF VARIABILITY OF THE DEPENDENT VARIABLES ATTRIBUTABLE TO MULTIPLE REGRESSION, ACCORDING TO SPECIFIED HIERARCHICAL ORDER (I)[a]

	Dependent variable		
	GRR, 1970	*GRR, 1975*	*Proportional decline*
Independent variables in hierarchical order (I)	*Significance, by probability level (percentage)*		
Gross domestic product per labour force member	1	1	1
Infant mortality rate	1	1	1
Proportion of literate females			
Proportion of urban population	5	5	1
Proportion of physicians			
Radio receivers per person			
Proportion of married women			
Per capita family planning budget			10
Family planning acceptor rate			
Family planning user rate			

[a] Except as noted, results not significant at the 10 per cent probability level.

[5] It may be noted that, as formulated, the F-test for the variable first in order is somewhat different from the test of significance of the bivariate (linear) correlation between that variable and the dependent variable, in the absence of other variables; the former tests the significance of the contribution to the multiple correlation by the variable in the presence of other variables in the multiple regression.

TABLE 5. FERTILITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: TEST OF SIGNIFICANCE OF THE INCREMENTAL PROPORTION OF VARIABILITY OF THE DEPENDENT VARIABLES ATTRIBUTABLE TO MULTIPLE REGRESSION, ACCORDING TO SPECIFIED HIERARCHICAL ORDER (II)[a]

	Dependent variable		
	GRR, 1970	*GRR, 1975*	*Proportional decline*
Independent variables in hierarchical order (II)	*Significance, by probability level (percentage)*		
Per capita family planning budget	—	—	1
Family planning acceptor rate	1	1	1
Family planning user rate	1	1	1
Proportion of married women	—	—	—
Proportion of physicians	—	—	—
Radio receivers per person	—	—	—
Gross domestic product per labour force member	—	—	—
Infant mortality rate	10	5	5
Proportion of literate females	—	—	—
Proportion of urban population	—	—	—

[a] Except as noted, results not significant at the 10 per cent probability level.

The results are shown in tables 4 and 5 along with the probability levels obtained. For the proportional decline in fertility, for example, the sum of squares attributable to the gross domestic product per economically active person includes not only the part attributable to the direct influence of the GDP figure on fertility decline but also that portion attributable indirectly, via the other variables. The portion of the sum of squares attributable to infant mortality likewise reflects the direct influence of infant mortality plus its indirect influence through the succeeding variables, but not through the GDP, because the latter preceded infant mortality in order of inclusion of variables. The portion of the sum of squares attributable to the third-ranked variable, the proportion of urban population, similarly reflects the variable's direct influence plus its indirect influence, but only through the succeeding variables, excluding GDP per economically active person and infant mortality rate; the same applies to the programmatic variables, which come first in the hierarchical order in table 5.

For the fertility levels in 1970 and 1975, the results show that when the analysis is begun with the social and economic variables, the three—GDP per economically active person, infant mortality rate and proportion of urban population—are significant at the 1 per cent or 5 per cent probability level. If analysis starts with the programmatic variables, on the other hand, the family planning acceptor and user rates and the infant mortality rate are significant; the other variables have no residual significant contribution.

For the proportional decline in fertility between 1970 and 1975, starting with the social and economic variables, the three—GDP per economically active person, infant mortality rate and proportion of urban population—are significant at the 1 per cent probability level; of the rest, the *per capita* budget for family planning did have a residual significant contribution, at the 10 per cent probability level. On the other hand, starting with the programmatic variables—*per capita* budget for family planning and family planning acceptor and user rates—all three were significant at the 1 per cent probability level and the other variables, with the exception of infant mortality rate, had no residual significant contribution.

Thus, the analysis shows that the three independent variables that are key indicators of the development process—GDP per economically active person, infant mortality rate and proportion of urban population—give as good a fit to the data on fertility levels as the two programmatic variables (family planning acceptor and user rates) taken together with the infant mortality rate. For the fertility decline, the same three socio-economic variables in conjunction with the *per capita* budget for family planning provide as good an explanation for the multiple regression as the three programmatic variables—*per capita* budget for family planning and family planning acceptor and user rates—in conjunction with the infant mortality rate.

The mutually interactive relationships between the development process and population programming have already been recognized in the World Population Plan of Action and elsewhere.[6] The present analysis has interpretive rather than predictive purposes: if policy considerations made a substantive input feasible in selected sectors, the inherent structural relationship among the variables might well change.

To sum up, the present study shows, with a certain degree of statistical confidence, the importance of the social and economic development processes, on the one hand, and of the programmatic inputs, on the other hand. In particular, we may note the key role of infant mortality, which appears in both sets of variables.

Concluding observations

The reader will appreciate that the present study is merely exploratory in nature. Some consideration may be given to improving the methodology and increasing the depth and scope of future studies. On the methodological side, some transformations of the measures could be considered that would result in increasing correlations. For example, a recent study by S. H. Preston showed that while the product-moment correlation between expectation of life at birth and *per capita* national income for 120 countries was 0.693, that between life expectancy and the logarithm of income *per capita* was 0.859.[7] In the present study, some suitable transformation would certainly have increased the

[6] *Report of the United Nations World Population Conference, 1974* (United Nations publication, Sales No. E.75.XIII.3), chap. I.

[7] S. H. Preston, "Causes and consequences of mortality declines in less developed countries during the twentieth century", paper presented at the Conference on Population and Economic Change in Less Developed Countries, New York (30 September-2 October 1976), manuscript, foot-note 1.

strength of a number of bivariate zero-order correlations, but one is faced with a new difficulty in computing multiple regressions, for two transformed variables may well weaken the correlations with a third (untransformed) variable. This is worthy of further investigation.

TABLE 6. LIST OF COUNTRIES INCLUDED IN THE MORTALITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

Region	*Countries*
Africa	Algeria, Benin, Burundi, Central African Empire, Chad, Congo, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Togo, Tunisia, Uganda, United Republic of Cameroon, United Republic of Tanzania, Upper Volta, Zaire, Zambia
Asia	Afghanistan, Burma, Cyprus, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Lebanon, Malaysia, Pakistan, Philippines, Republic of Korea, Sri Lanka, Syrian Arab Republic, Thailand, Turkey
Europe	Austria, Belgium, Denmark, Finland, France, Germany, Federal Republic of, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom
Latin America ...	Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru
North America ...	Canada, United States of America
Oceania	Australia, New Zealand

The first important requirement for a continuing study is to improve the data base with accurate information relating to recent dates. Depending on the availability of such data, particularly concerning the programmatic variables, the study may be extended to cover as many countries as possible which have national family-planning programmes. Within this group, moreover, an investigation could be made to identify subgroups of countries that may be considered homogeneous with respect to the study variables. A related study would be to assess the effects of the economic, social and demographic factors on use of family-planning methods, covering both the developing and the developed countries. Such a study could also be made at subnational geographical levels, as appropriate, to identify and explain the different fertility trends operating within a single country.

MORTALITY LEVELS

Intercountry mortality studies are fewer in number than those on fertility. In a recent study by S. H. Preston, the multiple regression on life expectancy at birth was calculated for three variables: income (in logarithm); percentage literate of the adult population; and calorie consumption (taken as the excess over a daily *per capita* consumption of 1,500 calories, and also expressed in logarithm). The calculations were worked out for 29 countries in 1940 and 120 countries in 1970. The regression coefficients for income and literacy were highly significant in both periods, but that for calorie consumption was insignificant, a result that was attributed to the greater measurement error in the data on the calorie variable. Another regression, computed for 36 countries, showed that only the degree of malarial endemicity was significant for the decline in life expectancy at birth. The other variables considered —increases in income, literacy and calorie consumption and *per capita* receipt of external aid, (both total and on water and sewerage projects)—were statistically insignificant. When the initial level of life expectancy was entered as an additional independent variable, it came out highly significant (at the 1 per cent level) and the income term was also significant (at 10 per cent level); the rest, including malarial endemicity, were not significant.[8]

The present study attempts to assess, in a specified hierachical order, the relative (additional) contribution of selected economic, social and demographic variables to 1970 mortality rates using national-level data from a large number of countries.

Another approach would be to apply factor analysis to the sex-age-specific death rates for various countries and periods. This analysis can be of help in identifying independent principal components, which then can be studied separately.[9]

Data base

The variables included in the study were selected from those used in the on-going study by the Population Division on the relationships between demographic and socio-economic factors in the context of development. All variables related to one of the following: gross domestic product (GDP) per economically active person; expenditure on health as a proportion of total government expenditure; proportion of physicians in the population; urban population (i.e., the proportion residing in cities of 100,000 or more inhabitants); calorie consumption and protein consumption *per capita*; crude birth rate; crude death rate; and life expectancy at birth. The variables referred to 70 developing and 25 developed countries, which together comprised a total population of 2,255 million, or 62 per cent of the world population (3,610 million in mid-1970). The countries are listed in table 6.

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[8] *Ibid.*

[9] S. Ledermann and J. Breas, "Les Dimensions de la mortalité", *Population* (Paris), vol. 14, No. 4 (October-December 1959); "Factor analysis of sex-age specific death rates", *Population Bulletin of the United Nations No. 6—1962* (United Nations publication, Sales No. 62.XIII.2).

Analytical methods and discussion of results

The present study used the same analytical methods as were followed in the fertility study. For the reasons given in the fertility study, the data were utilized without any transformation, logarithmic or otherwise. Pearsonian zero-order correlations were first calculated between the variables taken two by two, in order to establish their pair-wise linear relationships. At the 10 per cent probability level, consumption of protein did not show any statistically significant correlation with the other variables, and therefore was not considered further. The correlation coefficients between the other variables are shown in table 7, with their associated levels of probability. These do not, however, indicate the joint and residual effects of the variables on mortality levels.

Multiple regressions were next computed separately on the two dependent variables—crude death rate and life expectancy at birth; both were highly significant, at the 0.005 probability level.

As in the fertility analysis, the hierarchical method of multiple regression analysis was adopted, in which the variables were added in a multiple regression equation in a predetermined order. Three orders of inclusion were adopted for the purpose. The first order started with the GDP per economically active person and ended with *per capita* calorie consumption and crude birth rate; the second started with calorie consumption *per capita* and ended with GDP per economically active person and crude birth rate; the third started with the proportion of physicians in the population and ended with GDP per economically active person and crude birth rate.

As explained above, the hierarchical method used here attributes a portion of the mortality figures to the direct and indirect influence of each variable listed. The sum of squares attributable to each variable includes in every case the variable's direct influence. The sum also includes the portion that results from the variable's indirect influence, but only insofar as that influence operates through the remaining (unanalysed) variables. Thus in hierarchical order (I), for example (table 8), the portion of the sum of squares attributable to the variable "physicians" reflects the direct influence of the variable plus the indirect influence as it acts through the variables following it in the list: "urban population," "calorie consumption *per capita*" and "crude birth rate." The indirect influence of the variable "physicians" as it acts through "GDP" and "health expenditures" is not included, since these items precede "physicians" in hierarchical order (I).

TABLE 7. BI-VARIATE PRODUCT MOMENT CORRELATION COEFFICIENTS, INTERCOUNTRY MORTALITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

(*Significant at the 1 per cent level of probability, except as noted*)

	Health expenditure[a]	*Physicians*[b]	*Urban population*[b]	*Calorie consumption* per capita	*Crude birth rate*	*Crude death rate*	*Life expectancy at birth*
GDP per member of labour force	−.04[c]	.82	.67	.55	−.83	−.59	−.92
Health expenditure[a]		.14[c]	.20[d]	.07[c]	.10[c]	−.24[e]	.11[c]
Physicians[b]			.67	.34	−.83	−.57	.78
Urban population[b] .				.37	−.59	−.63	.70
Calorie consumption *per capita*					−.31[e]	−.18[d]	.26
Crude birth rate ...						.71	−.87
Crude death rate ..							−.92

[a] As a proportion of total government expenditure.
[b] As a proportion of total population.
[c] Not significant at the 10 per cent level of probability.
[d] Significant at the 5 per cent level of probability.
[e] Significant at the 10 per cent level of probability.

Multiple regressions were computed in the hierarchical orders adopted. As before, the statistical significance of the change in R^2 (R being the multiple correlation coefficient) was tested by the F-statistic.

The results are shown in tables 8, 9 and 10. For the first two orders, all the independent variables were found to make highly significant contributions to the mortality levels, regardless of the order of selection, in addition to their indirect contributions through the other variables; the contribution of calorie consumption was significant at the 5 per cent probability level, while all other variables were significant at the 1 per cent probability level. This can happen when the square of the multiple correlation coefficient (which is also the proportion of the variability in the dependent variable that can be attributed to or explained by the multiple regression), jumps in steps, as the variables are included one by one so as to make incremental R^2s significant.

TABLE 8. MORTALITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: TEST OF SIGNIFICANCE OF THE INCREMENTAL PROPORTION OF VARIABILITY OF THE DEPENDENT VARIABLES ATTRIBUTABLE TO MULTIPLE REGRESSION, ACCORDING TO SPECIFIED HIERARCHICAL ORDER (I)

(*Percentage*)

	Crude death rate	*Life expectancy at birth*
Hierarchical order (I)	*Significance, by probability level*	
GDP per member of labour force	1	1
Proportion of health expenditure	1	1
Proportion of physicians	1	1
Urban proportion of population	1	1
Calorie consumption *per capita*	5	1
Crude birth rate	1	1

TABLE 9. MORTALITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: TEST OF SIGNIFICANCE OF THE INCREMENTAL PROPORTION OF VARIABILITY OF THE DEPENDENT VARIABLES ATTRIBUTABLE TO MULTIPLE REGRESSION, ACCORDING TO SPECIFIED HIERARCHICAL ORDER (II)

(*Percentage*)

	Crude death rate	*Life expectancy at birth*
Hierarchical order (II)	*Significance, by probability level*	
Calorie consumption *per capita*	1	1
Proportion of physicians	1	1
Urban proportion of population	1	1
Proportion of health expenditure	1	1
GDP per member of labour force	1	1
Crude birth rate	1	1

TABLE 10. MORTALITY STUDY BY THE POPULATION DIVISION OF THE DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS: TEST OF SIGNIFICANCE OF THE INCREMENTAL PROPORTION OF VARIABILITY OF THE DEPENDENT VARIABLES ATTRIBUTABLE TO MULTIPLE REGRESSION, ACCORDING TO SPECIFIED HIERARCHICAL ORDER (III)

(*Percentage*)

	Crude death rate	*Life expectancy at birth*
Hierarchical order (III)	*Significance, by probability level*	
Proportion of physicians	1	1
Proportion of health expenditure	1	1
Urban proportion of population	1	1
Calorie consumption *per capita*	[a]	[a]
GDP per member of labour force	1	1
Crude birth rate	1	1

[a] Not significant at the 10 per cent level of probability.

For the third hierarchical order, calorie consumption did not make any additional significant contribution after the proportion of physicians, the proportion of health expenditure, and the proportion of urban population had preceded it; the other two remaining independent variables—gross domestic product and crude birth rate—continued to be significant.[10]

It will have been appreciated that the present study was exploratory in nature. Consideration will have to be given to improving the methodology and expanding the coverage of future studies. The first requirement for a continuing study is to improve the data base relating to recent dates. The data base should relate to both mortality levels and to changes, and should include infant mortality. The study could also be expanded to identify groups of countries that may be considered homogeneous with respect to the study variables; for large countries, the study also could be extended to sub-national geographical levels, as a step towards understanding the different mortality trends operating within a single country.

SUMMARY

In connexion with the monitoring of population trends currently being undertaken by the Population Division of the Department of Economic and Social Affairs, United Nations Secretariat, following the recommendations of the World Population Plan of Action and the Population Commission, two exploratory studies on fertility and mortality were initiated to assess the joint and residual effects of selected economic, social and demographic variables on recent fertility levels, on changes in fertility levels and on recent mortality levels in a number of different countries worldwide.

For the fertility study, 25 developing countries with national family-planning programmes were included; together, these countries had a 1975 population of 1,254 million, comprising 32 per cent of the total world population and 44 per cent of the population in the developing countries. For the mortality study, 95 countries were included, which together had a 1970 population of 2,300 million, or 64 per cent of the world population.

The first step in the analysis was to compute the simple linear correlation between the variables, taken two by two. This procedure established some statistically significant linear relationships, such as between the literacy rate among adult females and the proportional decline in fertility; it did not, however, indicate the joint or residual effects of the variables on fertility levels and on changes in fertility levels.

For the fertility study, the next step in the analysis was to calculate separately the multiple regressions of the ten independent (but obviously interdependent) variables on the three dependent variables, i.e., on 1970 fertility levels, on 1975 fertility levels and on the proportional decline in fertility. The three multiple regres-

[10] For the data of six Western European countries—Belgium, France, the Netherlands, Norway, Sweden and Switzerland—taken together for over a century (1867-1971), A. Sauvy found significant correlation between life expectancy at birth of females and the logarithm of the proportion of physicians in the population. For two more recent years, 1965 and 1971, J. C. Chesnais and A. Lefebvre have also found significant correlations of a similar nature, on the basis of 64 and 135 countries respectively (A. Lefebvre, "Nombre de médecins et espérance de vie", *Population* (Paris) vol. 31, No. 6 (October-December 1976), pp. 1289-1295.

sions were all statistically significant at either the 5 per cent or the 1 per cent probability level.

The final analysis adopted was the hierarchical regression method. The variables were added in a multiple regression equation in an order predetermined by the implicit conceptual approach. That is, instead of determining the marginal contribution of each variable by assuming that it was added last, the hierarchical method required the specification beforehand of the order of inclusion. Two orders of inclusion were adopted for the hierarchical decomposition method. The first started with the indicators of social and economic development, the family-planning programme variables being added last; the second started with the family-planning programme variables, with the economic and social variables being placed at the end.

The analysis showed that three variables that are key indicators of the development process (GDP per economically active person, infant mortality rate and proportion of population living in urban areas) gave as good a fit to the data on fertility levels as did the two programmatic variables (family-planning acceptor rates and user rates) when infant mortality rate was also included. For the fertility decline, the same three socio-economic variables, in conjunction with the *per capita* budget for family-planning programmes, provided as good an explanation of the multiple regression as three programmatic variables (*per capita* budget for family planning, family-planning acceptor rates and family-planning user rates) in conjunction with infant mortality rate. We may note the crucial role of infant mortality, which appears significant in both analyses, and also that of *per capita* budget for family planning, which appears to be significant in fertility decline even when the approach is primarily socio-economic.

For the mortality study, seven independent variables were selected: GDP per economically active person; proportion of health expenditure in total government expenditure; proportion of physicians in the national population; proportion of urban population; calorie consumption *per capita*; protein consumption *per capita*; and crude birth rate. The mortality measures were crude birth rate and life expectancy at birth.

Simple linear correlation coefficients were first computed. Protein consumption *per capita* did not show any statistically significant correlation and was therefore discarded as an independent variable. Multiple regressions of the remaining six independent variables were next computed separately on the two mortality measures; both were highly significant statistically.

Finally, the hierarchical regression method was adopted for further analysis. The independent variables were added in the multiple regression equation in a predetermined order, three hierarchical approaches being adopted. For hierarchical orders (I) and (II) all the variables made highly significant contributions to the mortality levels, irrespective of the order of selection, in addition to their indirect contributions through the other variables. However, in hierarchical order (III), in which calorie consumption was preceded by the proportion of physicians, the proportion of health expenditure and the proportion of urban population, calorie consumption made no statistically significant contribution to mortality level.

For future studies, consideration will have to be given to improving and updating the data and to extending both subject coverage and geographical coverage. The studies could also be expanded to identify groups of countries that may be considered homogeneous with respect to the study variables and, for large countries, the study could also be extended to sub-national geographical levels. Finally, a number of methodological issues also remain to be investigated.

MEETING OF THE *AD HOC* GROUP OF EXPERTS ON DEMOGRAPHIC MODELS

*United Nations Secretariat**

EDITORIAL REMARK

Upon a recommendation by the Population Commission at its seventeenth session in November 1973, the Secretary-General invited an *Ad Hoc* Group of Experts on Demographic Models to discuss the utilization of demographic models in the work of the United Nations Secretariat, particularly in the preparation of demographic estimates and projections.

The Group consisted of the following experts: Mr. Albino Bocaz (Chile), Mr. Jean Bourgeois-Pichat (France), Mr. William Brass (United Kingdom), Mr. Ansley J. Coale (United States of America), Mr. Ingvar Holmberg (Sweden), Mr. Nathan Keyfitz (United States of America), Mr. Henri Leridon (France), Mrs. Jane Menken (United States of America), Mr. Robert Potter (United States of America), Mr. Norman Ryder (United States of America), Mr. B. V. Shah (India), and Mr. K. Venkatacharya (India). The Group elected Mr. Jean Bourgeois-Pichat as Chairman, Mr. Norman Ryder as Vice-Chairman and Mr. Robert Potter as Rapporteur.

The Group met at United Nations Headquarters in New York from 8 to 12 December 1975. The discussions were confined to strictly demographic models. They thus excluded models embracing wider socio-economic and demographic interrelationships, as well as micro-economic models of fertility. The Group also decided that it would make a most effective contribution by excluding models of migration and urbanization. The discussions were therefore concentrated on three critical areas in the use of demographic models:

(*a*) The estimation of basic demographic parameters from incomplete data;

(*b*) Demographic projections; and

(*c*) Assessment of the impact of policies on population.

The reader will find in the following pages part of the documentation of the meeting, including a background paper, short papers contributed by some of the experts and a summary of the report.

* Population Division of the Department of Economic and Social Affairs.

CURRENT STATUS OF DEMOGRAPHIC MODELS

*Jane A. Menken**

Introduction

The construction of demographic models has proceeded rapidly over the past decade. Models are used increasingly in preparing population projections, devising and applying new methods for estimating population characteristics from faulty data and increasing our understanding of the dynamics of population growth and change. The purpose of this paper is to review existing demographic models in order to provide the background for two related projects: the selection of models that may prove useful in practical applications ranging from new estimation techniques and new bases for projection to the evaluation of proposed population policies; and the determination of needs for the revision or extension, in various ways, of existing models.

Much of the discussion here is taken from three recent reviews of portions of the relevant literature: W. Brass's background paper (1972)[1] entitled "Mortality models and demographic projections", A. Coale's paper (1975) presented at the meeting of the International Statistical Institute in September 1975 on "Methods of estimating births, deaths and marriages in less well-developed countries" and J. Menken's paper (1975b) entitled "Biometric models of fertility".

Uses of models

One major purpose of models is concise description of some aspect of fertility, mortality or other demographic process. If a particular model adequately represents reality, the characteristics of a given population can be summarized by the parameters of the model, thereby facilitating the study of variation among populations or within a population over time.

If the observations made on a population are subject to error (due to small sample sizes or to one or another type of misreporting), a suitable model may be used to smooth the data, thereby providing better estimates than would result from accepting the data at their face value.

When a model is postulated, methods of estimating its parameters must be devised and their adequacy tested. Both the development and comparison of procedures and the consideration of kinds of data sufficient for estimation purposes have proved fruitful. In a number of cases, demographers have been able to find, with the help of a model, procedures that employ indirect indices, based on data that would otherwise be considered inadequate for estimating a specified characteristic. Conversely, other studies involving models have indicated that certain procedures previously thought to provide adequate estimators were not reflecting relevant parameters well, or were serving only poorly to discriminate between alternative values.

Models are also of value in predicting or forecasting population trends. In this application, the population trends are treated as extrapolations from an appropriate model which is viewed as theory. N. Keyfitz (1971) called prediction the "trisecting the angle" of demography because most attempts, like those of mathematicians to trisect the angle, have failed. Yet, even in view of the uncertainties involved in making assumptions about the future, predictions are necessary. Models that describe current situations, especially those that contain some theoretical framework for considering future change, may provide some basis for the analysis of population growth or change.

Finally, models may be a vehicle for research into the possible effects of specified levels and changes of demographic determinants. This role is crucial in view of the difficulties of carrying out meaningful experiments in human populations; altering characteristics in a model is an easier and more feasible way to study the importance of each factor in the model system and to assess the magnitude of change induced by proposed alterations in a causal factor.

Types of models

As interest in this area has grown, so has the array of models of many types. To help understand and compare the features of different models, the terminology used to describe their structural differences and other characteristics will be reviewed briefly.

A model may be purely descriptive or it may be causal. Descriptive models usually offer patterns of the occurrence of a given event at various ages (e.g., life tables or nuptiality curves); causal models attempt to shed some light on the interaction between one or more factors or on their effect on a variable that is taken as dependent.

The mathematical approach taken in developing a model may be either analytic or numeric. Analytic

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[1] Names and dates within parentheses refer to the sources in the reference list appended to the present study.

models express assumptions about the individual variables in mathematical forms yielding expressions that summarize the interrelations among the factors or their effect on the dependent variable that is of interest. Solutions for causal models of this type usually are obtainable only if the assumptions are severely restricted and if the causal factors remain unchanged over time, as, for example, in stable population models. Analytic models may further be either stochastic or deterministic. In a stochastic model, if a population of size N is exposed to the risk, p, of a given event occurring, then the number of events that actually occur is a random variable with expected value Np (variance Npq, etc.). By contrast, in a deterministic model, p is viewed as the proportion of the population to whom the event will occur, and therefore Np events are recorded. Deterministic models are frequently referred to as expected value models.

In a numeric model, either macrosimulation or microsimulation may be employed. Because of the extent and complexity of calculations, numeric models are almost always computer models. In macrosimulation, a population is divided into subgroups according to specified criteria. Probabilities of the occurrence of various events (in a stochastic macrosimulation model) or proportions (in a deterministic one) are allowed to operate on the subgroups for an appropriate period of time. Component projection of population is the best-known example of a demographic macrosimulation technique and, like almost all models of this type, it is deterministic because proportions, not probabilities, are applied to determine the numbers of survivors and births in each category.

Macrosimulation models allow more realistic assumptions regarding causality than have been possible so far with analytic models. Because the capacity of even the largest computers limits the number of categories that can be treated and the range and number of analyses of results that are possible, macrosimulation models usually are developed to answer specific questions. The macrosimulation may be carried out either by standard extensions of component projection methodology or by the more recently applied systems analysis techniques using differential or stochastic equations.

Microsimulation, which is always stochastic, develops a history for each individual in the model population, thereby establishing the population structure. At least some characteristics are treated as being determined by a random device. Many more variables (and their interactions) may be introduced into this type of model. Analyses may be as detailed and varied as desired, since the output resembles a complete set of data from an ideal survey, and need not be limited to a restricted storage space. On the other hand, detailed data for input are not available for many of the most interesting variables and relations. Thus, the investigator is placed in the frustrating position of having to make "educated guesses" for input values. Also, because of the method of operating through random numbers, the results obtained constitute a random sample of possible results from repeated independent simulations. Hence, although this feature is an advantage in studying sampling variations when all parameters are held constant, there are cases in which large samples are required in order to obtain reliable results. This consideration does not arise in deterministic models, which calculate accurate results under the specified assumptions.

To summarize, the mathematical approaches to models may be classified in the following way:

- Analytic
  - Stochastic
  - Deterministic
- Numeric
  - Macrosimulation
    - Stochastic (rare)
    - Deterministic
  - Microsimulation
    - Stochastic (always)

A model in which probabilities or rates are unchanged from cohort to cohort is stationary in time; no probability is a function of calendar or "external" time. In certain models, however, probabilities may vary with age, marital duration or any other type of "internal" time. Such models tend towards a statistical equilibrium under suitable conditions. By contrast, a dynamic model permits secular change in probabilities, and is therefore usually more appropriate for the detailed study of the effects of gradual changes in demographic determinants.

The following, more specific discussion of models will consider, first, those involving a single factor (mortality, nuptiality, age patterns of fertility and marital fertility and birth intervals) and then models that attempt to describe whole populations.

Models of mortality

The life table is undoubtedly the first demographic model. Probabilities or proportions dying are assumed to be characteristics of different age groups and usually of different sexes. Specific life tables can also be devised for cause of death or for various ascribed or achieved characteristics of other subgroups of a population. Mortality rates at different ages have been found to be quite closely related. At least four systems of model life tables exist, which try to narrow the choice of a life table to those deemed feasible on the basis of examination of mortality risks calculated for actual populations. These systems vary in the range of human experience they encompass, so that one may be more appropriate than another for different areas of the world. The following description of the four systems relies heavily upon Brass's 1972 background paper.

In the mid-1950s, the first model life tables were developed by the Population Division of the Department of Social Affairs of the United Nations Secretariat under the aegis of Dr. Valaoras (United Nations, 1955). The tables were constructed as a one-parameter system on the basis of equations regressing the mortality rate in each five-year age group on a quadratic function of the rate in the previous age group and an equation relating mortality by age five to the infant mortality rate. To each level of mortality there corresponds a model life table for males, females and both sexes combined. The constants of the regression equations were estimated from some 157 published life tables.

There are three major criticisms of these tables. First, because each five-year value depends only on the next younger one, it can be expressed as a polynomial involving only the infant mortality rate. Therefore any bias will be accentuated by the "chaining" technique. Second, the choice of empirical tables is criticized as being both unrepresentative of major areas of the world and unselective, including as it does some tables of dubious quality. Finally, the one-parameter system has proved too inflexible, failing to describe adequately life tables known to be quite accurate. Brass terms the United Nations tables "victims of their own success".

Coale and Demeny (1966) published their model tables in the mid-1960s. They chose only those empirical life tables that met strict standards of accuracy. They divided the tables into four relatively homogeneous groups on the basis of their patterns of deviations from regression equations. Within each set, model tables were calculated from regressions on a measure of over-all mortality level for males. Female mortality was calculated from male mortality, using an equation linging e10 for each sex.

Because a number of historical series of life tables for certain countries were employed in the construction of the Coale-Demeny tables, these tables are thought to reflect patterns of mortality changing over time better than the earlier tables. Therefore, they may be appropriate for inclusion in population models to study the impact of mortality change.

Just because of the high standards of accuracy demanded of the empirical tables employed, which limited the number from non-European countries, the Coale-Demeny tables may not cover patterns of mortality existing in the developing world. Demeny and Shorter found that none of the four sets contained life tables appropriate to the Turkish experience, which was characterized by high childhood mortality and low adult mortality. Other examples also exist of well documented patterns that lie outside the range of these tables.

Ledermann and Breas (1959) carried out a factor analysis of some 157 empirical tables. These were not so rigidly selected for accuracy as were those chosen by Coale and Demeny, but they represented more developing areas. Analysis of the tables disclosed five factors that explained a large part of the variability among life tables. The first and largest factor measured the general level of mortality; the second seemed to measure the relation between childhood mortality and adult mortality; the third apparently related to mortality at older ages; the fourth related to mortality under age five; and the fifth factor supposedly reflected the male-female difference in mortality in the age range of 5 to 70 years.

Ledermann and Le Bras (Ledermann, 1969) then developed a model system consisting of six single-parameter sets, each based on the index used for specifying a table, and three two-parameter sets. The single-parameter sets are keyed to e^o_o, $_1q_0$, $_5q_0$, $_{15}q_0$ and $_{20}q_{25}$ for males and females combined and $_{20}q_{30}$ for females. The double entry tables combine $_{15}q_0$ with $_{20}q_{30}$ for females and $_{15}q_0$ with the annual mortality rate for ages 50 and over for both sexes together, and combine $_5q_0$ for both sexes with $_{20}q_{45}$, again for both sexes. Because of the complexity of these tables, the "density" of published tables per unit of range is low. The primary drawback of these tables is that the primary objective of estimating mortality from these specific indices has reduced the flexibility for other purposes. Another criticism is the reliance on logs for all regression calculations, since Coale and Demeny found they had to shift to an absolute scale to preserve linearity in parts of the mortality range.

The final system to be presented here is the logit, developed by Brass (1971) and based on the finding that the survivorship proportions from birth to age x in two tables (where $1_o = 1^*_o = 1$) are linearly related as

$$\text{logit}\ (1 - 1_x) = a + b\ \text{logit}\ (1 - 1^*_x)$$

where

$$\text{logit}\ p = 1/2(1n\ (p/1 - p)\ ).$$

This system is quite flexible since a, b and 1^* can all be varied. More restricted subsystems can be calculated by fixing some parameters. A set with $\beta = 1$ has been published by Carrier and Hobcraft (1971).

A worth-while study would be a comparison of these systems to find distinguishing characteristics, which might guide the choice of the system to be employed in a particular application.

Model cause-specific mortality tables have yet to be constructed. However, Preston, Keyfitz and Schoen (1972) published their collection of empirical cause-specific tables along with the mortality reductions to be expected if each specific cause were to be eliminated. Their analysis and collected tables, combined with historical studies of the causes associated with mortality decline, may lead to better models of the dynamics of changes in death rates over time. Construction of such dynamic models could provide a firmer basis for projections of populations, in which future mortality decline is ideally expected.

Models of nuptiality

Much of the work on nuptiality models has been directed towards finding a function to describe age-specific marriage patterns for both sexes simultaneously. A solution is critical if the two-sex population model is ever to be handled well mathematically. McFarland (1975, 1972), Keyfitz (1973) and Parlett (1972) all review the attempts (so far generally unsatisfactory) to model nuptiality when both sexes are explicitly included.

The work on marriage functions for a single sex is more successful in describing observed patterns. Coale treated nuptiality as a function of three parameters, which determine the location of the distribution, its horizontal scale (a constant reflecting the speed with which marriages were contracted) and the proportion ever marrying. He and McNeil (Coale, 1971; Coale and McNeil, 1972) found that a double exponential model with these parameters reproduced a wide range of recorded first-marriage frequency distributions. This standard function has been used to estimate population by age and marital status when no cross tabulation was available but separate census counts by age and by marital status existed (Coale, 1975).

Models of age-specific fertility

Age patterns of fertility vary among different populations. The variation arises in part from differences in the biological and social factors controlling childbearing within marriage, but also to a great extent from differences in the age pattern of marriage or the establishment of a stable sexual union. However, in different societies that practise little birth control the shape of the fertility distribution may be quite similar, except for differences in the age at which fertility starts. Brass (1968) postulated a two-parameter polynomial function to describe age-specific fertility rates. The parameters reflected the level or quantity of fertility and the earliest age of childbearing. Brass and Coale (1968) then suggested a method of estimating fertility from two types of data that can be collected in censuses and surveys. The data, tabulated by age of mother, are the number of births in the previous year (or other time period) and the number of children ever born.

Two quite different types of reporting errors affect these data. Fertility in the last year may be misreported because of imprecision in the reference period of the woman: births in the last eight months or the last 18 months may be reported. However, there is no reason to suspect differential bias by age of mother. Therefore, the age pattern of fertility can be inferred, although not the amount, and the mean age of childbearing can be calculated from this source. There is a tendency among older women to forget to report children who have grown and left home, so that with increasing age of the woman the number of children ever born is increasingly underestimated. Since young women usually have had only a few births, their reporting accuracy should be good. Therefore, the Brass procedure estimates the level of fertility from responses by young women to the question on number of children ever born.

From the model fertility schedule, Brass calculated the mean age of childbearing *m(a)* and the ratio of fertility in the past year for women aged 15-19 to that for women aged 20-24. These quantities can also be calculated from data of the first type already described. By matching the ratio and/or the mean age of childbearing to values from the model, the earliest age of childbearing can be selected.[2] Then, choosing the constant so that the number of children a woman might expect to bear in a lifetime was five, Brass calculated, for each starting age s, the number of children women in age groups 15-19, 20-24 etc. might be expected to have under his model fertility schedule. Comparing values with those reported by young women in the sample provides a multiplicative factor for adjusting the level of fertility. Thus, a fertility schedule can be generated from data collected in a single survey. The Brass model permitted an estimate of fertility to be made for much of Africa from such sparse and inaccurate information (Brass and others, 1968).

The Brass model is appropriate only to a limited range of fertility patterns. Empirical regularities have been sought in age-specific fertility for other cases; Romaniuk, alone (1973) and with Mitra (1973), found that a three-parameter curve, the Pearson Type I curve, satisfactorily describes the trajectory of age-specific fertility in Canada. The parameters can be estimated from total fertility (the sum of all age-specific fertilities) and the mean and modal ages of the observed curve. Romaniuk and Mitra employed their model to predict future fertility under various sets of assumptions concerning changes in these last three quantities.

Age-specific marital fertility

Coale returned to the more intuitive and demographic idea that fertility is determined by entry into marriage (defined as a stable sexual union) and fertility within marriage. In addition to the nuptiality model described earlier, Coale (1971) also proposed a common pattern of fertility within marriage. He took note of the natural fertility pattern described by Henry (1961), in which there is no voluntary control, and of the characteristic departure from natural fertility that occurs when couples practise voluntary control of marital fertility. Natural fertility itself may vary because of differences in health, lactation practices and the like. Since control of fertility is usually practised to an increasing extent as a woman grows older, the deviation of controlled marital fertility from natural fertility increases with age. Coale therefore proposed a model with two parameters, M and m:

$$4(a) = Mn(a)\ exp.\ (m\ .\ v(a))$$

where $r(a)$ = marital fertility at age a

M = factor determining the level of natural fertility

$n(a)$ = natural fertility by age (taken from the Hutterite marital fertility schedule)

[2] Brass (1968) suggests a slightly more complicated selection procedure. This briefer method, however, suffices as an example of model application.

$v(a)$ = an empirical function representing the characteristic deviation from natural fertility found in a wide range of data on controlled fertility populations

m = degree of control.

These models can be combined so that age-specific fertility is given by

$$f(a) = g(a) \cdot r(a)$$

where

$g(a)$ is the cumulative proportion married calculated from the double exponential model.

One major application of the multiplicative model is Lesthaeghe's description (1971) of the effect of nuptiality on fertility. He first found a pair of nuptiality and marital fertility curves that described situations (characteristic of many developing countries) in which early and near-universal marriage and little voluntary control are producing high fertility, and a pair of curves that described the late marriage and widespread control customary in Western Europe. Postulating a series of nuptiality curves representing gradual changes from early to late marriage and a series with gradual increases in the degree of fertility control, he concluded that either slowing the pace of marriage or introducing changes in marital fertility can change birth rates and population growth rates but that neither measure, alone, can possibly reduce current levels in many developing countries to their targeted values; such reduction is possible only if marriage is postponed to ages older than those found in any known population (current or historical) or if control is practised to a greater degree than any continuing population has been known to achieve. This valuable lesson—that family planning alone, without concurrent social change in marriage patterns, can only fail—has yet to be perceived in many places. The work with this model conclusively demonstrates the important role of determining fertility at age of entry into a sexual union, which itself affects the effective length, rather than the biological length, of the reproductive span in a woman.

Coale and Trussell (1974) constructed model schedules of patterns of age-specific fertility. When age patterns only are needed, one parameter in each of the two model curves $r(a)$ and $g(a)$ is unnecessary: neither the proportion ultimately marrying nor the level of natural fertility, M, affects the shape of this curve. Therefore, only the three parameters reflecting earliest age at marriage, speed with which marriages are contracted and degree of marital fertility control need be incorporated into these model tables. Their tables fit the whole range of observed fertility schedules and extend the range to situations for which rates have rarely been observed accurately—for example, early marriage and natural fertility. One of their model tables for the age distribution of fertility is incorporated into the most recent population projections for the United States of America (United States of America, Bureau of the Census, 1975). Extending Brass's method from the restrictive single fertility pattern, these projections are able to fit a model schedule from data on parity by age for women in the first three age groups (15-19, 20-24, 25-29). A new method of fitting a fertility curve was devised, based on reports of parity by marital duration, since it is felt that age is less reliably reported than is the length of time since marriage (Coale, Hill and Trussell, 1975). A second advantage of this method is that it works even when age at marriage has recently changed, whereas the age procedure does not.

Other marital fertility curves, either by age or marital duration, or both, have been located by several researchers (Farid, 1973; Murphy and Nagpur, 1972) and fit certain sets of observed data well. However, as Lee and Lin (1975) point out, these models "seem to give satisfactory fits to the time distribution of births and thus are useful in filling gaps in fertility data. However, with no references to reproductive behaviour leading to occurrences of childbirth, models of this type remain largely descriptive". Because such models shed little light on causation, others are needed to understand why large differences in marital fertility exist even among non-contracepting populations, and how changes may occur.

Lee and Lin (1975) proposed an analytic model of marital fertility, based on a simplified biological model of fertility that allows fecundability to decline with parity. They were able to estimate the level of fecundability, a parameter reflecting the rate of decrease with parity, and the duration of the nonsusceptible period. The model fits several sets of data on birth rates by marital duration quite well, and offers, rather than just a curve to fit the observations, a demographic explanation for them.

Birth-interval models

The known differences between fertility rates in different populations cannot be explained completely either by differential sterility or by differences in age at marriage. Therefore, if different numbers of children are born in approximately the same reproductive period, then spacing patterns must have varied. Models that focus on the timing of births within marriage and on the intervals between births have been developed to examine these differences. These models refer only to continuing non-sterile sexual unions. Only a small number of biological factors are included, which relate to one or more of the segments making up the interval between live births (Potter, 1963): the post-partum period following a birth until both ovulation and cohabitation resume; the susceptible period until conception occurs; and the period of gestation (which ends the birth interval, unless a spontaneous or induced abortion occurs). In this latter case, the woman usually becomes susceptible again after a short post-partum period, and susceptibility and nonsusceptibility alternate until live birth occurs, ending the interval. The length of the susceptible period is thought to be determined by fecundability, defined as the probability that a non-contracepting, susceptible woman will conceive in a given month (Gini, 1924). Fecundability may be reduced by contraception and depends upon the frequency of intercourse as well as on the viability of ovum and sperm. It should therefore be thought of as an attribute of a couple, even though usually ascribed to the woman. The frequency of pregnancies that fail to yield live issue governs the number of infertile pregnancies before the next live birth; induced abortion affects fertility by increasing this probability.

Louis Henry and Mindel Sheps evolved analytic models relating all of these factors to birth intervals and numbers of births according to marital duration. Henry's series of articles analysing deterministic models formulated as integral equations recently appeared in English translation (Henry, 1972). In addition to examining the effect of various factors on birth rates, he suggests procedures for estimating these underlying variables from genealogical data. Perrin and Sheps (1964) presented a stochastic model of reproduction as a Markow renewal process. Their model permits spontaneous and induced abortion to be considered separately. It also allows some of the fertility determinants, such as fecundability, to vary among women.

Although these models are highly simplified and unrealistic in many respects, they provided insight into the relations between the specified factors and birth rates. The marital fertility rate, after the first few years of marriage, is given by the inverse of the mean birth interval when parameters do not change with age. Therefore, a long post-partum period, caused either physiologically (because ovulation does not resume) or socially (because of taboos against a lactating woman engaging in coitus), can lead to a much lower birth rate that when brief nonsusceptible periods typify a population. After work with models had highlighted the extent of the effect of the post-partum period on fertility, several studies were initiated to actually measure this variable and its dependence on duration of lactation (Perez and others, 1971; Chen and others, 1974). This topic will be discussed further shortly.

These simplified models also helped clarify ideas about the possible effects of a family planning programme. For example, abortion, used alone, was shown to be a poor method of fertility control. Abortions are usually performed quite early in pregnancy and the woman is susceptible to another conception shortly after the pregnancy ends. If no contraception is being used, the woman will usually conceive within a few months if her fecundability is fairly high. The birth interval will be increased only slightly unless abortion is resorted to repeatedly. Thus, one abortion reduces the number of children a woman is expected to bear during her reproductive life by much less than one. Abortion alone is seen to be a particularly inefficient fertility control if one considers the medical costs to the physical welfare of the woman and the economic costs of repeated abortions. Abortion has a much greater effect on birth rates as a back-up measure (when contraception fails) because the susceptible interval is increased when fecundability is reduced by contraception.

It was also demonstrated that reductions in birth rates caused by contraception are less than the effectiveness of the contraceptive. That is, if a contraceptive reduces fecundability by 90 per cent, it might reduce the birth rate of users by only 70 per cent, depending upon length of post-partum period and frequency of abortion. Sheps and Perrin (1963) also noted that a highly effective contraceptive used by a fairly small proportion of a population reduces birth rates more than use of a less effective contraceptive by a much higher proportion of people.

These illustrations indicate the role that even simple models can play in understanding the effects of levels of the variables included in the models on fertility and the implications for changes of various types and in establishing the need for measurement of certain variables. More extensive descriptions may be found in several of the references appended to the present study (Henry, 1972; Sheps, Menken and Radick, 1969; Sheps and Menken, 1973). These complete models require simplifying assumptions that are too far removed from reality to permit the models to serve as adequate bases for estimation procedures. In most cases either all women are treated as having the same reproductive parameters and certain durations (e.g., the post-partum period) are treated as constants, or else no allowance is made for changes with age. Many procedures assign values to almost all the parameters and then derive conditional estimates of the remaining determinants, estimates that may be quite biased and therefore misleading (Menken, 1975, chap. 3).

Further work on reproductive models has taken at least three different directions. More extensive models have been developed, focusing on one determinant or on one portion of the birth interval; model builders have turned to simulation methods to explore the effects of less restrictive assumptions about the determinants of reproduction in more complex populations; and simple versions of the biological models have been incorporated into analytic models that consider other determinants of population.

Models of fecundability—and thus of the susceptible period—have a 50-year history (see, for example, Gini, 1924; Pearl, 1933; Stix and Notestein, 1940; Henry, 1953). Work with such models has demonstrated that fecundability varies among women in most populations and has considered the method of estimation and types of data that best reflected these differences (Tietze, 1959; Potter, 1960; Potter and Parker, 1964; Sheps, 1964; Majumdar and Sheps, 1971; Suchindren, 1972; Sheps and Menken, 1973; Menken, 1975; Bongaarts, in preparation). Tietze (1959) and Potter (1960) showed that when fecundability varies among women, the more fecundable usually conceive sooner; thus as time goes on women who are still susceptible are selected more and more from the lower end of the distribution of fecundability. Measures based on the assumption that all women are equally likely to conceive were found to be sensitive both to the extent of variability and the length of observation, necessitating the development of new procedures. One recent set of conclusions is that survey data are usually inadequate for measuring fecundability because it is virtually impossible to elicit reliable estimates of how long it took until conception occurred. In addition, in populations in which contraceptive practice is the norm, women who are not users are so highly selected for subfecundity or concealed fertility control that an estimate of their conception rates cannot reflect the population level well (Menken, 1975).

A model of the post-partum period was developed by Ginsberg (1972) working with data collected in Chile (Perez and others, 1971). The data clearly document the effect of full lactation (i.e., feeding the infant with breast milk only) on postponing resumption of ovulation; this finding was confirmed in Bangladesh by Chen and others (1974), while the model elucidates the pattern of resumption.

Models related to both the post-partum period and the susceptible period helped Potter and others (Potter and Masnick, 1971; Potter, Masnick and Gendell, 1973) to study the effects of contraceptive use accepted as a consequence of a post-partum programme (directed towards women who had recently delivered a child). The researchers wanted to take into consideration the frequency of discontinuation of use of the method; they found that the reduction in births decreased, for any given length of use, the more the use period overlapped with the anovulatory period (the period when the woman already had natural protection against another conception). These results seem intuitively obvious—after the fact; yet the full importance of contraceptive overlap with temporary (biological) sterility was not recognized until models were used to investigate the implications of this situation fully.

Other models seek to clarify questions about abortion, including its relation to fecundability measurement (Abramson, 1973), the effect of increased induced abortion on spontaneous abortion rates (Potter, Ford and Moots, 1975) and the extent of variation among women in the probability of abortion (Leridon, 1976). In each case, a model helped to increase our understanding of the type and magnitude of influence of certain fertility determinants.

Models of population growth and change

Stable population theory (Lotka, 1939), which was basic to the development of later models in demography, proved that a population subject to fixed age patterns of fertility and mortality would ultimately have a constant age distribution and invariant rates of birth, death and population growth. Later, it was shown that estimates of fertility and mortality based on age composition and growth were approximately valid even if mortality has been declining (United Nations, 1967). Tabulations of the stable populations resulting from the Coale-Demeny model life tables, fixed age patterns of fertility and various growth-rates are now among the basic tools for demographic estimation (Coale and Demeny, 1966).

A group of French historical demographers (Demonet, Dupaquier and Le Bras, 1974) recently set out to calculate the characteristics of stable populations with fixed schedules of nuptiality as well as of mortality and age-specific marital fertility. Their purpose is to provide a set of indices that can be matched with those calculated from historical records. Such a comparison might thus determine a group of one or more stable populations and the fertility, mortality and nuptiality patterns that could have led to the indices observed in such populations. The kinds of data recorded include the usual measures (rates of birth, death, marriage and net reproduction, and age composition) plus others useful to the historical demographer (distributions of deaths by age, proportion widowed, average age at marriage, ratio of births to marriages, percentage of mothers alive at the marriage of their children and distributions of families by the age of the mother and the number of living children who are under 14 years of age).

The tables resulting from these calculations will assume that nuptiality follows the Coale-McNeil model, mortality the Ledermann model life tables and marital fertility a set of tables to be published by Le Bras. Calculations will be based upon ranges of parameters for each of the constituent demographic models that are judged feasible, singularly or in combination. When these tables become available, they will serve as an extremely useful tool for analysing historical studies.

An extensive range of computer simulation models of human populations has appeared over the past decade.[3] Many more variables can be incorporated into these models, including patterns of marriage, divorce, remarriage, mortality and natural sterility. Variables specifically related to fertility and family planning that can be incorporated into these models include patterns of acceptance of birth control methods (which may depend upon desired family size and achieved parity), length of use and patterns of switching among various methods. Another important feature of these models is that they allow for changes with age. Only a few examples can be mentioned, briefly, in this overview study, but they will indicate the range possible.

Computer simulation models are not yet at the stage where it is possible to achieve a consistently good fit to observed data or where a good fit indicates that the underlying parameters used in the computer calculations are close to those of the observed population. In fact, it has been shown that quite similar results may

[3] For reviews of existing models see Holmberg (1970) and Menken (1975a; 1975b); for a collection of representative papers in this field see Dyke and MacCluer (1973).

be achieved with quite different sets of parameters (Sheps and others, 1970). In part, this problem is caused by the lack of enough good data for us to know the range of likely values for the variables included as independent determinants of fertility. Therefore, at this time the most useful role of simulation models is in providing a way to assess both the short-term and long-term implications of any given set of assumptions concerning the levels, interrelations and changes in fertility determinants.

This capacity is particularly valuable when implementation of a family-planning or other population policy programme is being considered. How should the programme be structured to produce maximum effect? Of the fertility control alternatives that are feasible, which would reduce birth rates the most? If a programme is put into effect, can it, under the best of circumstances, achieve the targeted reduction in births? Each of these questions can be explored by simulation, giving some idea of what can be expected from a particular programme if real life resembles the model (Sarma, 1970; Potter, 1971; Rao and others, 1973). Simulation of various programmes can aid planners in evaluating alternatives in relation to targets, in selecting reasonable target levels as their goals and in deciding which programme to attempt to carry out (Nortman and Bongaarts, 1975; Potter, 1974; Mode, 1975). The use of simulation models has also been proposed as a way of estimating the long-range effects of continuing a programme over several generations (Potter, 1972).

Models can also help to determine the properties of estimation procedures. After a hypothetical population is constructed from given parameters, a proposed method of analysis can be applied to the simulated data. If it closely reflects the values actually used, the method can be applied to real data with greater confidence (Barrett, 1971; Clague and Ridley, 1973). Sampling variation can be examined, as can the ability of the estimation procedure to resist the effect of various types of reporting errors (Lachenbruch, Sheps and Sorant, 1973).

Another application of computer models has been to consider the effects of contraceptive use on individual families. For example, Potter, Sakoda and Feinberg (1968) asked whether contraceptive use for spacing purposes might prevent some couples from reaching their desired family size within a reasonable number of years of marriage. In one part of their study, they postulated that couples desired three children spaced two, five and eight years after marriage, and that they would use a 90 per cent effective contraceptive for spacing and a 99 per cent effective one after the third birth. They found that over 96 per cent of couples could be expected to have at least three children within 10 years, even when fecundability varied; thus extensive contraceptive use would not interfere with couples achieving the desired moderate family size.

These results are suggestive when we consider the current situation of very long birth rates in the United States of America. If these rates result from postponement of births by women now in their twenties, then the United States birth rate could rise as rapidly as it has fallen in recent years when these women do begin child-bearing. Even if they wait until age 30 to have their first baby, most will be able to have at least three children during their remaining reproductive years, thus raising birth rates once more. Few demographers predicted the massive decline in birth rates that we have just undergone, and none expected it to occur so rapidly. There is no biological evidence to suggest that births being postponed now cannot be made up at older ages. So predictions of continuing low birth rates are not based on demographically inevitable thinking.

The work just described illustrates the usefulness of certain demographic models in studying variation within a population.

Since the number of population models is large and the literature scattered, examples of existing models will be reviewed briefly. Unfortunately, descriptions of the various models are usually not detailed enough to determine precisely the extent of similarities or differences between the more complex models. However, these simulation models do vary in their treatment of fertility. The demographic approach treats the occurrence of a birth as a probability, which may be specific for selected variables, including age, marital status, parity and interval since the previous birth. The biological approach explicitly includes the determinants of the birth interval: fecundability, the probability for each type of pregnancy outcome, the duration of the period following conception when a woman is not susceptible to another conception and, in some cases, parameters related to family planning. The former approach is useful primarily for tracing the consequences of fertility change for population change, the latter for assessing the results of changes in reproductive parameters (including the effects of family planning practice) on fertility.

Macrosimulation models that formulate fertility demographically are actually population projection models, and will not be discussed here.

Microsimulation models with a demographic approach to fertility

POPSIM (United States of America, National Center for Health Statistics, 1973) is a flexibly designed large-scale microsimulation model. It was designed to simulate the principal demographic processes, excluding migration. Its population can be defined either as a one-sex or two-sex cohort or as a two-sex cross-sectional population. Rather detailed input data are required. Birth probabilities may vary with age, marital status and parity. Marriage is a function of age and current status. Several methods of family planning can be simulated at once. Probabilities are necessary for acceptance of each method and, when one method is dropped, for switching to each of the others or to no method. Duration of use is determined by dropout rates, which are functions of age, parity and the method employed. Use-effectiveness and the proportion of women using a method determine the reduction in the birth rate. This model is intended as a multipurpose tool for demographic analysis.

Orcutt and his colleagues (1970) are attempting to develop a model of income distribution by simulating the effect of the behaviour of family members on the family's income status over time. For this purpose, they are developing a microsimulation model with demographic components. A long-term goal is to provide links between individual probabilities and the state of the current economy—to have desired number of children dependent upon over-all economic conditions, for example. Their model is still in its early stages of development.

Macrosimulation models with a biological approach to fertility

FERMOD and FERMOD-A have been developed by Potter and his associates (Potter and Sakoda, 1966) as large-scale deterministic macrosimulation models representing a homogeneous marriage cohort of women with a reproductive period of specified duration and constant probabilities of miscarriage and stillbirth, as well as constant durations of gestation for each pregnancy outcome. Post-partum anovulation is given a constant duration following a miscarriage or a stillbirth but a probability distribution following a live birth. Fecundability can be varied according to parity, thus permitting increasing contraceptive efficiency as desired family size is approached and attained.

Potter (1971) also developed ACCOFERT, a model that projects forward in time a cohort of women of the same age who have just delivered and who have accepted a method of family planning. Fecundability and sterility are assumed to be functions of age, as is the probability of a fetal loss or a stillbirth. Duration of pregnancy and of the anovulatory period following an abortion are both constant. The post-partum nonsusceptible periods following a stillbirth or a live birth have a probability distribution. Contraception effectiveness is constant and there is a discontinuation life table. Work with ACCOFERT has quantified the inadequacy of a family-planning programme limited to a single contraceptive method and with a significant dropout rate. This model has also been used to study births averted by various methods.

A model was developed at the University of Cairo (Tolba, 1966) to supply numerical results for a version of the Perrin-Sheps (1964) analytical model. All parameters (fecundability, probability of fetal loss and durations of pregnancy and post-partum nonsusceptibility) are constant. Extensive tables have been published studying the effects of changes in the levels of these parameters—for example, of decreasing fecundability, increasing fetal wastage and increasing the post-partum nonsusceptible period following a live birth.

Venkatacharya (1969, 1972) has used the simulation of the mean and variance of intervals between successive births and since the most recent birth in order to study the effects of specified contraceptive programmes and to evaluate the adequacy of the open birth interval as a measure of recent changes in fertility.

The capacity of the computer limits the number of variables possible in most macrosimulation models. Thus, none of those described above include provisions for marriage or mortality, and little variation is feasible over time or between individuals in the population.

An exception is the female cohort model constructed by Bongaarts as a set of differential equations (Tietze and Bongaarts, 1975). The Coale marriage model is assumed. Age patterns of fecundability, sterility, probabilities of abortion and mean post-partum period can be specified. Applications include a study of the effects of several patterns of contraception and abortion and an attempt to reproduce age-specific fertility in historical high-fertility populations.

Microsimulation models with a biological approach to fertility

REPSIM-A and its revised version, REPSIM-B (Ridley and Sheps, 1966), permit considerable variation in biological and demographic factors, including certain family planning assumptions. It deals with an age cohort of women, allows fecundity parameters to vary with age and between women, and also includes variation in age at entry into sexual union (marriage), at dissolution of marriage, at sterility or at death. Provision is made for mortality of women, their husbands and their infants and for remarriage. Three types of fertility control are included: induced abortion, sterilization and family planning (defined as contraception, rhythm or coitus interruptus). Acceptance may depend upon parity or upon the gap between current parity and desired family size.

Barrett (1971, 1972) and Barrett and Brass (1974) describe a model of a marriage cohort in which fecundability varies among women according to a beta distribution. Sterility is a function of age. Probabilities of fetal wastage are age-dependent. The duration of pregnancy is fixed but the post-partum nonsusceptible period has a variable duration specific for each pregnancy outcome. Barrett has studied the types of data that would be needed to produce results comparable to empirical data, the timing of averted births and the pattern of approach to a new birth-rate level following a change in reproductive behaviour. Barrett and Brass have examined the problem of determining the amount of variability in numbers of live births that is due to chance as opposed to systematic components, in an attempt to separate a component that might be explainable by external social and economic factors.

Jacquard (1967) implemented a model simulating a cohort of women from age 15 to age 45. Probabilities of death, of marriage and (following marriage) of widowhood and divorce are age-dependent. Fecundability increases from age 15 to some age a_1, remains at a plateau for a period and then declines with age. The probability of a live birth is constant. Post-partum nonsusceptibility is a random variable depending upon fetal loss. Provisions for contraceptive effectiveness and use for spacing or limiting pregnancies are included. Length of use depends upon parity. Applications have included the study of levels of contraceptive effectiveness and an attempt by Bodmer and Jacquard (1968) to "fit" data obtained from a group of highly fertile women.

Holmberg (1970, 1972) has reported a model in which a birth cohort of women is followed from age 15 to menopause. Each woman is exposed to age-specific probabilities of death, sterility and marriage until marriage occurs. Fecundability varies with age and its peak varies between women according to a beta distribution. Contraception of fixed effectiveness may be accepted either after the desired number of children are born or for spacing purposes. The available literature on estimates of the distributions of components of the reproductive process has been reviewed to find realistic input data. The model has been used in attempts to reproduce empirical data and in studies both of the importance of changes in levels of different variables and of the effects of introducing additional complexity into a model.

POPREP (Lachenbruch, Sheps and Sorant, 1973) is a modification of POPSIM that incorporates many of the features of REPSIM, so that biological parameters are included. POPREP has been applied in the study of bias in suggested fertility measures, in the testing of new measurement procedures (Poole, 1973) and in experiments simulating the effect of recall error on birth intervals.

Venkatacharya (1970) examined the effects of the proportion of susceptible women on indices used in evaluating population control programmes. His model follows a cohort of women, starting from a given age between 15 and 34 until they reach age 45. Fecundability varies with age, probabilities of fetal wastage are constant and post-partum nonsusceptibility varies according to a probability distribution.

The models considered here vary in the required form of input data. For example, Jacquard (1967) and Barrett (1971) both allow the post-partum nonsusceptible period to follow a random distribution. In the former case, the input data must specify the probability that the anovulatory period will last one month, two months and so on. Barrett, in contrast, assumes that this period is equal to one month plus the sum of two random variables, each with a geometric distribution with parameter r. Therefore a three-month nonsusceptibility period is assigned a probability of r^2, a four-month period has a probability of $2r^2(1-r)$ and so on. The only input, then, is the value of the parameter r. Assuming that the distribution of a variable has some functional form, as Barrett does, usually saves both computer storage space and calculation time. The user of such a model must weigh whether or not the particular form specified is consistent with his own conclusions about the shape of the distribution.

In the past few years, special-purpose models have been described in papers whose primary focus is not the model but the particular application. In most of these papers the detailed structure of the model is not presented, but they are mentioned here for completeness. TABRAP (Nortmann and Bongaarts, 1975) has the laudable purpose of estimating the level of family planning acceptance necessary to produce a specified birth-rate reduction. Mode and Littman (Mode, 1975) also have attempted to evaluate family planning programmes and their effects through stochastic models constructed with the use of differential equation techniques.

With this extensive and varied list of existing models —a list known to be incomplete, because information on certain models is still to be published, the needs of a proposed project may well be met with no necessity to write a totally new programme.

Models of family characteristics determined by fertility and mortality patterns

Goodman, Keyfitz and Pullam (1974) considered the number of relatives an individual woman, selected at random from a population, might be expected to have. General expressions were found, using integral equations and recurrence relationships, for the expected number of descendants (daughters, granddaughters and so on) for a woman aged a; expected number of progenitors (mother, grandmother etc. and combinations thereof) expected to be alive when the women is aged a; expected numbers of siblings, nieces, aunts, cousins and other kin; and, finally, mean size of household. Examples of calculations with actual fertility and mortality schemes were given to provide some indication of the variation in kinship structure produced by these strictly demographic constraints.

Ryder (1973) considered three "classic demographic situations": high equilibrium (high fertility and mortality), disequilibrium (high fertility and low mortality) and low equilibrium (low fertility and mortality). Allowing all women to marry at age 20 and assuming a triangular parity distribution, he was able to calculate a number of reproductive indices, including the expected numbers, in a cohort, who are ever widows or widowers, the expected years of life spent in each family role for individuals (e.g., mother, unmarried daughter, wife) and for two family members (e.g., joint persons years spent as unmarried brother and sister) and several other measures of length of family life and family size. The differences resulting from the three demographic situations postulated are both striking and illuminating. In most cases the increase in the number of years in a given role is very large when there is a change from high equilibrium to disequilibrium, with only a small later increment when fertility declines. The exception is the total number of sibling combinations (i.e., siblings alive at the same time as the index child). The number of combinations rises dramatically when the move from high equilibrium to disequilibrium takes place and becomes minuscule when fertility drops. Ryder contends that these calculations provide a "cogent explanation for the persistence of high fertility, despite a substantial decline in mortality". The only disadvantage to the disequilibrium family, he finds, is the relatively high consumer/producer ratio.

Further work in the area of family structure and its variability is clearly desirable.

Possible applications by the United Nations Secretariat

New techniques may be accepted by the United Nations to estimate demographic indices from incomplete or inaccurate data from all countries. Implementation of the estimates of fertility by the Coale-Trussell methods, of mortality by the Brass techniques based on stable population and other techniques appropriate for survey data could make acceptable population estimates available for an increased number of countries.

For projection purposes, fertility might be factored into its nuptiality and marital fertility components, and, on the basis of estimates from data, the future trajectories of population size and composition might be traced from changes in the parameters of nuptiality and marital fertility models.

A project to assign to each country the type of model life table most suited to its individual characteristics would take some of the guesswork out of predicting mortality changes by restricting them to within the "family" of model selected.

Extension of the family models to include variation in addition to expected values could be useful, particularly when the effect of policy decisions is of concern.

Finally, the increased use of population models may help policy planners to accept the limitations of particular population policies and to work with some real notion of the magnitude of the changes that proposed policies might be expected to induce. Exercises of this type would prevent automatic failure due to inflated expectations and aid in the decision-making process by clearly spelling out the implications of proposed measures.

In each of these areas, at minimum, the work of the United Nations Secretariat may profit from increased application of already existing demographic models.

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MODEL SCHEDULES OF NUPTIALITY AND FERTILITY IN POPULATION PROJECTIONS

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In this brief report I shall discuss two principal topics: first the possibility of projecting the marital status of a population by age using a soundly based model of the evolution of the forces determining nuptiality; and, second, the projection of fertility by estimating the fertility of married persons and of non-married persons, having previously projected the distribution of the population by age and marital status.

Projection of the marital status of a population by age, using a model of the evolution of the forces determining nuptiality

The development of a standard curve for the frequency of first marriages in a cohort is described in a series of articles published in the last four years.[1] The most convenient version of this curve is a closed-form analytical expression developed by Donald R. McNeil:

$$(1)\ g(a) = (0.19465/k)\,exp\,\{(-0.174/k)\ (a\text{-}a_0\text{-}6.06k) - exp\,[(-0.2881/k)(a\text{-}a_0\text{-}6.06k)]\}$$

This curve has been found to fit very closely the distribution of first marriage frequencies by age in a variety of cohorts. To obtain a fit, one selects values for two parameters in equation (1): a_0, the earliest age at which first marriages occur in appreciable numbers; and k, a scale factor expressing the number of years of nuptiality in a given population equivalent to one year in the standard schedule (i.e., $k = 0.5$ would indicate that the number of marriages that would occur in an age span of a full year in the standard population would occur in half a year in the given population). A third parameter is not contained in the equation; this is a constant by which all first marriage frequencies should be multiplied to arrive at the proper proportion ever-married when first marriages have been effectively concluded. The ogive of first marriage frequencies (the cumulated value of the function from the early stage of marriage to any particular age) is the proportion ever-married in a cohort. No closed-form expression for the integral has been found, but there are a number of standard computer programmes for numerical integration.

There are also empirical regularities, less thoroughly explored, in the proportion of the ever-married population in a cohort that is currently divorced or currently widowed. Observation of a number of populations indicates that the proportion of the ever-married who are currently divorced rises approximately linearly from an early age until about age 50, then rises at a decelerating rate until a maximum is reached at about age 70, with the proportion remaining fixed above age 70. One possibility for estimating the proportion divorced, then, is to estimate the slope of this straight line for each cohort. Such an estimate can be based on the progression of recorded slopes for earlier cohorts, for example. A tolerable fit to the proportion widowed of those ever-married is attained by multiplying a standard curve of this proportion, by age, by a factor that consists of one constant parameter plus another parameter times age. Thus, the marital status of a cohort could be specified (*a*) by the three parameters required to determine the schedule of first marriage frequencies (and therefore of the proportion ever-married by age); (*b*) by a single parameter, to specify the pace at which the proportion divorced among those ever-married increases with age; or (*c*) by two parameters, to specify the curve of widowed as a proportion of the ever-married.

In populations in which nuptiality statistics are complete and accurate, the evolution of these parameters can be ascertained empirically for cohorts who have passed through the principal ages of marriage—for cohorts, let's say, now over age 50. It is also possible to utilize the soundly based standard curve of first marriage frequencies to estimate the parameters of first marriage for cohorts that are still in the middle stages of marriage. In an unpublished doctoral dissertation written at Princeton in 1973, Douglas Ewbank found that because a closely fitting standard curve of first marriage frequencies exists, it is possible to ascertain parameters of the first marriage frequency distribution from rather severely truncated experience. Experiments with Swedish data, in which marriage frequencies were artificially truncated, show that the estimation of parameters from data extending only a few years after the modal age at first marriage provides a close match to the remaining first marriage frequencies. Figure I shows the values for the estimated mean age at first marriage, the proportion ever marrying and the scale factor for first marriage frequencies for the birth cohorts of

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[1] Ansley J. Coale, "Age patterns of marriage", *Population Studies*, vol. XXV, No. 2 (July 1971), p. 193; Ansley J. Coale and D. R. McNeil, "The distribution by age of the frequency of first marriage in a female cohort", *Journal of the American Statistical Association*, vol. 67, No. 340 (December 1972), p. 743; Ansley J. Coale and T. James Trussell, "Model fertility schedules: variations in the age structure of childbearing in human populations", *Population Index*, vol. 40, No. 2 (April 1974), p. 195.

Sweden (females) from 1893 to 1948. These parameters (fitted by minimum chi square) show a long trend of declining mean age at first marriage and an increasing pace at which marriages occur. They also show a more complex pattern in the proportion ever-married—a rise to a maximum of about 95 per cent for the cohorts born in the 1920s and 1930s, and then a precipitous decline for the cohorts whose first marriage experience has been very recent. We are experimenting with projecting the future marital status of Swedish cohorts, making various extrapolations of the trends in parameter values. First-marriage frequencies, estimated by construction utilizing the trend values of the parameters, yield extremely good fits to period data through the early 1970s.

The estimation of the proportion divorced and the proportion widowed could follow either of two procedures. The first is to use the procedure mentioned earlier, estimating the fraction divorced (or widowed) of those ever married on the assumption of a simple form for this proportion as a function of age. This estimate is then combined with observations of how the relevant parameters have been changing and with assumptions about the continuation of trends into the future. In application to the recent Swedish nuptiality experience this procedure poses the problem of a very sharp rise in the last six or seven years in the rate in which the proportion divorced by age increases. The tendency (mentioned earlier) for a linear rise with age in the proportion of those divorced to those ever married has been broken by a steepening of the increase in the most recent experience of each cohort.

An alternative system for estimating the same function (divorced as a fraction of those ever married) is to construct the proportion divorced according to the probability by age of (*a*) divorce for the married and (*b*) remarriage for the divorced. These would be calculated for a recent period, applying the procedure outlined in a recent article by Schoen and Nelson.[2] The parameters of the first-marriage frequency distribution for successive cohorts can be fitted to data on first-marriage frequencies in populations (such as that of Sweden) where the registered data are detailed and accurate. In other instances it may be necessary to fit the cumulated first-marriage frequencies (proportion ever-married by age) to data on marital status in successive censuses (if these are closely enough spaced) or to the proportion ever-married as recorded in successive large-scale surveys (such as the current population survey of the United States of America).

Such procedures will permit the construction of population projections classified by age and marital status. The projections, like any other methodologically sound projections, will be orderly, and consistent with the assumptions of those who make them; they will foretell the future only to the extent that the analyst can successfully estimate the evolution of parameters depicting behaviour that has not yet occurred.

Projection of fertility, using the projected marital status of a population by age

The conformity of marital fertility to a schedule that can be specified by two parameters is described in articles referred to earlier.[3] Marital fertility is assumed to depart from "natural" fertility to an extent expressed by multiplication by the factor $exp\ m\ .\ v(a)$. To specify marital fertility, then, it is necessary first to estimate the level of natural fertility and then the value of the parameter m in the expression just given.[4] With such estimates of marital fertility, and the projections of the population classified by age and marital status described above, the number of legitimate births can readily be estimated.

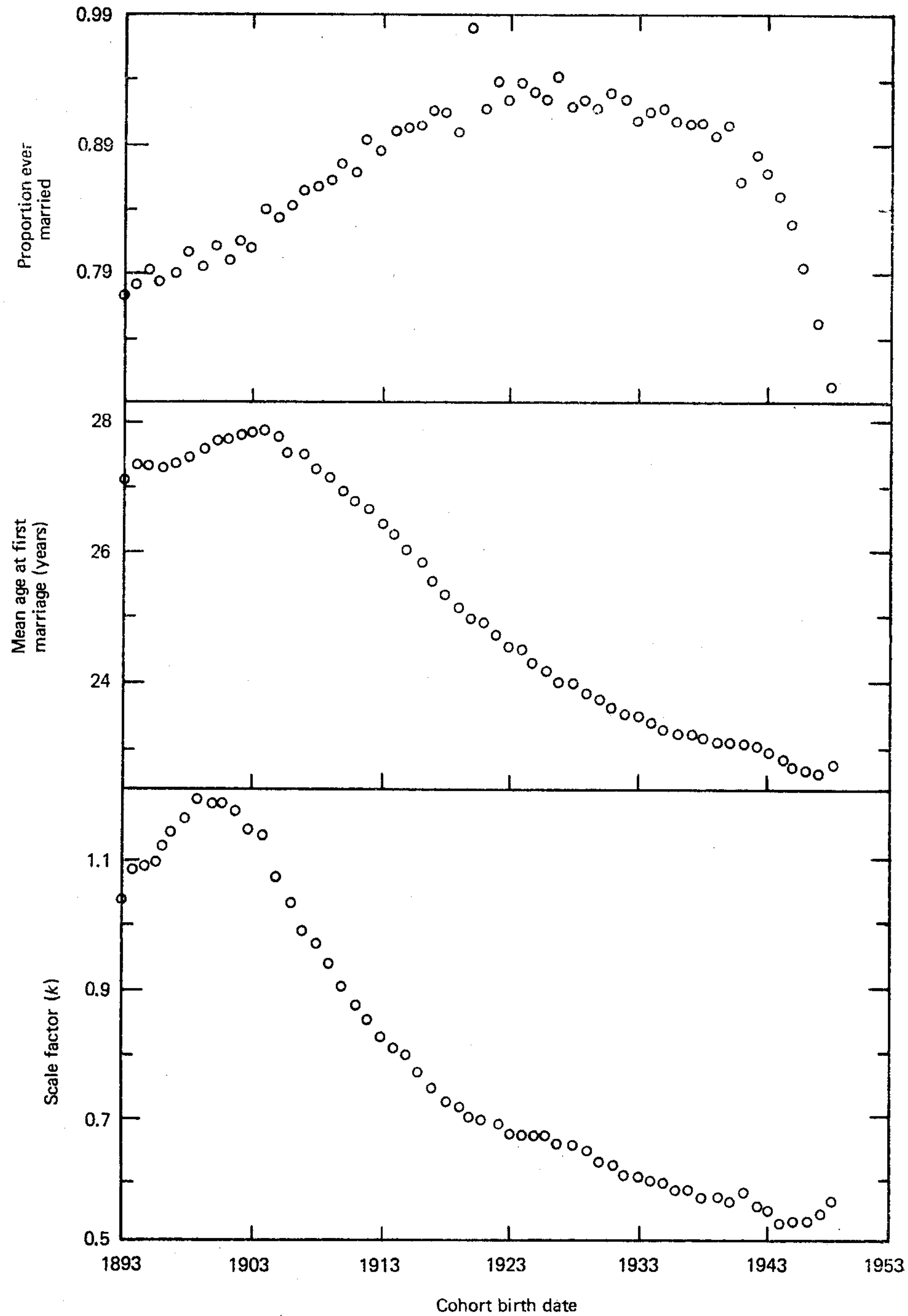
To estimate the number of births occurring outside of marriage, I suggest calculating the ratio of illegitimate to legitimate fertility by age—calculating, that is to say, the age-specific rate of childbearing by women who are not married, and dividing by the rate at the same age by women who are married. The evolution of the ratio by age can be traced through the recent past and extrapolated. The extrapolation will then serve as the basis for a projection of illegitimate fertility.

[2] Robert Schoen and Verne E. Nelson, "Marriage, divorce, and mortality: a life table analysis", *Demography*, vol. 11, No. 2 (May 1974), pp. 267-290.

[3] Coale, *loc. cit.*; Coale and Trussell, *loc. cit.*

[4] Coale and Trussell, *loc. cit.*

Figure I. Parameters of first marriage rate frequency distribution for female birth cohorts, Sweden, 1893-1948



NOTES ON EMPIRICAL MORTALITY MODELS

*W. Brass**

The word "empirical" is used in the title of this paper to distinguish models that have been developed to describe observed mortality measures (which may be subdivided in different ways) from models that are derived from biological or social theories. The models that are of practical importance for the demographer, such as the Coale-Demeny regional life tables, belong in the former category. In contrast, the latter category includes, for example, R. E. Beard's theory of aging based on the breakdown of cells (Beard, 1971)[1] and broad philosophical speculations such as those of Ibn Kaldun. The separation, of course, is not complete. Empirical systems, such as the Gompertz curve for the force of mortality at late ages, have been given a theoretical justification; and social theories, such as that linking expectation of life to family income, can be formulated in quantitative terms and tested by observation. The hope for the future is to be able to construct models on a more secure socio-biological base, as only then can there be reasonable assurance about consistency and continuity over time. At present, however, the descriptive, "empirical" approach is the most useful.

From the early 1950s until recently the central theme has been the construction of systems that give schedules of mortality by sex and age (model life tables) specified by a small number of parameters of level and pattern. The original United Nations model life tables were defined only by one parameter of level (United Nations, 1955). The best known of the later alternatives are more flexible. The Coale-Demeny regional system (Coale and Demeny, 1966) has four sets with varying patterns, but each set is determined by one parameter of level; the Carrier Hobcraft tables (Carrier and Hobcraft, 1971) use the linear logit transformation of a standard life table probability of surviving from birth to age $p_s(X)$ to generate a system with two parameters, one for level and one for the relation between adult and childhood mortality; and the Ledermann models (Ledermann, 1969) provide six one-parameter sets and three two-parameter sets, the latter based on particular combinations of mortality measures.[2]

The theoretical analysis by Ledermann and Breas (1959), supported by the demographic interpretation of Bourgeois-Pichat (1962), showed that a close representation of empirical life tables required five parameters, one of which was sex.[3] None of the parameters can plausibly be explained away as arising from errors in the observations (although observation error may exaggerate the variability associated with one of the parameters affecting death rates at late ages). All the model systems, therefore, fall short of the precision with which, in theory, they could represent observed mortality. In the hands of skilled practitioners, however, this imprecision has been of minor importance.

The uses of these models are, broadly, of three types: estimation of mortality from incomplete and/or indirect measures (age distribution, orphanhood, proportion ever widowed and the like); population projection or predictions; and theoretical examination of the demographic implications of different death rate levels, patterns and changes, for example for age composition. In these applications a model with more than two parameters is rarely needed. Either the uncertainty of data accuracy or parameter validity is too large to justify further refinement, or the relationships explored are not sensitive to all the possible dimensions of variation as, for example, when only mortality over a limited age range is relevant. Ingenious choice and adaptation of the existing model systems (by such devices as splicing together childhood and adult mortality from different tables of a Coale-Demeny set or changing the standard in the logit relation) can be quite effective, even in applications where greater detail and precision is justified. Nevertheless, a more systematic approach would permit gains both in tidiness and in convenience.

It is possible to construct a mortality model with enough parameters to describe observed patterns with great accuracy. For example, the simple logit system can be extended by the operation:

$$p_s(x) = p^*(x) + gA(x) + hB(x)$$

where $p_s(x)$ is the new set of standard probabilities of surviving (which can then be modified by the linear logit transformation); g and h are the third and fourth parameters; $p^*(x)$ is a "standard for standards"; and $A(x)$ and $B(x)$ are fixed functions of age-specific deviations from this "standard for standards".

Suitable values for $A(x)$ and $B(x)$ can be derived by methods analogous to those used in modifying a Gaussian distribution by a Gram-Charlier expansion or

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[1] Names and dates within parentheses refer to the sources in the reference list appended to the present study.

[2] One of Ledermann's combinations is similar in principle to the Carrier-Hobcraft system.

[3] In most applications of the systems described here it is possible to introduce sex as a parameter by treating the sexes separately.

an Edgeworth series; analytical expressions can be found for a series of derivatives of the distribution function $F(z)$ (equal to $e^z/(1+e^z$ for the logit system) and these can be expressed in terms of $p^*(x)$.

In a Gram-Charlier type expansion, $A(x)$ would be the third derivative:

$$A(x) = p^*(x) \quad \{1\text{-}p^*(x)\} \quad \{1\text{-}6p^*(x) \quad (1\text{-}p^*(x))\},$$

and $B(x)$ would be the fourth derivative, thus:

$$B(x) = p^*(x) \, \{1\text{-}p^*(x)\} \, (1\text{-}2p^*(x)) \\ \{1\text{-}12p^*(x) \, (1\text{-}p^*(x))\}$$

Addition of linear multiples of these to $p^*(x)$ would give a set of standards $p_s(x)$ with the same mean and standard deviation as $p^*(x)$ but with different skewness and kurtosis on the logit scale.

Alternatively, expressions for $A(x)$ and $B(x)$ can be formulated that also involve the first two derivations. The new set of standards can be formulated in such a way that they are matched with $p^*(x)$ by having the median located in the same place and having the same values of the range of mortality, $p(x_1) - p(x_2)$, experienced between a selected pair of ages, x_1 and x_2.

The latter system has recently been developed by Basia Zaba to include a simple way of estimating g and h in order to yield suitable new standards, which can then form the base (using the traditional linear logit transformation) for fitting observed life tables with a high degree of accuracy.

The performance of this system is good because $A(x)$ and $B(x)$ as specified are good models of the commonly encountered types of divergence of observed life tables from the standards usually employed—that is, linear combinations of $A(x)$ and $B(x)$ alter the pattern in early adulthood very little, but allow wide variations to be introduced in the local patterns of infant, childhood and old age mortality.

An important question is whether there are, embedded in the four or five parameter dimensions needed for accurate expression, models with fewer parameters (preferably one)—parameters that can be selected for use from a knowledge of auxiliary variables. Such variables might be regions, ecological conditions, mortality at another time and so on. Even at the early stages of model life table construction these ideas were present, as shown by the "regions" category of the Coale-Demeny sets and the adoption of the "African" standard as the basis of the Carrier-Hobcraft calculations. The evidence suggests that simplifications of this kind are possible but that more study is needed to formulate them effectively, that is, to produce mortality models in which levels and sex/age patterns are expressed in terms of socio-economic parameters. Thus the relation of female to male mortality is certainly not the same in all Asian countries (Bangladesh and Thailand, for example, differ markedly) but there may be two distinct sub-groups, each relatively homogeneous, which could be defined by some social characteristic.

An intermediate factor in differences between patterns of mortality in two populations where the over-all incidences are similar is the composition of deaths by cause, since causes vary greatly in their age incidence. Deviations may also exist in the age patterns of deaths from a cause when the level is kept constant, but this influence is likely to be much smaller. Recent studies of mortality by cause provide steps towards the construction of more sensitive models. Preston and Nelson (1974) have examined the relation between the standardized death rates by cause groups (11 categories) and the over-all rate in 165 national populations (only some 45 countries were actually included, since mortality in different periods was included). The authors show that a simple linear relation

$$M_i = a_i + b_i M$$

exists between the cause rates (denotetd by M_i) and the over-all rate (M); a_i and b_i are constants specific to cause. The linear relation describes the observations well, although the addition of a quadratic term M^2 improves the fit. The largest deviations of populations from this relationship are dominated by a few causes of death, particularly cardiovascular, respiratory and diarrhoeal diseases. A good fit to the cause of death regressions is, in fact, almost a corollary of the original United Nations finding that a one-parameter life table model has considerable representative power. But the study also indicates which causes of death are likely to be critical for the construction of a four- or five-parameter cause model to link with the sex/age system.

Further progress will come from the development of sex/age models by cause of death. Polissar has recently completed a doctoral thesis at Princeton on this topic. The exploration by Preston and Nelson (1974) suggests that there are high correlations among the variations in rates for certain causes of death with the over-all mortality level. Age patterns of incidence are also similar for broad groups of diseases. It is therefore possible that a model of the form

$$p(x) = \prod_i p_i(x)$$

could be constructed, where $p_i(x)$ is the probability of survival to age x when only disease group i is operating, where there are four or five groups and where each $p_i(x)$ is a one-parameter function. In the simplest formulation, $p_i(x)$ is expressed as

$$(p_i^*(x))^{k_i}$$

where (*) indicates a fixed standard survivorship and k_i the parameter. This implies a force of mortality by cause varying in the same ratio at each age, but the formulation does not fit the empirical evidence well enough to be promising. By a slight modification however, a much more satisfactory model can be specified.

The relation

$$p(x) = \prod_i p_i\ (x)$$

is the same as

$$\mu(x) = \sum_i \mu_i(x)$$

where $\mu_i(x)$ is written for the force of mortality at age x. As noted above, a constant proportional change in mortality at each age is not adequate, but a linear model seems quite good (consistent with the slightly different approach used by Preston and Nelson). This can be described schematically in the following way.

The first operation is to divide mortality from a cause of death into two categories. For convenience, the first category will be called "resistant" and it will be assumed that the incidence remains constant. The second will be called "avoidable" and it will be allowed to vary in the same proportion at each age. Then

$$\mu_i\ (x) = {}_r\mu_i(x) + C_{i.a}\ \mu_i(x)$$

where the r and a prescripts denote the forces of mortality for the resistant and avoidable parts respectively, and C_i is the proportionality constant, for cause of death i, which will vary among populations (over space and time) but not with age x. For over-all mortality this gives

$$\mu(x) = \sum_i {}_r\mu_i\ (x) + \sum_i C_{i.a}\mu_i\ (x)$$

$$= {}_r\mu\ (x) + \sum_i\ C_{i.a}\mu_i\ (x)$$

where ${}_r\mu_x$ is the force of mortality for resistant deaths from all causes.

Although this is an algebraically adequate description of the model, for applications it is more convenient to relate it to a one-parameter model life table system. To define this system assume that there is a proportional relation between C_i for different causes of death; in other words, $C_i = C.k_i^*$ where the k_i^* values are fixed and C varies among populations. Then

$$\mu(x) = {}_r\mu(x) + C\Sigma\, k^*_{i.a}\mu_i\ (x)$$

$$= {}_r\mu(x) + C_a\mu(x)$$

where ${}_a\mu(x)$ is a fixed force-of-mortality pattern by age for all avoidable causes of death. This gives a model life table system with one parameter, C, which, by a suitable choice of the ${}_r\mu(x)$ and ${}_a\mu(x)$ functions, is in fact an extremely good representation of average changes in mortality patterns by age with level. It can also be written as

$$p(x) = {}_r p(x)\ [{}_a p\ (x)]^{\ C}$$

in terms of probabilities of surviving to age x when the different categories of mortality are indicated by the subscripts.

The cause model can then be related to the one-parameter reference system by

$$\mu(x) = {}_r\mu(x) + C_{.a}\mu(x) + \sum_i \delta_{i.a}\mu_i\ (x)$$

$$= {}_r\mu(x) + C\ [{}_a\mu(x) + \delta\mu(x)]$$

where

$$\delta_i = C_i - Ck_i = C\ [k_i - k_i^*]$$

and $(k_i - k_i^*)$ can be regarded as deviations in the given population from the reference mix of causes denoted by k_i^* and resulting in the pattern ${}_a\mu(x)$. The function

$$\delta_\delta\mu(x) = \Sigma_i\ [k_i - k_i^*]\ {}_a\mu_i\ (x)$$

represents the age deviations, over-all, from the reference model.

But deviations from the reference mix of cause-of-death mortality only affect the age incidence to the extent that the patterns by cause differ from the over-all pattern. In a final step it is necessary to introduce cause-pattern residuals:

$${}_g\mu_i(x) = {}_a\mu_i(x) - g_{i.a}\mu(x)$$

where g_i is chosen to make the value of ${}_g\mu\ (x)$ zero at some convenient age (say 30 years). Then

$$\mu(x) = {}_r\mu(x) + C\ [1 + \sum_i (k_i - k_i^*)]\ \ {}_{.a}\mu(x) + C_{.g}\mu(x)$$

where

$${}_g\mu(x) = \sum_i\ (k_i - k_i^*)\ {}_{.g}\mu_i(x)$$

expresses the age differences from the reference model as the sum of the products of the cause mix and age pattern deviations. The appropriate life table of the reference set taken for comparison is here the one that agrees with the cause model in the force of mortality at age 30 years, but other choices are possible.

Such a re-parameterization in terms of causes of death could lead to a number of valuable applications. In many developing countries, broad indications about age/sex patterns of mortality are becoming available, although the methods for making the estimates are indirect and uncertain because of limitations in the scope and accuracy of the data. The use of models to combine such demographic pointers with the (equally doubtful) medical information available as to the severity of different health problems would provide firmer and more precise measures for both. Some causes of death have been tentatively associated with age patterns of mortality. For example, heavy infant diarrhoea has been associated with an African standard shape in childhood, and severe tuberculosis with the Coale-Demeny North Regional set high rates in adolescence and early adulthood. Parallel to this there have been associations (even more speculative) of mortality age patterns with ecological situations. Thus the African standard characteristics in childhood may reflect the disease-transmission patterns of environments favourable to tropical parasites; mountain or desert conditions may result in relatively low adult mortality compared with the childhood incidence. Turkey and North Africa are, perhaps, examples. Causes-of-death—sex/age models could clarify these interactions.

An important outcome would be the creation of a better defined yardstick for further study of the determinants of mortality falls. This is not the place to review this controversial and complicated topic. The influences are clearly multi-factorial and have impacts whose contributions vary with age and situation. Careful specification of concepts and measurement is then required before claims about the weight of various determinants can be judged. Preston (1975) has recently analysed relations between life expectancy and income *per capita* in national populations, bringing out the alteration in the pattern of association over time and the weakness of the correlation between changes in the two variables. He implicates medical technology—advances in the treatment of particular diseases—as a major element in the alteration of the association between income and mortality. Although the selective nature of the data available for higher-mortality populations may have biased the results, there is no reason to reject the conclusion that the cause-of-death composition has an important bearing on the interpretation of the determinants of changes. A better understanding of the past in terms of cause-of-death mortality models and their ecological and sex/age pattern correlates would contribute to projections and predictions for particular populations. This would be especially valuable in models of alternative paths of development, as it would facilitate the introduction of more realistic links with economic factors.

The constructs considered have been macro models; they are descriptive, in other words, of average mortality incidences for large groups of persons. There is now beginning to be a need for micro models, which would represent the patterns of death in small units, primarily families. So far, the applications for which such models are required concern child mortality, and the relevant variables that must enter into the specification are such family characteristics as the age of the parents, birth order and spacing. It is known that probabilities of death in childhood are strongly influenced by these variables. They thus have an effect on family formation. Any attempts, then, to explore with any precision the family and household structures that result from specified fertility assumptions must incorporate mortality models of this type. To consider the economic implications of childbearing and childrearing in terms of aggregate averages only is a crude exercise, which would benefit from greater attention to distribution effects.

An extremely simple model of this class has been used by Brass and Barrett (1975) in a computer simulation study of measurement problems that arise in the attempt to determine whether child mortality in a family has a volitional effect on the numbers of subsequent births to a couple. Since child mortality is related to fecundity through birth spacing and order, correlations can arise that are irrelevant to the effect sought but mimic its consequences. In the Brass-Barrett model, the force of mortality in each of the first 18 months of life was increased linearly with the number of births to the same couple in the five years preceding that of the child at risk. This device reproduces quite well observations on variations in child death rates by spacing and total births per mother. Work is now proceeding on the extension and refinement of this model for application to family-formation studies.

The family-formation effects of very early childhood mortality are closely similar to those of abortion. Foetal deaths are logically part of the total mortality picture, but they have been widely neglected in model construction. There is enough evidence to justify the description of spontaneous abortion rates by months from conception from the second month onwards by a decreasing geometric series with a ratio slightly greater than 1:2. The wastage has been of the order of 25 per cent of recognized pregnancies in the few thorough studies. The conception wastage may be an appreciably larger part of the total in the first two months than it is subsequently. The high proportion of pregnancies that are aborted emphasizes that it is a serious failure not to incorporate foetal wastage into mortality models that are used to explore reproduction. A strong argument can be made that a better understanding of abortion is essential for the interpretation of fertility levels and trends, particularly in developing countries. The materials are scanty but not completely lacking for the construction of a more refined foetal wastage model—relating it to both childhood mortality and family characteristics. As always, advances made in the collection of data and in the conceptual formulation are likely to be mutually stimulating.

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MODELS OF FAMILY DEMOGRAPHY

*Norman B. Ryder**

This is a brief statement of the case for the construction of models of family demography, to serve as complements to the conventional, individual-oriented demographic models. The concepts underlying family-oriented models are already familiar to those who work with census data on households and families; relevant theoretical developments are to be found, for example, in papers on the mathematics of kinship. Family demography, as a specialized field within the area of population studies, deserves broader development and application.

Family demography may be defined as the study of the determinants of the number, size and composition of families. Consider a simple model in which the definition of "family" is restricted to a co-resident group in which all members have primary relationships (husband/wife, parent/child, sibling/sibling) with one another and none of the junior generation is married. Then all persons in the population may be classified according to their membership in one or another of the following groups: families (consisting of two generations and subdivided, for convenience, according to whether the senior generation has one or two members and whether the junior generation has one or more than one member); couples (consisting of one generation, i.e., two spouses); and individuals (the residual category of those who do not reside with a parent or a child or a spouse).

In order to maintain a running account of the number of representatives of each type of group, the status transitions for which we must specify functions are those familiar in individual-oriented models (death, parenthood, marriage and divorce) and also a transition that may be referred to as "passage." We have coined this term to identify the departure from a family of a member of the junior generation; passage is ordinarily, although not necessarily, associated with the marriage of the individual concerned. The complexities of such a model derive from the circumstance that these status transitions affect not only the individual concerned but all other members of the group of origin and the group of destination to maintain the appropriate level of conceptualization, we should say that any status transition affects the classification of those groups. Furthermore, although we have ample information concerning the dependence of such events as death and marriage on age, gender and other individual characteristics, little is known of their dependence on the characteristics of the group of which the individual is a member at the time of the occurrence.

This principle is implicitly recognized in various conventional measurement procedures. For example, fertility is frequently studied in relation to marital duration, a characteristic of a couple rather than of an individual; a prominent variable in divorce research is the number of children the divorcing couple has; nuptiality is commonly investigated as a function of the characteristics of both prospective spouses; and mortality is recognized to be strongly dependent on the marital status of the individual. The proposal then is to tailor family demography models in terms of this principle: that the events that occur to individuals who are members of family groups be considered as dependent on the characteristics of those groups.

It would seem that, just as the natural unit of temporal analysis for the behaviour of individuals is age, so would it be marital duration for couples and, in the case of families (as defined above), the interval since the birth of the first child.

The author, in a previous paper,[1] used a simple version of the above framework to examine the consequences for families of a decline in mortality without a decline in fertility. Some problems and possibilities of that exercise may be indicated. It was found convenient to reconstitute the net reproduction rate so that, instead of cycling from birth to birth, it cycled from marriage to marriage. Thus, instead of net reproduction rate consisting of age-specific survival and age-specific fertility, its components were duration-specific fertility and parental survival by duration, on the one hand, and child survival on the other. This reconstitution permits a focus on families, which "begin" at marriage, rather than on individuals, who "begin" at birth.

The emphasis on parental survival helped to make prominent the importance of what might be called the efficiency of remarriage institutions. If there were complete remarriage of widows, immediately upon death of spouse, then the only survival relevant to fertility would be that of females. If, on the other hand, there were no remarriage of widows, then the relevant survival would be the joint survival of husbands and wives

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[1] "Reproductive behaviour and the family life cycle", *The Population Debate: Dimensions and Perspectives* (United Nations publication, Sales No. E. 75.XIII.5), pp. 278-288.

(something like the square of female survival). The efficiency of remarriage—in terms of the probability of remarriage and the length of the interval between dissolution and remarriage—is given by the continuum between the individual and the joint survival curves. It is this phenomenon that makes the gross reproduction rate less than a pure measure of fertility, since it is dependent on mortality in all cases except that of complete remarriage. Comparable considerations apply in the case of divorce.

The central problem of the previous paper was the measurement of family size. To accomplish that objective, the family was defined as a group that contained an actual or a potential parent/child pair; the category "potential pair" covered the case of a couple in which the wife had not yet reached the maximum age of childbearing. Size was interpreted in person-year terms, from the beginning of marriage until the termination of the family as defined above. Since the definition hinged on the coexistence of particular kinds of members, the calculations took the familiar joint survival form. The approach was adaptable to the consideration of other family relationships as well, such as mother/daughter or brother/sister.

One specific application of the model involved a consideration of the burden of dependency over the family's history. This required a budget of those person-years spent within ages of dependency, compared with those person-years spent within productive ages. An important assumption was that a child would contribute to the budget for his or her family of orientation between the time of becoming a net producer and the time of marriage. The impression from such a calculation is that the increase in dependency associated with a decline of mortality is much less than would be suggested by a comparable stable population calculation. The chief reason for that contrast is that the family person-years budgets of dependency and production are streams over time, whereas the stable population calculation is cross-sectional. Thus, from one standpoint, the stable population contains a distribution of families by marital duration that is concentrated in the earlier durations—that is, those in which the burden of dependency is largest; from another standpoint, the family budget of person-years fails to cope with the consideration that it is not feasible in the aggregate to borrow from the future in order to meet the needs of the present. There was, however, an implication that came out of the contrasting calculations: When a population grows, that growth can be considered, from the perspective of family demography, as a product of growth in family size and growth in family numbers. The former, but not the latter, would be perceived as the responsibility of the families concerned; the latter would make those responsibilities more difficult to fulfil. This difference of perspective may account in part for the persistence of high fertility.

Some problems intrinsic to such exercises may be indicated. First, the simplicity of the model is dependent in large part on a set of arbitrary assumptions, each of which is an important element in the empirical outcome. Those assumptions, in effect, are specifications of prevailing social norms, such as rules concerning widow remarriage and the contribution of premarital individuals to their family of orientation. The working of the model creates orphans and dependent aged, without specifying their sources of support. Such problems as these may be viewed on the one hand as an unresolved aspect of a computer program; on the other hand they are pervasive social problems, for which a society finds one or another solution and crystallizes that solution in the form of norms. Neither societies nor computers will function unless every contingency is accommodated.

Second, it is apparent that our data base is inadequate to answer a number of problems that are implicit in working with group characteristics. For example, joint survival calculations are used throughout family demography calculations, but it is apparent that two members of the same family cannot legitimately be considered to be randomly drawn from the same general population. Spouses select one another, they pass on their genes to their children, all members of the family share the same environment, and, when one of them dies, the viability of the survivors is jeopardized or (occasionally) enhanced. These are important demographic questions, and we know rather little about them.

The third problem is familiar to any person who has attempted to programme the formation of families. In the above model, it was specified that all females married at age 20 and all males at age 25. In most stationary populations, the stipulation that all persons of both sexes marry can be met only if the age at marriage, by sex, is approximately the same. Since this is contradictory to socio-economic reality, it is obvious that social arrangements are adapted to the demographic context. Furthermore, in the specific disequilibrium context examined, there was a very substantial shortage of males under any assumption that they be older than their brides. In approximate terms, there is a shortage of $100r$ per cent for every year of difference in age between males and females, in a population with rate of growth r. The strong implication is that growth impairs the prospects of female nuptiality. For example, with a growth rate of 3 per cent per annum, males are likely to encounter difficulties in accumulating the material requisites for marriage. Suppose they become ready for marriage by age 25. Either they marry females of a younger age, such as 20, in which case some 15 per cent of females must remain spinsters; or they marry females of the same age, in which case females spend five more years single before entering marriage. The problems of the marriage market both for the society and for the computer programmer are complex and important.

The final noteworthy problem is that the model in question had averages as its typical output, and ignored variance. As a general principle, the amount of demographic heterogeneity varies directly with both the level of mortality and the level of fertility. Once again, this is both a difficult assignment for the programmer and an important social fact. High variability implies large proportions of very large and very small families; extinction and explosion of families must be commonplace, as must be social customs adapted to cope with such circumstances. One justification for the extended kinship system is that it works like an insurance policy to cover the exigencies that would be faced in relative isolation by the members of any particular nuclear family. It seems plausible, in the presence of high demographic variability, that there would evolve a strategy of aiming at a higher level of fertility than would be necessary to achieve replacement, so as to reduce the probability of extinction. Moreover, a household that had become too large in consequence of this strategy could solve its problem by the relatively simple organizational solution of fission, whereas a household that had become too small would need to resort to fusion, an organizationally difficult assignment. As a footnote to this discussion, variance in demographic processes assures that, within the community, a range of examples should always be available to demonstrate the consequences of one or another reproductive option. Finally, it seems likely that what is called "fatalism" is not an irrational response to the great role that chance plays in human affairs; to put it the other way around, the reduction of demographic variability may be an important condition for an increase in reproductive decision-making.

The strongest argument for models of family demography is the opportunity they provide for joint consideration of demographic, economic and sociological variables. The theory underlying this judgement may be sketched briefly as follows. The biological characteristics of the individual life cycle, in particular the long stage of immaturity, make it mandatory for individual and societal survival that there be a flow of resources from some other persons in the direction of the infant and child. The set of such commitments represents the raison d'être of the family. Every individual life (assuming survival to old age and consequent dependency) is a sequence of net consumption, net production and, again, net consumption. The family is society's way of coping with this fact; it is the agent for transferring resources across generations. The solution takes the form of implicit contracts built into marriage and parenthood, specifying diffse and long-standing commitments (sets of rights and responsibilities) that extend over time. These contracts stipulate that resources will flow from one person to another because of their familial relationships and their locations in the life cycle. The possibility of fulfilling such contracts is obviously conditional not only on productivity but also on the demographic magnitude of the obligations.

Normative arrangements such as these are the fabric of the social system; they are implanted through socialization and maintained through social control. Although, typically, they are followed only imperfectly and are hedged about with specifications of particular situations in which they may be ignored, these arrangements tend to persist until the departure from the norms becomes systematic. One subject of high interest is the extent to which such a demographic change as a decline in mortality, if it is not matched by a corresponding rise in productivity, makes the fulfilment of familial contracts difficult or impossible because of a change in the balance of person-years on either side of the direction of flow. Obligations that can be fulfilled only partially produce tension and strain, bringing into question the shape of those obligations and provoking normative change—that is, societal change. For example, both the father/son relationship and the relationship among siblings are prejudiced by mortality decline, because the amount of inheritance varies inversely with the net reproduction rate, while the time of inheritance varies directly with the expectation of life. Marriage also raises comparable problems concerning questions of resource flow, such as dowry and bride price.

The argument can be pushed one step further. There is a continuum of family types, ranging from those in which the family of procreation is dominated by the family of orientation to independence of the former from the latter. As a general rule, the dominance relationship is associated with high fertility, and the independence relationship with low fertility. A flow of resources in one intergenerational direction typically implies a flow of power in the opposite direction. Of all the sanctions available for one generation to control another, perhaps the most important are threats of non-fulfilment of contract as a response to insubordination. The hypothesis is that failure to carry out familial commitments reduces the power that the family of orientation has over the family of procreation, and fertility declines. Thus the general proposition is that demographic change produces a quantitative disturbance of resource flows, as governed by prevailing norms; this leads to a modification of those norms, which in turn produces further demographic change. One of the important tasks of family demography is to identify and measure such sequential processes.

As a simple example, consider a computer program that has, as sociological input, the specification of the direction of resource flows between family members. For example, one could stipulate that a child received resources from the family of orientation up to age A and contributes resources to the family of orientation between ages A and B. At age B, the responsibilities of the person shift to the family of procreation. Between ages B and C the person contributes resources both to the family of procreation and to the family of orientation (as parents become dependent). Beyond age C, the person receives resources from the members of his or her family of procreation.

Associated with this system are a pattern of consumption by age, at a level signifying the scale of living, and a pattern of production by age, at a level signifying productivity. Those functions are probably inter-dependent with other specified values. For example, the level of productivity is likely to be a function of age A, viewing education as human capital investment. For another example, one form of consumption would be a higher value for A and a lower value for C. In turn, consumption and production functions are interrelated through investment.

This interdependent system can be established at equilibrium for any particular set of values of the demographic processes, the norm and the consumption and production functions by age. The equilibrium is disturbed by the introduction of new values for the demographic processes, and the options available to restore equilibrium can be identified in terms of consumption level and normative modification. More realistic models would likely introduce independent modifications of production and consumption functions, and perhaps also of norms (as a consequence of a developing ideology of individualism, for example). Barring interfamily transfers, the system would need to be in continual balance, on a duration-specific basis, throughout the family's existence. Clearly, the relative sizes of the generations involved are dependent on fertility and mortality (values that are roughly captured by the net reproduction rate) and their locations in time are dependent on the relationship between the mean length of life and the mean length of generation.

In summary, models of family demography are advocated because they force attention to normative parameters (relationships among individuals) as well as to the demographic and economic variables that are conventional in individual-oriented models. Only by explicitly incorporating the normative system can the theory of demographic change be integrated with a theory of social change.

USE OF FAMILY-BUILDING MODELS TO ASSESS THE IMPACT OF POPULATION POLICIES UPON FERTILITY IN THE DEVELOPING COUNTRIES

*Robert G. Potter**

Introduction

The position will be taken in this note that when the data are available—which is rare—family-building models can do a fairly realistic job of simulating cohort natural fertility as determined by a certain set of biological factors through which most other factors—that is, social and economic factors—have to operate to influence fertility. However, both for reasons of greater logical complexity and because of exacerbated data requirements, these models fare less well when simulating human fertility that is regulated by a variety of family planning practices. As a consequence, we must question the capacity of family-building models to produce quantitative predictions of the impact of population policies on period fertility in developing countries. It would seem that for the foreseeable future, the most that can be accomplished with family-building models will be the construction of gross idealizations of regulated fertility and the use of these constructions to demonstrate the relevance of particular factors, to clarify mechanisms, to test the validity of proposed indices of fertility change and to indicate some of the conditions under which a specific population policy might be more or less effective in reducing fertility.

In this short statement, some definitions and premises are first laid down. The unequal tasks of delineating natural and regulated fertility are next reviewed. Finally, a few insights about manipulating fertility, which have been gained from family-building theory, are briefly sketched.

Definitions

Most nations setting numerical demographic goals have done so by designating some reduction of the crude birth rate or growth rate, to be attained within a specified target period, such as five years (Watson and Lapham, 1975). Accordingly, for purposes of this note, it is appropriate to define "impact upon fertility" as a measurable change in period fertility.

Population policies relevant to fertility are conveniently (if not very imaginatively) grouped into two classes: family-planning policies aimed at directly or indirectly fostering the wider practices of some combination of contraception, induced abortion and sterilization; and a residual class of "other" policies, which, for present purposes, includes such policies as delaying marriage, expenditures for disease control, nutritional supplements and governmental action (or inaction) bearing on internal migration or lactation practices.

"Family building" connotes the number and timing of pregnancies and births in the reproductive histories of individual couples (Sheps and Menken, 1973). In the absence of parity-dependent regulatory practices, fecundity variables are able to express themselves quite directly in natural fertility. In the presence of such practices, fecundity factors undergo considerable modification to produce regulated fertility.

The more comprehensive family-building models have typically treated natural fertility in terms of four main, age-dependent functions corresponding to fecundability, nonsusceptible periods (gestation and postpregnancy anovulation), probabilities of pregnancy outcomes and limits of the reproductive period (Holmberg, 1970; Leridon, 1973). These limits comprise age at entrance into a first sexual union and age at onset of secondary sterility, although the two ages merge in cases of primary sterility.

In fairly straightforward ways, one or more of these four basic functions may be selected for modification or elaboration, in order to reflect practices of fertility regulation. Thus, to represent induced abortion, the likelihood of foetal wastage is incremented (Sheps, 1964); or, for more refinement, induced abortion is distinguished as an additional pregnancy outcome in direct competition with the outcome of spontaneous abortion (Potter, Ford and Moots, 1975). Contraception is registered by modifying fecundability (Sheps and Perrin, 1963). For each method of contraception considered, additional parameters are postulated, representing continuation and effectiveness of practice (Potter, Jain and McCann, 1970). To these parameters are added transition probabilities to represent the chances of shifts among possible pairs of methods, including the "null method" of nonpractice of contraception (Mode and Littman, 1975). Sterilization may be treated either as a highly effective, zero-discontinuation method of contraception or else, more awkwardly, as an intensification of the secondary sterility function.

Limitations

A family-building model delineating natural fertility and one simulating regulated fertility subject to a cafeteria-type family planning programme entail two

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quite different orders of complexity. With respect to the former, all functions—fecundability, length of non-susceptible periods, the probabilities of different pregnancy outcomes and limits of the reproductive period—exhibit strong age dependencies and significant variation among women at any given age. The essential simplicity of a model of natural fertility is that, without major distortion, the four basic functions may be taken as operating independently of one another, with the exception of the dependence of non-susceptible periods upon outcome of pregnancy. As an example, Bongaarts has successfully fitted the detailed fertility characteristics of a sample of 512 eighteenth-century Canadian women, stratified by age of marriage, on the basis of a family-building model that allows for the age-dependence of all four basic functions but provides between-woman heterogeneity only for fecundability (Bongaarts, 1976). Interestingly enough, the structure of Bongaart's model conforms with five recommendations made by Jacquard and Leridon (1973).

The greater complexity of models of regulated fertility has several sources. The fecundability function, greatly elaborated in order to reflect the practice of several contraceptives, becomes parity-dependent as well as age-dependent. As a consequence of incorporating sterilization and induced abortion, two other basic functions—end of the reproductive period and probabilities of pregnancy outcomes—also acquire a parity dependence. These parity dependences become the vehicle through which family-planning goals—including goals regarding both spacing and family size—are operationalized. Resultant linkages between the probabilities of resorting to induced abortion and practising contraception mean a failure of independence between fecundability and probabilities of pregnancy outcomes. Then too, any variation in family planning goals adds an important source of between-women heterogeneity.

Various technical approaches have been employed to develop family-building models: difference equations (Henry, 1972, chaps. 2 and 3); list processing (Potter and Sakoda, 1966); Markov and semi-Markov processes (Sheps and Menken, 1973, DasGupta, 1973); systems analysis (Bongaarts, 1975); and micro-simulation (Barrett, 1969; Horvitz, and others, 1971; Jacquard, 1967; Ridley and Sheps, 1966; Venkatacharya, 1971). The first two approaches are the least flexible of the five mentioned. The third and fourth approaches, by recourse to nonstationary transition probabilities and watiting times, are computationally efficient with respect to handling age dependencies but show much less efficiency when made to cope with age-parity dependences, additional constraints among the four basic functions or more than one source of heterogeneity among women. The micro-simulation approach, which takes couples through their reproductive period one at a time, commands maximum flexibility, since each couple's basic parameters (lengths of survivorship, desired family size and the like) may be drawn randomly from the appropriate probability distributions, to register the heterogeneity that exists among couples, and then the chosen parameters may be changed over time to register age and parity dependences.

Markov and semi-Markov processes have been the most frequently used approaches. A weakness in their application has been that, with the main exceptions of Ginsberg's work on lactation anovulation (Ginsberg, 1973) and estimates of fecundability by Sheps and his co-workers (Sheps and Menken, 1973; Menken, 1975), investigators have failed to make full use of estimation theory in order to test either the appropriateness of assumptions or the goodness of fit of these models to data.

Most family-building models relate to cohorts—birth, marriage or acceptor cohorts—rather than to period populations. They are thus well designed to follow the family-planning behaviour of couples over entire or residual reproductive periods; they are, however, ill-adapted for drawing conclusions about the effects of family-planning policies upon changes of period fertility. A formal solution to this problem is to generate a sufficiently long time series of cohorts and then aggregate across age, year by year. However, since the conventional time unit in family-building research is one month, and a reproductive career may span 360 or more months, the requisite number of cohorts makes this solution unattractive. A more realistic solution has been to couple the microsimulation model POPSIM, which simulates a period population, with a family-planning module that invokes family-building variables to determine annual births (Lachenbruch, Sheps and Sorant, 1973). Alternatively, C. J. Mode, by a mathematical *tour de force*, has represented reproductive histories as terminating semi-Markov renewal processes, which are then embedded in a generalized age-dependent branching process in order to obtain the equivalent of a population projection (Mode and Littman, 1974a); this formidable apparatus has seen only one application (Mode and Littman, 1974b).

Unfortunately, the flexibility of micro-simulation cannot make up for inadequate data. As they are not directly observable, the parameters specifying effectiveness and continuation of any contraceptive have to be estimated indirectly by means of a life table analysis, usually based on a clinic follow-up study (United Nations, 1969). These analyses are prone to problems of non-representativeness, short duration, small sample size and bias from loss to follow-up. For example, intrauterine contraception—like periodic abstinence and steroid contraception—is not a single method at all, but a whole family of related methods, each with its own distinctive profile of physical characteristics, side effects and service personnel; the result is dissimilar continuation curves and differentiated effectiveness. Between countries, and within a country over time, the mix of available contraceptives changes, often rapidly. Hence generalization is hazardous from one country to another, and indigenous evidence for one nation quickly becomes obsolete.

For contraceptives subject to irregular practice—such as the pill, condoms and, indeed, most traditional contraceptives—the suitability of the life table approach is open to challenge, as is its concept of continuation.

Because contraceptive follow-up studies usually follow the method rather than the couple adopting it, there is seldom a data base for measuring the likelihood of shifting among principal methods or of repeating with the same one.

Perhaps one can best summarize the above catalogue of problems by saying that with respect to simulating regulated fertility, family-building models, too ambitiously detailed, saddle the user with an impossible job of estimation.

It is not intended to argue that family-building models have no value for assessing the impact of population policies on changes in fertility in developing countries. They do (Sheps, 1966). Some population policies bear on natural fertility directly. Even where regulated fertility is the issue, family-building models still are useful for indicating relevant factors, for clarifying mechanisms, for assessing the validity of measures of fertility change and for specifying the conditions under which a specific policy might be expected to have larger or smaller fertility effects. What all these latter applications have in common is the possibility of proceeding by combining a fairly realistic model of fecundity with highly simplified assumptions about family-planning practices. The remainder of this note is devoted to a few examples.

"Other" population policies

First let us consider a few examples relating to non-family-planning population policies. Past work has shown that when nuptiality factors are controlled, natural fertility, measured as a total fertility rate, can vary as much as 50 per cent from one group to another (Henry, 1961). The largest component in this variation appears to be post-partum anovulation as related to lactation practices. From this standpoint, it may be argued that if a Government wants to reduce fertility, it should not stand indifferent to a trend, observed in many developing countries (Berg, 1973), for women to shift from prolonged breast-feeding to bottle-feeding. The associated enhancement of fertility is potentially large unless practice of contraception and abortion is already widespread. Family-building models may be utilized to assess the enhancement under stated conditions of fecundity and lactation practice and also to estimate how much acceptance of a defined standard contraceptive is needed to eliminate the potential rise in fertility (Potter, 1975).

Family-building models can be advantageously employed as a means of quantifying the effects upon fertility of specified decreases in infant mortality and early childhood mortality operating through the mechanism of less frequent interruption of lactation by death of a child and consequent increase in expected length of anovulation (Preston, 1972). Unless the initial level of infant mortality is very high—on the order of 150 or more infant deaths per 1,000 births—the effect upon fertility proves to be rather minor and becomes trivial in the presence of widespread contraceptive practice.

An important policy issue is whether an extensive programme of free food supplements would, besides ameliorating health, also raise fecundity significantly. It has been alleged (Frisch, 1975) that chronic malnutrition—even at levels well short of starvation—operates to reduce fecundity, possibly through all four of its main aspects (that is, through reduced fecundability, augmented risk of intrauterine mortality, later reproductive maturation coupled with earlier menopause and longer post-partum anovulation under prolonged lactation). The validity of most of these alleged influences remains controversial. With respect to post-partum anovulation, for example, it may be argued that malnutrition, by reducing the quantity of a mother's milk, forces her to wean earlier, and that this earlier shift from full to partial breast-feeding hastens her resumption of ovulation. Obviously, any conclusions drawn from a family-building model about the effects of an enriched diet upon natural fertility will depend on the modeler's detailed assumptions about the response of each of the four basic fecundity functions to nutritional improvement; more field-work is needed to narrow the range of plausible assumptions.

Another application of family-building models that is currently stalled is tracing the fertility impact of programmes aimed at reducing the incidence of venereal disease. The manners in which the four basic fecundity functions are altered by specific venereal diseases is not yet well enough worked out to make it worthwhile to try to project, by means of family-building models, the consequences for cohort fertility of designated reductions in the frequencies of these diseases.

A latent function of heightened internal migration (e.g., rural-to-urban migration) may be more frequent and longer temporary separations of spouses. Family-building models offer a vehicle for studying the effect on fertility of such separations. Relevant dimensions are expected length of separation and time patterning —whether separation is seasonal, recurrent at intervals other than one year, or randomly distributed. Even in the absence of widespread family planning, the impact of separations lasting longer than a month may prove less than might first be anticipated since, like contraceptive practice, separation of spouses can only prolong the wife's stay in the fecundable state, but cannot be expected to augment her gravid, post-partum anovulatory or secondary sterility states.

Family-planning policies

Attention now turns to a few examples pertinent to family-planning policies in developing countries. Barring late marriage or preference for a sizable number of widely spaced births, the attainment of desired family size tends to occur by the middle of the reproductive period, leaving a "risk period" averaging ten years or longer when further births are to be avoided. Family-building models, even of a crude sort (Potter, 1960), have shown that continuity, combined with high effectiveness of contraception, is required if contraception is to provide, by itself, a reasonable assurance of no excess pregnancies. These results become a potent argument for a policy endorsing induced abortion as a backstop to contraception. Tietze and Bongaarts (1975) have estimated total abortion rates required at each level of contraceptive effectiveness in order to realize replacement-level fertility under conditions of fairly high fecundity.

The residual reproductive histories of women backstopping contraception by induced abortion may be compared with those of another like-sized cohort of women sharing the same fecundity and the same calibre of contraception, but eschewing abortion. Dividing the number of excess births experienced in the latter cohort by the number of induced abortions required by the former to avoid further births defines a ratio, which may be interpreted as fractional births averted per induced abortion. This ratio can be used to show that the efficiency of induced abortion depends primarily on the calibre of the accompanying contraception, with efficiency increasing as efficiency of contraception increases. At much lower levels of sensitivity, the efficiency of abortion increases given a later age of gestation at time of abortion, proximity to end of the reproductive period, higher rates of spontaneous abortion or lower stillbirth rates (Keyfitz, 1971; Potter, 1972; Venkatacharya, 1972; Williams and Pullum, 1975). More particularly, when contraception is absent, abortion becomes quite inefficient, two to three abortions being required to avert a single birth, dependent on fecundity factors.

The weakness of a single-method contraceptive programme is easily demonstrated by constructing a hypothetical population in which all wives accept a single contraceptive upon attainment of desired family size, practice contraception at the continuation and reacceptance rates observed for that method in the experience of a national family-planning programme favouring that same method, but then have neither another contraceptive nor induced abortion to turn to (Potter, 1971). The high levels of excess fertility that are computed under these conditions validate the present trend in national family-planning programmes towards offering a wider and wider selection of contraceptives to their clients.

It is tempting to claim a relatively high potential fertility for young acceptors of programme contraception when they show shorter past-birth intervals than average for their age groups. However, as may be demonstrated by the proper family-building model (Barrett and Brass, 1974), this apparently higher fertility may be attributed mainly to capitalizing on chance, since even in the absence of contraception (and given homogeneous fecundity and the same marriage age), a cohort will vary by chance in the ages at which they attain a given desired family size. On the other hand, at older ages, if acceptors exhibit a considerably shorter open interval than coeval non-users, their current fecundity may be expected to be appreciably higher than non-users by virtue of a lower incidence of secondary sterility.

With adaptation, a family-building model may sometimes be used to test the relative efficiency of quite specific family-planning strategies. An example is the comparison of two IUD insertion strategies: post-amenorrheic versus post-partum (Potter, Masnick and Gendell, 1973). Expected intervals to next conception, following a birth, are compared when a single IUD is accepted under one or the other insertion strategy but with fecundity factors and the IUD continuation rate held constant. When IUD continuation is poor and post-partum anovulation long, the efficiency of the post-partum approach (inserting devices soon after child-birth) is heavily penalized by overlap of the wearing time with post-partum anovulation when the woman is protected anyway. The strategy of deferring insertion until after a first menstrual period virtually eliminates this overlap, but the efficiency of this approach proves very vulnerable to procrastination, so much so that unless most insertions take place within one or two months of the first menstrual onset, postamenorrheic insertees fare less well than their post-partum sisters.

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MEASUREMENT OF DEMOGRAPHIC IMPACT OF FAMILY-PLANNING PROGRAMMES THROUGH SIMULATION MODELS WITH REFERENCE TO INDIA

*K. Venkatacharya**

INTRODUCTION

Efforts to control fertility through large-scale family-planning programmes necessitate the development of procedures to measure, as accurately as possible, the success of these programmes over a period of time; this is referred to as the problem of "family-planning programme evaluation". Evaluation of a programme can be based on a number of criteria, the ultimate one being the demographic criterion: Does the programme in question lead to a reduction in fertility? The reduction in fertility can be estimated through the number of averted births due to a family-planning programme; in this paper our concern will be with this births-averted or fertility-reduction aspect of evaluation.

A second problem is that of planning the future of a family-planning programme—that is, determining how many acceptors of each method are necessary in each year in order to achieve specific objectives, often stated as a given birth rate or growth rate at a certain future date. This "target-setting" problem, as it is often called, is related to the evaluation problem, and it plays an important role in family-planning programme administration.

The conventional methods of demographic analysis that were used to tackle these problems in India in the late 1960s suffer from serious limitations. The study of natural fertility is itself complex, and it is rendered more complex by the introduction of contraception, with varying contraceptive effectiveness, varying duration of use, switching from one method to another and so on. Consequently, conventional demographic tools are inadequate.

The estimate of number of births averted through the use of contraception is derived in the first place by obtaining an estimate of the number of births that would have occurred to the same women, on the assumption that they used no contraception, later reducing the total, depending upon contraceptive effectiveness and its duration of use.

In the early methods of estimating births averted, the number of births that would have occurred to contraceptors in the absence of contraception is estimated by using either age-specific marital fertility rates or 12 divided by the mean live birth interval. Both of them are "steady-state" rates; these methods are referred as "first methods" throughout the rest of this discussion.

The following pages offer a methodological critique of the model-building efforts leading to computer models in the context of the Indian family planning programme. There follows a brief discussion of some research problems faced in this new field of computer models of human fertility.

PROBLEMS WITH EARLY METHODS OF ESTIMATING BIRTHS AVERTED

The first methods failed to take into account, among other things, initial susceptability—that is, the risk of conception to contraceptors, if they were not to adopt contraception. For instance, an IUD is normally inserted either when a woman is in the susceptible state or a month or two prior to the onset of menstruation. Salpingectomy, on the other hand, is normally carried out following a live birth, when the woman would initially be in the nonsusceptible post-partum period. Even if all other variables were to be equal, this difference in initial susceptibility status between IUD adopters and salpingectomized women would result in differential patterns of birth occurrence in the absence of contraception. Consequently, estimates of births averted are functionally dependent, at first, on initial susceptibility (although simulation studies indicate that the impact of these differences tends to wear off after five years or so).

A second problem, which stems from the first, is to determine the distribution of births averted over time. On the assumption that the woman does not contracept, the first methods assume that the occurrence of a birth does not depend on initial susceptibility, and thus that it is independent of the duration since contraception was adopted (i.e., since "initial time"). The reality, however, is otherwise. As table 1 shows, the probability of occurrence of a birth depends both upon initial susceptibility (which varies with the method of contraception) and upon the duration since initial time. These probabilities were based on a computer model using a number of demographic and biological inputs (Venkatacharya, 1971).[1] The table clearly brings out the difference that can arise in the estimate of births averted by using age-specific marital fertility rate—a steady-state rate—instead of a rate specific to initial susceptibility and duration since initial time.

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[1] Names and dates within parentheses refer to the sources in reference list appended to the present study.

TABLE 1. PROBABILITY OF GIVING BIRTH FOR A WOMAN NOT USING CONTRACEPTION, WITH INITIAL SUSCEPTIBILITY STATUS OF IUD USER OR SALPINGECTOMIZED FEMALE IN EACH CALENDAR YEAR SINCE INITIAL TIME

Age group	ASMFR	IUD Years since initial time					Salpingectomy Years since initial time				
		1	2	3	4	5	1	2	3	4	5
15-19	0.183	0.026	0.279	0.282	0.276	0.292	0.002	0.098	0.266	0.289	0.291
20-24	0.295	0.030	0.353	0.315	0.295	0.299	0.002	0.012	0.314	0.305	0.296
25-29	0.293	0.028	0.324	0.280	0.245	0.234	0.002	0.012	0.272	0.296	0.233
30-34	0.217	0.017	0.208	0.194	0.163	0.148	0.001	0.007	0.173	0.223	0.148
35-39	0.131	0.008	0.107	0.107	0.087	0.074	0.000	0.004	0.089	0.134	0.074
40-44	0.062	0.003	0.038	0.032	0.020	0.009	0.000	0.002	0.043	0.063	0.049

SOURCE: K. Venkatacharya, "A model to estimate births averted due to IUCDs and sterilizations", *Demography*, vol. 8, No. 4 (1971), pp. 491-505.

Apart from these specific limitations, the first methods are structurally incapable of handling many variables at a time, especially the biological variables. Also, they do not permit the inclusion of many of the finer points that a planner might wish to examine in studying the interrelations between the socio-economic, demographic and biological variables and the occurrence of births with or without contraception. All these considerations provided impetus for the use of computer simulation models for estimating births averted and related problems.

The model work so far undertaken in India can be classified into two types. Models of the first type use three steps to estimate births averted: first, taking the contracepting women by age at initial time and obtaining future survivors within marital duration and under 50 years; second, deriving birth probabilities by age, initial susceptibility and duration since initial time; and, third, reduction of births obtained in the absence of contraception, taking into account the effectiveness of the contraceptive and its duration of use. It is for the second step that simulation models are applied; the birth probabilities can be derived through one of the two basic computer models: models based on expected values and models based on Monte Carlo technique. The Monte Carlo models are more flexible and general than expected-values models, but involve sampling errors.

In a model of the second type, a micro-simulation model of the whole population is developed, with maximum flexibility with respect to family-planning and fertility parameters. Such a model is very complex and its construction involves considerable time and money, but it can provide a powerful tool for tackling many population problems, particularly the evaluation of family-planning programmes. In India models of both types have been developed and these will be discussed subsequently.

COMPUTER SIMULATION MODELS IN INDIA

Initially, a simple recursive model was developed, which gave the probability of a live-birth conception after a certain number of months since a woman of a specific age or age group started reproduction in a susceptible or non-susceptible status. The functions used in the model were fecundability; probabilities of a conception ending in a live birth, still birth or abortion; probabilities of gestation periods leading to each type of conception; and post-partum periods following each type of conception. The input distributions were taken to be discrete, empiric and compact, to permit their computation on a desk calculator.

Through this simple model the probabilities were obtained of women having a live-birth conception after one, two, three, four or five years since the initial time; the probabilities were specific to age, susceptibility and duration since initial time. Also, by assuming a certain age distribution of women with a specific initial susceptibility (corresponding to a method of contraception), and by assuming a certain level of mortality, it was possible to specify the number of births that would occur for a woman in the five years since the initial time; after five years, the usual age-specific marital fertility rates were used. Using these birth rates (assuming no substitution) the numbers of births averted in each year were obtained. When the contraceptive method was salpingectomy or vasectomy, which are 100 per cent effective, all the above births were averted. For the IUD and other less perfect contraception, the numbers of births averted, as obtained above, were deflated, taking into account the contraceptive effectiveness and duration of use (Agarwala and Venkatacharya, 1970). This procedure has been used to estimate births averted by the national family-planning programme in India during 1956-1968 (Agarwala, 1969). Potential fertility has been assumed to be the same for the contraceptors and general population of women.

These estimates of births averted by year were used in a component projection, along with assumed future trends in mortality and in fertility in the absence of contraception. The results were presented as estimates of the future birth rates that would result from a specific family-planning programme.

Further, assuming the achievement of a certain trend in targeted future birth rates as a result of family-planning efforts, the numbers of births to be averted in each future year were derived, taking into account the future births averted due to the earlier family-planning efforts. These births to be averted were used in deriving new acceptors of each method of contraception (assuming a pre-set mix of contraceptive methods).

A micro-simulation model (cohort type) using the Monte Carlo technique has been used to obtain a matrix of live birth probabilities specific to age, initial susceptibility and duration since initial time. The model involves demographic and biological inputs similar to those used in the simple recursive model. Each matrix of birth probabilities is based on 3,000 "woman-histories" (100 women of each age from 15 to 44) and two such matrices were obtained for each method of contraception to study the impact of sampling error on births-averted estimates (Venkatacharya and Das, 1972). Using these probabilities, the model was used to derive the estimated number of births averted due to the Indian family-planning programme between 1956 and 1967. It was found that for the sample size used in the model and the inputs used (which are close to actual Indian experience), sampling fluctuations in the elements of the birth probability matrix had only a negligible impact on the estimate of births averted (Venkatacharya and Das, 1972).

The impact of induced abortion on Indian birth rates has also been studied using the same model with appropriate input values (Venkatacharya, 1972).

Another model—based on expected values and similar to the recursive model described earlier—has been developed to derive the birth probabilities specific to age, initial susceptibility and duration since initial time (Venkatacharya, 1971). This model also makes use of the various demographic and biological variables mentioned above. Estimates of births averted through the family-planning programme operating in India during the period 1956-1969 have been obtained using this model (Venkatacharya, 1971). These estimates were quite close to those derived using the micro-simulation model described above.

The above estimates of births averted were carried forward to derive future birth rates as a result of the Indian family-planning programme, and to determine as well the future targets necessary to achieve pre-set objectives, along the lines indicated earlier.

The substantive findings of the above models varied depending on the inputs used and assumptions made; these variations will not be touched upon in this paper.

The general finding indicated by these studies is that the crude birth rate of India has decreased from 45 per 1,000 in 1956 to about 38 per 1,000 in 1975.

One of the problems in using a steady-state rate in deriving births averted is the timing of births. In the first methods, and also in many other methods, the estimated births averted were assumed to have been averted one year after the adoption of contraception, irrespective of the method used. It has been found that this assumed one-year lag did not exist and, further, that the lag varied from one method of contraception to another (Venkatacharya, 1971).

Another important question in connexion with the timing of births is whether this time lag depends on the trend of the acceptors over time. To answer this question the expected-value model has been extended, with minor changes. This revised model showed that the relation between the trend in the contraceptors and the time lag is quite complicated. The significant findings are that the time lag is not always one year and that it is not constant over years; it is highly influenced by the time trend of contraceptors (Venkatacharya, 1975).

A more complex and general simulation model (COMPSIM) of the whole population of India has been developed at the International Institute for Population Studies, Bombay. One of the striking features of the model is that it deals with fertility and family-planning aspects in greater detail, taking into account many demographic and biological variables. The model yields both cohort and period rates, with and without contraception. Acceptance of family planning is assumed to depend upon (among other functions) age, parity, initial susceptibility, previous failure of contraception and survival of last child. A general description of the model is given elsewhere (Venkatacharya and others, 1974); however, the main results of the model have not been published yet.

Immerwahr (1974) has developed a Monte Carlo model, less sophisticated than COMPSIM, to project married women, taking into account the effects of the family-planning programme. He has used this model to study the impact of some Indian family-planning measures on selected aspects of population growth.

The computer model efforts described here have contributed greatly to the evolution of refined methods of births-averted estimation and related problems in India. The COMPSIM model in particular is likely to further this evolution.

Research problems

Simulation models are not a panacea for problems of family-planning programme administration in the developing countries. There are a number of problems in the application of these models that require special attention.

One major problem is deciding how to handle sampling error in the simulated results. Researchers often circumvent this problem by increasing sample size, certainly a practical solution, given the capacity of high-speed giant computers. However, this solution cannot be applied in all cases; it is still necessary to apply theoretical statistical inference procedures to simulated results, and to examine the problems that arise therefrom.

Second, in applying simulation model techniques to the developing countries (such as India) the problem of input distributions often arises. These inputs, for so vast a country as India, must be in the form of regional estimates, which are lacking now. In other words, methods must be developed for estimating, from the limited data actually available, model input data that will be useful in simulation models. It may be noted in this connexion that computer models can be used in this field, leading (it is to be hoped) to new estimation methods.

Third, because simulation results are subject to sampling error, it is always efficient to restrict simulation to only that area or segment where it is necessary. This leads to the development of mixed models, where part of the model is a Monte Carlo simulation and the rest based on expected values. This field needs to be further explored and strengthened.

Finally, it is time that some attempt be made to systematize the many demographic computer model efforts that have been carried out around the world during the past decade or so. The construction of computer models involves large amounts of time and money, and any avoidance of repetition would be helpful. I therefore suggest that the Population Division of the Department of Economic and Social Affairs, United Nations Secretariat, or some such international body, give serious consideration to the following goals:

(*a*) Providing a framework for describing and assessing basic computer models in the study of both natural and controlled fertility. This will involve working out the types of data required, computer facilities needed, a hierarchy of models (depending on the accuracy and depth of insight sought) and so on;

(*b*) Providing an information manual for all existing models. A researcher faced with a specific problem could then first consult the manual to find an appropriate, existing model. Only if it were necessary would he then develop a new model of his own;

(*c*) Providing better co-ordination, through international seminars, among various research projects. Rather than being only special-purpose tools, as they are at present, demographic models could then be designed, wherever possible, to deal with larger and more general aspects of the area of research.

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SUMMARY REPORT

DEMOGRAPHIC MODELS AS TOOLS FOR ESTIMATING BASIC DEMOGRAPHIC MEASURES FROM INCOMPLETE DATA

In view of the multifarious and rapid developments that have been taking place in the estimation of demographic measures from incomplete and inaccurate data, and the emergence of new techniques in that area, as well as the increasing number of demographic surveys and censuses, the Group felt that the manual on methods of estimating basic demographic measures from incomplete data, compiled by the Secretariat in 1967,[1] needed to be brought up to date. When the manual was compiled, the developing world was characterized by a fairly static fertility situation, although mortality was declining. Since then there has been widespread decline in fertility and in mortality. While the 1967 manual mainly emphasized levels of fertility and mortality, fertility and mortality trends have since become a major concern. The Group accordingly recommended that efforts should be made by the United Nations Secretariat to prepare a new manual, which would represent a compilation and systematization of recently developed techniques for the evaluation and estimation of basic demographic measures applicable to the demographic situation of the developing countries, where both fertility and mortality were undergoing changes.

There is also a need for improvement in the area of mortality estimation, particularly with respect to model life tables.[2] When applied to the developing countries, and to some developed countries as well, mortality estimates sometimes deviate from the Coale-Demeny family of regional model life tables. Such deviations tend to occur under conditions of culture and environment different from those prevailing in Europe, on which the empirical basis of the Coale-Demeny model life tables mainly rests. For instance, discrepancies arise in some developing countries where there is higher female than male mortality; in some developed countries where gaps between male and female mortality are getting wider; and in some countries where relatively high rates for child mortality prevail compared with those for adult mortality. In that connexion, one should note the flexibility of the logit system,[3] which has the merit of being extendable by certain mathematical techniques to a four- or five-parameter system. However, it is doubtful whether such an unwieldy system, though technically feasible, would be of much use. It would be better to seek to identify ecological and environmental conditions within which satisfactory fits to age-sex patterns of mortality could be obtained with one- or two-parameter systems. Alternatively, adaptation of existing model systems to a population may be accomplished by splicing together different levels and different steps over time; this will be possible only in cases where there is enough guiding evidence.

Existing United Nations model life tables also need to be revised and brought up to date.[4] A possible way of expediting this would be to undertake, in conjunction with the World Health Organization, a more extensive study of the causes of death, in which connexion more data are needed. In improving model life tables, consideration should be given to the possibility of projecting further advances of life expectancy at birth beyond the currently assumed limit of 77.5 years for females and 75.0 years for males. In the meantime, efforts should be made to consider all the available methods of constructing model life tables, including those developed on the basis of the logit system and the Ledermann model.[5]

With respect to fertility estimation, and with particular reference to patterns of age-specific fertility, the Group felt that the recently published model fertility schedules of Coale and Trussell,[6] which took account of nuptiality, were useful for areas in which detailed data obtained by other, conventional measures were lacking.

In the further development of the Brass methods of estimation,[7] there have been a number of refinements in ways of drawing inferences about fertility and early childhood mortality through the use of data on parity

[1] *Manuals on Methods of Estimating Population, Manual IV: Methods of Estimating Basic Demographic Measures from Incomplete Data*, Population Studies No. 42 (United Nations publication, Sales No. 67.XIII.2).

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

[3] W. Brass, "On the scale of mortality in biological aspects of demography", *Biological Aspects of Demography*, W. Brass, ed. (London, Taylor and Francis, 1971), pp. 69-110; Norman Carrier and John Hobcraft, *Demographic Estimation for Developing Societies* (London, Population Investigation Committee and London School of Economics, 1971).

[4] The *Ad Hoc* Committee of Experts on Methods of Revising United Nations Model Life Tables, meeting in April 1972, recommended the revision and updating of United Nations model life tables (see E/CN/9/273).

[5] Sally Ledermann, *Nouvelles tables-types de mortalité*, Institut national d'études démographiques, Série Travaux et documents, Cahier No. 53 (Paris, Presses universitaires de France, 1969).

[6] Ansley J. Coale and T. James 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.

[7] William Brass and others, *The Demography of Tropical Africa* (Princeton, Princeton University Press, 1968), chap. III, particularly pp. 104-120.

and child survivorship by marital duration.[8] The advantage of using duration of marriage instead of age for the estimation of fertility measures is beginning to be recognized in cases where age reporting is characterized by gross misstatement. In a number of less developed countries with inadequate age reporting, superior robustness is to be expected from fertility measures obtained by tabulation of women by duration of marriage. This is because the age distribution of fertility depends very much on age at marriage, while duration-specific fertility may be regarded as more uniform. The information required is often asked for in censuses and the tabulation of duration-specific fertility involves little extra cost. The method is an advantageous one, especially in populations where the practice of birth control is negligible and in populations with almost no fertility outside of marriage.

It is very important to know more about patterns of errors in demographic data, particularly misreporting of age in the developing countries. If an inventory could be prepared of types of such misreporting, together with hypotheses as to their aetiology, then it might be possible to establish model patterns of age misreporting, which would be useful for demographic estimation.

New dimensions in population projections: role of demographic models

Demographic projection includes not only the total population projections but also projections of the population by labour force, urban/rural population, households and families, educational characteristics and so on. Throughout the Group's meetings, the discussion centred on the total population projections that provided the basis for such specialized projections. The Group also considered three types of demographic projections according to their purpose: (*a*) population forecast, (*b*) analytical projections studying influences of the component factors of population structure and growth and (*c*) normative projections with concrete demographic targets.

Demographic projections themselves are regarded as a type of demographic model, namely, the descriptive macro-simulation type. The model in current use is the "cohort-component" method, based on the application of successive schedules of age- and sex-specific fertility, survival and international migration rates to a bench-mark population. In United Nations projections, as in others, it is tacitly assumed that the demographic transition coincides with a gradual enhancement of social and economic development, with resultant declines in mortality and fertility. These declines are sometimes conceptualized as being accelerated by existing or anticipated population policies and family planning programmes in given individual countries.

Most population projections have provided a range designated as low and high variants. However, experience shows that the actual growth of population in the years close to the initial date of the projections sometimes goes beyond the projected range. It is suggested that a possible remedy to this problem might be to widen the projected range immediately after the starting date of the projection or to provide a range of estimates of the base population instead of only one base population.

Given adequate data, in a cultural setting of non-ambiguous marriage, the introduction of marital status and the use of illegitimate and legitimate fertility rates to derive fertility rates will provide a more realistic framework for the projection results, but not necessarily improve their accuracy. There is more constancy in the proportion of the never-married and in marital fertility rates than in the age-specific fertility rates over time. Fertility rates derived in conjunction with the pattern of change of marital status will help in the better understanding of population dynamics. In this connexion, the Group felt that the Coale-Trussell model would be useful for improving the United Nations system of world population projections. An alternative, cruder method of taking nuptiality into account would be to block ages 15-44 and take the proportion currently married.

Current techniques of demographic model building make it possible to make the short-range projections for ages 5-14 with relatively greater confidence than the long-range projections. The Group thus suggests that, within the entire scheme of population projections, emphasis should be placed on short-range projections.

In presenting projection results, it would be very useful to make a distinction between surviving members of the initial population born before the projection period and the survivors born during the projections period, since the former can be estimated more accurately than the latter.

With reference to developing countries, the Group did not feel that to rely on intricate socio-economic demographic models in order to estimate future levels of fertility and their speed of change was a very promising strategy. It would be more difficult to estimate future changes in possibly relevant socio-economic factors than to estimate the fertility parameters themselves. Accordingly, the Group proposed that more efforts should be made to ascertain interrelationships between demographic variables themselves (fertility, mortality, nuptiality, migration, growth rate and so on), as these types of interrelationships would be most useful for future projections.

With regard to the usefulness of simulation models, and particularly micro-simulation models, for demographic projections, the Group felt that if demographic projections were interpreted in a narrow sense, in other words, as referring only to the process of calculation, then micro-simulation models were of limited use. But if demographic projection was construed as including

[8] See, for example, Jeremiah M. Sullivan, "Models for the estimation of the probability of dying between birth and exact ages of early childhood", *Population Studies*, vol. 26, No. 1 (March 1972), pp. 79-97.

the time-consuming process of basic data evaluation and studies leading to the formulation of assumptions on future fertility and mortality, then more assistance could be expected from micro-simulation. From the latter perspective, the use of micro-simulation in projection work should be encouraged.

Demographic models to assess the impact of population policies

It is necessary to consider two aspects of the problem of how to incorporate the factor of changing population policy into hypotheses about future levels and patterns of demographic parameters (especially fertility) for developing countries. First, are the policies specific enough to guide government actions, and can such actions be carried out effectively and successfully? The Group felt that those questions were better researched by techniques other than simulation studies. Second, are the specific action programmes derived from the general policy goals suitable and effective enough to achieve the latter goals and are the action targets specified in terms of the so-called "intermediate variables" properly selected to meet the policy goals? With regard to the latter point it was argued that demographic models, and particularly micro-simulation models, were a useful tool for evaluating the possible results of government actions with respect to policy. It might prove advantageous to use micro-simulation models to incorporate policy factors into long-range projections, particularly with regard to the fertility component.

The Group discussed the advantages and disadvantages of employing demographic simulation analysis. It was pointed out that a simulation analysis could be used for several purposes, for example in the theoretical exploration of demographic processes that, because of the lack of data or the nature of thet problem, cannot be studied empirically. More specifically, family-building models are useful for indicating the relevance of particular factors, for clarifying mechanisms, for testing and assessing the validity of proposed indices of fertility change and for identifying the conditions under which a specific policy might be more or less effective in reducing fertility.

The Group also discussed the choice between macro-simulation and micro-simulation. Many participants felt that micro-simulation might be the only possible choice if the problems to be investigated were complicated ones. In such cases, if the deterministic approach is used, the number of categories to be included and the range and number of analyses to be treated rapidly become unmanageable even for large-storage computers. But under other circumstances, where the problems are less complex or the model has to be simple because of data limitations, a macro model might give better service.

A common problem is the lack of data for micro-simulation analysis. A major criticism levelled against micro-simulation models is that they usually demand detailed data, which must cover every part of the reproductive process to a degree that is seldom achieved even in the most statistically developed countries. As a consequence, fairly eclectic data must be used in applying the models. This gives rise to the question whether the biological data used in the models are valid generally.

In addition to the current severe constraints in the availability of data for micro-simulation models, the lack of knowledge about interrelationships among demographic variables and biological variables limits the scope and adequacy of the logical structure of demographic models dealing with the assessment of policy impact. The theoretical development of demography through more empirical research should go hand in hand with the development of more comprehensive and more realistic micro-simulation models. The latter would certainly provide an important feedback to promote the development of the former.

Whenever it proves unfeasible to treat the impact of social or economic factors upon fertility or nuptiality through cohort-component projection techniques, micro-simulation models might offer a feasible alternative, in the sense that their use could throw light on some important aspects of demographic and socio-economic processes. It was recommended that the United Nations should promote or stimulate further development of micro-simulation models, including basic research and data estimation, since such models could prove to be a useful policy analysis tool in coming years. One possibility might be for the United Nations to provide an inventory of all existing models of micro-simulation in that area and prepare guidelines or manuals concerning the use of basic computer simulation models for users in developing countries; such guidelines would deal with, among other things, types of data required, computer programmes, facilities required and the hierarchy of demographic models, depending on the accuracy and scope of analysis. Broadly, the Group recommended that the United Nations should serve as a clearing-house for information on demographic models.

The Group stressed the need to use micro-simulation models to tackle specific problems of estimation and policy assessment. It would be helpful if the United Nations could convene another meeting of experts to discuss and review the contributions of micro-simulation models towards improved methods of demographic analysis. The findings should then be widely disseminated.

In general, the Group concluded that micro-simulation in population studies should be encouraged, as micro-simulation can be an important aid in the study of the impact of economic and social factors on fertility. They emphasized, however, that if models are too ambitiously detailed there is a danger of saddling the user with an impossible job of estimation.

The Group suggested, finally, that extension of the family demography models to include variation in addition to expected values would be useful, particularly when the effects of policy decisions are a matter for concern.

PROGRESS REPORT ON POPINS: A WORLD-WIDE POPULATION INFORMATION SYSTEM

*United Nations Secretariat**

Introduction

In the field of population, as in such other issues of global concern as nuclear energy, agriculture and development, the importance of information dissemination and exchange is being increasingly recognized. Several factors may be thought to be responsible for this development. First, there is the increasing interest in and preoccupation with national, regional and world population trends. Added to this is the recognition that these trends can no longer be seen as the sole concern of demographers, but rather that population and population problems affect virtually every aspect of society; relations between, on the one hand, population and, on the other, social, economic, cultural, environmental and other factors have come to constitute an integral part of what is referred to as the "population problem". In the third place, there has been a very rapid expansion of the field of population policies, programmes and supporting activities as, in response to prevailing demographic trends, policies and action in the field of population become a matter of interest to a growing number of countries, decision-makers and planners, scholars and those engaged in action programmes. This "opening up" of the population field has been accompanied by an unprecedented growth in the volume of population literature on a world-wide basis. No simple and completely satisfactory method exists for ascertaining the amount of literature in the field of population. However, for anyone working in the field there is more than sufficient evidence on a day-to-day basis to confirm this "documentation explosion". Of course, all these developments would not have had the impact on information activities were it not for a revolution of no less importance in the technology of gathering, processing and disseminating information.

Background of POPINS

The importance of the systematization and exchange of population information was brought out in the discussions of the United Nations Population Commission at its seventeenth session in 1973. In its report on this session the Commission "expressed interest in the possibility of computerizing demographic information along the lines being developed by UNESCO in the social sciences. Several members recommended that the Population Division should collaborate with CICRED (the Committee for International Co-ordination of National Research in Demography) in this project".[1]

Further on in the same report the Commission noted that "the need for an international bibliographic system on population matters was felt, and members of the Commission indicated that such a system could provide most valuable services in view of the rapid increase in the publication of studies on population which makes it most difficult for government officials and scholars, particularly those in developing countries, to keep abreast of developments."[2]

The World Population Plan of Action adopted at the 1974 World Population Conference emphasizes the dissemination and exchange of information in the field of population repeatedly. In paragraph 15 the Plan singles out the exchange of information as one of the major means (besides increasing international activity in research, and the provision of assistance) for attaining its primary aim of expanding and deepening the capacity of countries to deal effectively with their population problems. In addition, the Plan of Action includes a number of recommendations on information activities, specifically addressed to governments, international organizations, regional and national research institutes and voluntary organizations. Thus paragraph 80 of the Plan states that "special efforts should be made to co-ordinate the research of regional and national institutions by facilitating the exchange of their findings." Paragraph 90 notes that "voluntary organizations should be encouraged to share experience regarding the implementation of population measures and programmes." In the following paragraph (91), international organizations, both governmental and non-governmental, are requested to strengthen their efforts to distribute information on population and related matters. Countries sharing similar population conditions and problems, are invited in paragraph 102 of the Plan to exchange experience in relevant fields. Finally, in paragraph 100 the Plan states that "International co-operation should play a supportive role in achieving the goals of the Plan"; one of the forms this support could take, the Plan notes, is "furthering the exchange among countries of information and policy experiences".

* Population Division of the Department of Economic and Social Affairs.

1 *Official Records of the Economic and Social Council, Fifty-sixth Session, Supplement No. 3*, para. 255.
2 *Ibid.*, para. 361.

In response to the views expressed by the Population Commission, CICRED, in collaboration with the Population Division of the United Nations Secretariat's Department of Economic and Social Affairs and with the International Labour Office, organized a meeting on demographic information storage and retrieval. Held in Mexico in September 1975, this meeting brought together representatives of population information services; information systems; major population research centres and other interested organizations. The meeting noted the need to effectively identify, systematize and disseminate scientific and technical population information; to redress the serious imbalance in the flow of information between developed and developing countries; and to make population information rapidly available for decision making, planning, research and education in the context of social and economic development. Accordingly, they recommended the establishment of a world-wide population information system, referred to as POPINS. As a first step, the meeting proposed the undertaking of a feasibility study on such a system and the establishment of a small Technical Task Force and an Interim Steering Committee to prepare such a study.

The POPINS Interim Steering Committee (ISC) held its first meeting at Headquarters in January 1976, under the chairmanship of the Director of the Population Division of the Department of Economic and Social Affairs. At that time the ISC developed the terms of reference of the study of the Technical Task Force (TTF) and nominated its co-ordinator and its five members, representing different regions as well as organizations specifically interested in information activities. The TTF met during April 1976 in Honolulu at the East-West Center to start the drafting of its study. Individual members of the TTF continued to work on the study after the Honolulu meeting, and the TTF met again in Princeton, N.J., at the Office of Population Research in September 1976 in order to finalize its study. In the third week of September a joint meeting of the ISC and TTF was held in Washington, D.C., at George Washington University. At that meeting the ISC approved the TTF study and prepared its report to the United Nations. The proposals approved at the joint meeting were submitted to the Population Commission at its nineteenth session in January 1977. The Population Commission re-affirmed the importance (as stated in the World Population Plan of Action) of the sharing, exchange and dissemination of information in the field of population, and submitted a draft resolution to this effect, with specific recommendations, to the Economic and Social Council for adoption at its next session. The Council is taking up consideration of the resolution in its session now in progress.

A MULTILINGUAL THESAURUS FOR POPINS

The same meeting, organized by CICRED, that proposed the feasibility study of a population information system also recommended the preparation of a multilingual demographic thesaurus. Although there already exist a number of thesauri related to one or another aspect of population,[8] most of these are concerned principally with specific aspects of the population question. The need for a multilingual thesaurus of terms, covering demographic and population studies in general but compatible with the existing thesauri, would therefore fill an existing gap. The preparation of the thesaurus was undertaken by CICRED. The new thesaurus is to differ in one other respect from most existing population-related thesauri: the decision was taken at the outset to prepare the thesaurus in three languages—English, French and Spanish. Since one consideration underlying the preparation of the thesaurus was that it should serve as a tool for a world-wide system, coverage of at least the major languages was indicated. Three teams were thus set up, one for each of the languages. Each consisted of representatives of demographic research institutes, familiar with information treatment; their work is being co-ordinated by a consultant.

In the first phase of work the different teams drew up lists of terms that were susceptible of being entered into the thesaurus as descriptors. These word lists, together with other materials (and taking into account the existing thesauri) were consolidated in a meeting of a working group at Chapel Hill, North Carolina, in June 1976. In the second phase, these descriptors were assigned to broad subject categories and the resulting classification was examined at a second meeting of the working group in San José, Costa Rica, early in 1977. Finally, the third stage, now being implemented and to be completed in early 1978, is devoted to the question of "relations" between descriptors. It is the intention that upon completion of this stage, the thesaurus will be tested in a number of demographic centres to eliminate any imperfections. After the necessary modifications the final version is expected to be published at the end of 1978. The thesaurus will appear separately in the three language versions and will contain, it is anticipated, some 3,000 descriptors, distributed among some 18 broad headings.

POPINS: THE CONCEPTUALIZATION STAGE

Faced with the severe time constraints imposed on their work, together with the complexities of the tasks involved, the TTF and ISC concentrated in their reports on basic principles and recommendations. These constituted what the ISC referred to as the "conceptualization stage" for a world-wide population information system. It is not possible to give an exhaustive description of the findings and proposals emerging from the TTF study and ISC report in this brief progress

[8] These include the "Fertility modification thesaurus, with focus on evaluation of family planning programs", prepared by Columbia University; the "Population/family planning thesaurus", University of North Carolina; and the "Population/fertility control thesaurus", George Washington University, to name but a few of the most important.

report. The major conclusions, however, can be summarized as follows:

(*a*) The development of a world-wide population information system is feasible and such a system can and should be developed consistent with the following aims: to provide comprehensive subject coverage; to include all relevant published and unpublished literature; to encourage the active participation of both developed and developing countries; to ensure that institutions of individual countries have access to all population information about their own countries; to reduce unnecessary duplication of services; to provide a channel through which related systems and services could share their experience; and to improve the two-way flow of information between developed and developing countries and between members of a region.

(*b*) The primary purpose of such a system would be to serve the needs of its users. An essential condition for achieving this objective is better access to and availability of materials, particularly national materials at national levels. The system, therefore, should be capable of providing the user with the full range of information on his own country, including adequate back-up services. Hence, the establishment and/or strengthening of national centres becomes a basic prerequisite for the functioning of the system. In consequence of this primacy of access to national information, the proposed system is conceived of as a decentralized one; emphasis should be on the active collaboration between countries, and on co-operative arrangements among them. On a world-wide scale, the successful operation of POPINS would imply the need for continuing and close liaison between a central co-ordinating unit and each national organization, with regional centres or units as important links between the other two.

(*c*) The major need for increased access to population information evidently exists in the developing countries. Most developed countries already have access to the technology required for a national information system and possess the resources for developing their own information services. These include limited holdings of the basic population literature; extensive holdings, outside the country, of national studies that are not available within the country; an inadequate national system or, more often, no system at all and no appropriate infrastructure for developing such a system; lack of access to suitable technology; shortages of trained staff and training facilities; lack of relevant information in existing services; and limited awareness of population information systems and of their value. Reducing these constraints should, therefore, be a fundamental part of the development of a world-wide system. Accordingly such a system should be accompanied by extensive supporting programmes, in particular, training programmes at different levels.

(*d*) The proposed system should take full account of the current and potential capacities of existing systems. The review of existing population information services revealed that the activities of existing systems are considerable, but that the degree of their utilization is limited. It was estimated that although such services could in principle cover a major proportion of the world's literature on population, their expansion would not be followed automatically by a corresponding increase in the use of the information, especially in developed countries. The greater involvement of national governments, or of organizations selected in consultation with governments, would be essential to stimulating user activities in the developing countries and regions. Within this broader context the development of a world-wide system should be approached through close collaboration with existing systems.

(*e*) A world-wide system should take into account the diversity of "technical" approaches to population information activities and programmes. Computerization has much to commend it in the context of a world-wide system, particularly in the location and "repatriation" of materials and in broadening the scope of materials covered. Computerization by itself, however, will not aid significantly in overcoming the existing constraints; in fact computerizations without appropriate back-up services, including programmes of technical assistance and training at national levels, might have the effect of reinforcing existing constraints. Even so, it should be emphasized that technology has an important function in the development of a world-wide population information system, and that it would be difficult to conceive of such a system without computerization.

(*f*) The establishment of a world-wide population information system can be justified only if it serves a wide range of users, not only researchers but also policy makers, planners, practitioners and other members of the population community. The subject matter of the system should, therefore, be broad in scope. Accordingly, the provisional general list of topics covers a wide subject area, including: demographic analysis and research; research and analysis of the interrelations of population and socio-economic developments; integration of population factors in development planning; population policies; action programmes and other programmes designed to influence demographic behaviour; and other supporting activities and programmes.

(*g*) As already suggested, the operation of such a system as the one proposed here envisages units at different levels. Central to the whole system would be the national centres, which would assume such responsibilities as building a core of essential literature and of the country's periodical literature, including the so-called "non-conventional" or "fugitive" materials; compiling and up-dating of national bibliographies; providing bibliographical citations (and, as appropriate and possible, abstracts of publications) to the central co-ordinating unit; making services available to national users; and determination of training requirements. The regional centres would also be an important element, the functions of which would include building up a core periodical literature of the region; the promotion of national bibliographies by national centres; and servicing users of regional materials. The central co-ordinating unit would be concerned principally with the over-all operation of the system. This would include the development of required capacities and mechanisms for submission of inputs; merging of national and regional inputs; publication of printed bibliographies; maintenance of the thesaurus; and the provision, on request, of technical assistance and other consultancy services.

Institutional arrangements

From its inception, POPINS has had close relations with the United Nations. The first meeting organized by CICRED, it may be recalled, was convened in response to the earlier decisions taken by the United Nations Population Commission. This meeting decided also that the reports of the Technical Task Force and Interim Steering Committee would be submitted for consideration by the Population Commission at its nineteenth session. The Director of the Population Division of the Secretariat's Department of Economic and Social Affairs acted as chairman of the Interim Steering Committee, which counted amongst its members representatives of United Nations regional commissions and demographic centres.

The report of the Interim Steering Committee concluded that the over-all co-ordination of the system would be best facilitated by location within the United Nations system and proposed that the POPINS Working Group, which would carry out the second stage of systems plannings should be located within the Population Division of the Department of Economic and Social Affairs, United Nations Secretariat.

In its discussions of POPINS, the Population Commission emphasized the importance of population information activities and the need for increased access to population information, especially in the developing countries. Members of the Commission noted that the further development of POPINS should be carefully considered, taking into account several factors that were also emphasized in the TTF study and ISC report. These include the operating costs of the system; the number of users; the need to provide assurance that countries providing inputs would also have access to the information provided; the study of different options and their relative cost-benefit ratios and the relationship between POPINS and other systems. The Commission recommended, as noted, that further work should be pursued on an exploratory basis. Finally, the Commission adopted a draft resolution, for adoption by the Economic and Social Council, requesting the Secretary-General to continue exploratory studies, in consultation with Governments, with the collaboration of regional commissions and specialized agencies, and with the advice of experts. The draft resolution urged that, in these studies, emphasis be placed on:

(*a*) Gathering information about the volume of literature, institutions, potential users and their needs, especially by means of in-depth studies, on a small number of national and regional institutions, to estimate the amount of information that exists and to identify current and future needs of users;

(*b*) Consultations at the national and regional levels on arrangements for collaboration with existing programmes, especially concerning discussions with possible funders of the system; and

(*c*) Aspects related to the design of the study, with particular attention to the operating costs of the possible options of the system at the national, regional and international levels.

The Economic and Social Council, at its sixty-second session, approved the Resolution as proposed by the Population Commission.

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