ST/ESA/SER.A/66

Manual IX

The Methodology of Measuring the Impact of Family Planning Programmes on Fertility

United Nations

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Department of International Economic and Social Affairs
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Manual IX

The Methodology of Measuring the Impact of Family Planning Programmes on Fertility

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NOTE

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FOREWORD

The Population Commission of the United Nations at its seventeenth session requested the Secretary-General to include in the work programme of the United Nations studies designed to increase the effectiveness of family planning programmes and to improve assessment of the effectiveness of these programmes.[1] In partial fulfilment of this request, the Secretary-General convened the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility at Geneva from 20 to 27 April 1976.[2] Among the results of that meeting was a recommendation, endorsed by the Population Commission at its nineteenth session, that the United Nations should develop a manual on methods of measuring the impact of family planning programmes on fertility in order to disperse more widely knowledge in this area, which is currently found among only a few experts in even fewer countries. This text was developed in compliance with that recommendation and in the hope that, with its assistance, expertise in family planning evaluation will become a part of the resources of every national family planning programme.

[1] *Official Records of the Economic and Social Council, Fifty-sixth Session, Supplement No. 3*, paras. 264 and 346.

[2] For participants in the Expert Group meeting, see *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E. 78.XIII.2), p. 137.

Most chapters of this *Manual* include illustrations utilizing the actual statistics of particular countries. However, in order to avoid publishing evaluation results that may be at variance with results done by national experts who may have more intimate knowledge of relevant conditions in their countries, this text does not identify any country by name. Instead, each country is given an alphabetical indicator, such as Country A, which is its reference throughout the text.

This *Manual* was developed by the Population Division of the Department of International Economic and Social Affairs of the United Nations Secretariat in close collaboration with the Committee on Demographic Aspects of Family Planning Programmes of the International Union for the Scientific Study of Population (IUSSP). Members of the Committee acted as consultants to the project. Several chapters of this text were reviewed by the committee at its Seminar on Patterns of Response to Family Planning Programmes, which was convened at Liège, Belgium, from 12 to 15 April 1977. The comments were provided to the authors, who took account of them in revising their texts. John A. Ross, Associate Professor of Public Health, Columbia University, New York, read the complete text, which profited greatly from his comments and suggestions.

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Explanatory notes

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

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., 1974/75.

Use of a hyphen (-) between dates representing years, e.g., 1973-1975, signifies the full period involved, including the beginning and end years.

Reference to dollars ($) indicates United States dollars, unless otherwise stated.

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

INTRODUCTION*

*United Nations Secretariat**

The second half of the twentieth century has witnessed a marked increase in government use of policy instruments to effect demographic, social and economic change. And this phenomenon has become more widespread in both developed and developing countries. Along with family and child allowances, special grants and conveniences for mothers of newly born children; and proscriptions and provisions relating to abortion, sterilization and the supply and distribution of contraceptives, the national family planning programme has become widely used as a measure directed towards influencing human reproductive behaviour. It is typical, however, of policies designed to influence fertility and other demographic and social phenomena that researchers have had only from meagre to moderate success in measuring the extent to which the policy measures have achieved the intended objectives.

Over the past two decades, major population policy efforts in many developing countries in particular have been centred on large-scale family planning programmes. It is important, consequently, that the tools for evaluating the effect of these programmes should be honed to the point where they can be used with reasonable facility and efficiency and with maximum confidence as to the validity of the results that they produce.

A. Types of evaluation

The national family planning programme is a wide assortment of activities geared towards an ultimate objective. But achievement of the final goal depends necessarily upon accomplishments at different levels or, in other words, upon attainment of a variety of subobjectives. Each of the latter goals can be subjected to evaluation; and, as good administrative practice, this task is done periodically as a guide in operational strategy. Thus, evaluation is done in terms of both intermediate and ultimate objectives, as well as in light of plausible outcomes of the programme which are not specified as goals:[1]

(*a*) *Intermediate objectives.* A number of intermediate goals can be subjected to evaluation, including efficiency of workers, periodic achievements of workers, recruitment of acceptors, programme logistics and yield from communication efforts;

(*b*) *Long-term or ultimate objectives.* Such objectives may be, among other things, reduction of infant and maternal mortality and improvements in the general well-being of mothers and children; reductions in subfecundity or infertility; reductions in induced abortions; a decline in fertility; or achievement of a specified rate of population growth.

Relatively little has been done to ascertain, reliably, what the planning programmes established for various health-related purposes have accomplished. Conversely, much effort has been devoted to perfecting methodologies for assessing the impact of the programmes on fertility. Further, most programmes of as long as three years duration have been evaluated for fertility impact, even where the programmes did not have fertility decline as an objective.

B. Purpose of the manual

This *Manual* is intended as a guide by which middle-level professionals may assess the impact of family planning programmes on fertility. Its further purposes are to assist programme directors in improving management through better evaluation; to present in a single volume a complete methodological statement on the currently used evaluation tools, so that individuals engaged in family planning programme evaluation research may have a handy reference; and to provide material for teaching and training courses in the methodology commonly applied in this field. The *Manual* offers illustrations and principles designed to assist researchers who have reasonable competence in mathematics and statistics to apply the accepted methods of evaluation and offers suggestions as to how the results of evaluation obtained by each method should be interpreted. The *Manual* is to serve as an aid in the use of the following methods that have been advanced by various scholars as being appropriate tools for assessing family planning programme impact on fertility:

(*a*) Standardization approach;

(*b*) Standard couple-years of protection (SCYP);

(*c*) Component projection approach:

(i) Computerized model;

(ii) Model for desk calculators;

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* Population Division, Department of International Economic and Social Affairs.

[1] For a more detailed discussion, see W. Parker Mauldin and Gwendolyn Johnson-Acsádi, "Introduction", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 1–16.

(*d*) Analysis of reproductive process;

(*e*) Multivariate areal analysis;

(*f*) Simulation;

(*g*) Experimental designs;

(*h*) Fertility projection/trend analysis (illustrations of this method are given in annexes I and II).

C. Issues of evaluation

It is established that fertility trends are influenced by a large assortment of demographic, social, cultural and economic factors, and that determining the contribution of any one of those factors to fertility change is an exceedingly difficult task. Yet it is precisely this task that the evaluator seeks to accomplish when undertaking evaluation. If there has been a change in the level of fertility, the task is to determine what portion may be ascribed to family planning programme activities. Or, if no change is evident, it is necessary to ascertain what the level of fertility would have been had there been no family planning programme, because the stability may be due to counter-effects of lower fertility among some women due to the programme and rises in fertility among others as a result of certain modernization factors. In working through either or both of these problems with the methodologies now in use, a number of methodological issues must be dealt with, and there is no real consensus as to how this task should be done.[2]

These issues, upon which hinge evaluation studies, are: (*a*) the estimation of potential fertility; (*b*) correlated variables and interaction; (*c*) uncontrolled variables; and (*d*) independence of method. They represent the recognized limitations of evaluation methodology, and some of them are encountered no matter what method of evaluation is being applied. Evaluators must have a thorough understanding of these issues and must take them into account in applying the methods and in interpreting the results.

Except for the issue of independence of method which, when replication by different methods is sought to determine validity of results, is also one of the criteria for choice of method, these issues are not discussed here, owing to their complex nature and to the fact that they must be treated exhaustively or not at all. Such a treatment is aptly accomplished in the two relatively recent publications that the reader is urged to consult for a thorough discussion of the issues and problems of family planning programme evaluation.[3]

D. The method to choose

This section contains a brief discussion of some of the considerations that enter into the choice of a method or evaluation approach. It is not intended to be exhaustive but to alert the researcher to the problem of choosing an evaluation approach in light of the methodology currently used. A more analytical treatment of this subject is offered in a recent article which examines the circumstances in which it is suitable to apply certain categories of methods.[4] The reader might find it also helpful to examine the matter of method choice within the framework provided in that source.

Researchers developed the several methods currently used to determine how much effect a family planning programme has had on fertility within a given segment of time evidently in response to, among other things, the needs of administrators for the information, the type and amount of useful data at hand, the degree of technical expertise that could be marshalled for the purpose and the urgency attached to finding an answer. Although some of the methods were devised as much as a decade and a half ago, in large measure, data availability and amount of technical expertise or familiarity with a method are still among the principal reasons that a researcher chooses a particular method as the tool for evaluation. Clearly, knowledge of family planning programme evaluation techniques should be more widely disseminated. Only a slight introduction to the structure of each evaluation technique or method is sufficient to disclose that they are essentially dissimilar, being based on different hypotheses, assumptions, data and base populations. Thus, a choice among them should involve more scientific considerations than, for example, familiarity with the method.

The question concerning the method that should be employed is faced by any evaluator who has the minimum data required and the technical competence to execute more than one method.[5] But even if all conditions for utilizing all of these methods were fully met, selection of an evaluation approach would not be a simple matter. First, there is a lack of agreement among scholars as to the relative efficiency of the various approaches;[6] each approach has certain advantages and disadvantages. Further, some methods are applicable in some circumstances and not in others. And there is no consensus as to when each is the method to be preferred or as to the meaning and relative validity of the results obtained.

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[2] Excellent guidance is found in C. Chandrasekaran and A. I. Hermalin, eds., *op. cit.*; and in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E. 78. XIII. 2), especially pp. 3–42 and 137–161.

[3] *Ibid.* These sources contain extensive discussions of these methodological issues.

[4] Jacqueline D. Forrest and John A. Ross, "Fertility effects of a family planning programme: a methodological review", *Social Biology* (in press).

[5] The United Nations Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility, which was convened at Geneva in April 1976, found that the factual basis does not exist for choosing a method of evaluation according to strict scientific criteria. It accorded highest priority to research directed to developing knowledge in the sphere. It took note, however, that in the selection of a method certain criteria could be applied. See "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 137–161.

[6] The United Nations is attempting to alleviate this problem by sponsoring a number of national case studies in which several or all of the measures are applied to a single set of data with the view to ascertaining the relative yield (in terms of birth rate decline due to the programme) of each method applied. For information on the first three case studies, see *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues*, pp. 43–136.

Some programmes will have been in existence for only a few years and others much longer; some will have been implemented in a relatively stable society and others in a climate of social, economic and cultural upheaval. These conditions influence the method of choice. The researcher should therefore, to the extent possible, become thoroughly familiar with all methods before making a choice, and the text of this *Manual* is designed to facilitate this undertaking. The following discussion is not intended to serve as a guide to choosing a method, but to point out some of the reasons why the researcher might choose or reject a particular approach.

In addition to such considerations as the information needed and the data available and technical feasibility of application, some of the principle questions determining the choice of methods are: (*a*) what it is desired to measure; (*b*) the population for which evaluation is needed; (*c*) whether it can separate programme from non-programme effects; (*d*) the time period to which the measurement relates; and (*e*) the independence and reliability of the method. It is generally recognized as a short-coming of the methodology of evaluating programme impact on fertility that it is difficult to determine the degree to which the reproductive behaviour of persons who do not accept a method from the programme is none the less influenced by it is not an easy matter. Hence, there is concern about what a method actually measures.[7] Further, in certain circumstances the aim of evaluation is to determine births averted for those who accepted a method from the programme; in other cases the intent may be to determine births averted, i.e., programme impact on fertility, in the entire population as a whole. And it is difficult to know whether and to what extent the change in fertility has occurred in response to the programme or is a result of changes in social, demographic and economic conditions. Thus, when this question is of interest, the method should be capable of separating these effects.

Because time can be seen either as a short- or a long-run element with differing consequences, it is crucial in evaluation. First, there is the question how long a programme must run before its impact can be measured. Then the researcher must decide whether the interest is in short-term effects, which might be deduced from changes in period rates brought on by birth spacing, or in long-term effects suggested by the completed fertility of women 45 or 50 years of age. Of course, if the programme has been in effect for a sufficient period of time, the researcher would in most cases wish to measure both its short-term and its long-term effects.

The current state of knowledge about evaluation is not such that the results of evaluation exercises can be accepted without question. This situation is due to a variety of problems and issues which are dealt with in the chapters that illustrate the methods. Confidence in the product derived by application of a specific method is enhanced if there is replication of results when one or more additional evaluation approaches are used. Consideration of a method to be applied in establishing replication is whether it is independent of the other methods used. Reliability of results obtained by a method may also be established in other ways, as will be observed from material provided in the succeeding chapters.

1. *Objective of the evaluation*

The evaluator may be interested in determining either the impact of the programme on acceptors' fertility or in the total effect of the programme. Fertility projection/trend analysis is a means of assessing total programme effect, for it attributes a close association between projected fertility and the movement of measures of actual fertility to the effects of the family planning programme; if no association were evident, it would be assumed that the programme had not had an effect.

Standardization, which, generally speaking, should be a first step in evaluation, is capable of establishing how much of the change in fertility was due to demographic factors of age structure and marital status, and thus also to changes in marital fertility. The latter result would indicate whether further analysis was warranted; and if so, the researcher would then choose a method to determine how much of the change in marital fertility could be attributed to the programme.

Methods that deal with acceptors only, such as experimental design, are an aid to assessing the direct impact of the programme. The indirect effect, i.e., the impact of the programme on the fertility of non-acceptors, may be determined by a number of approaches. A practical method is to obtain a measure of total programme effect and to calculate the indirect effect as the difference between that measure and the direct effect obtained by use of a method dealing with acceptors only. A note of caution is in order, however, as the approaches should be independent of each other and conflicting assumptions should be avoided.

2. *Period covered*

If the evaluation is to cover only a short period, say, less than one year, none of the evaluation approaches that has fertility as a variable would suffice. Instead, it would be required to apply some yardstick such as numbers of acceptors, with appropriate assumptions as to continuation rates and effectiveness of the contraceptive methods. The couple-years of protection (CYP) method,[8] though flawed in methodology, has been indicated as a method suited for short-period evaluation.[9] Because it is very crude, that method is not illustrated in this volume; instead, the "standard" couple-years of protection approach is offered.

When evaluation covers periods of up to five years, the standard couple-years of protection approach, which reduces programme acceptances to a single measure

[7] *Ibid*, pp. 137–161.

[8] The couple-years of protection method yields an index of the prevalence of use of specific methods. It estimates the number of couples protected against the risk of pregnancy during one year.

[9] "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", *loc. cit.*, p. 155.

combining mixes of method, age and expected fertility level, may be appropriate. It differs from CYP mainly in that its product is births averted in terms of a standard unit of contraception.

When the evaluation is to cover periods in excess of five years, both the standardization approach and the component projection approach are particularly appropriate. The latter method shows the probable course of the crude birth rate given a certain regimen of contraceptive practice. Fertility projection/trend analysis may also be considered suitable and especially if there is evidence that a strong fertility trend was under way prior to initiation of the family planning programme.[10] Regression analysis may be applied whenever the time period is at least one year.

3. *Population covered*

The population for whom the evaluation is needed is also a factor determining the evaluation approach. Case-by-case matching is a productive means of studying acceptors, but this method is not illustrated in this text. However, the approach has many commendable aspects and is to be preferred if resources and conditions permit.[11] If the evaluation is to deal with acceptors of specific methods, several approaches are possible. The component projection approach treats the behaviour of acceptors only, as does the standard couple-years of projection method.

Reproductive process analysis might be the approach to choose, provided that the data demands can be satisfied. With this method, the units of analysis are segments of contraceptive use. As summarized by Forrest and Ross,[12] this approach follows acceptors from acceptance through continuation to termination or pregnancy and birth events, and the yield is an estimate of the births averted due to utilization of programme contraception.

Some methods attempt to measure the effect of the programme by analysing the behaviour of the entire national population. If the interest is in this direction, the researcher may apply fertility projection/trend analysis, standardization or multivariate or other areal analysis.

4. *Separation of programme and non-programme effects*

Evaluation of family planning programme effects upon fertility obviously implies that the researcher will determine the change in fertility that is attributable to programme activities as distinguished from the amount of change due to factors not directly related to the programme. Separating programme and non-programme effects is one of the more difficult problems associated with family planning programme evaluation. Some evaluation approaches either do not attempt this task or merely carry an assumption, with certain conditions, that any fertility below what is expected or what has been determined to be the potential is due to the programme. Programme and non-programme effects can, of course, overlap; the latter effects can facilitate the former. However, deciphering relative effects in these circumstances calls for a different level of analysis.

Several approaches are designed to separate programme and non-programme factors. Reference has already been made to the standardization approach, by which it is possible to separate the effects of age structure and nuptiality and to determine how much change is due to changes in marital fertility, which may possibly, but not certainly, be due to the programme. Multivariate areal analysis can be applied so as to separate changes due to the programme from those brought about by social and economic improvements or by other factors, including cultural changes that may be indicative of modernization. This approach can also distinguish changes in national fertility due to the altered behaviour of acceptors from changes due to the reproductive behaviour of persons who are not participating in the programme. One view is that the most appropriate procedure for understanding the relative importance of family planning programmes vis-à-vis development is regression analysis.[13]

Another type of areal analysis suited for this purpose is experimental design, in which the populations of different geographical areas are subjected to different programme treatments. It is a method most easily implemented in the early stages of a programme, when different areas can be subjected to different degrees or quality of programme activity; and, as a control, one or more areas may be left without a programme. However, for political and moral considerations, it may not be acceptable to withold from programme treatment the population of an area merely for the sake of evaluation research.

It has been said that simulation is generally inappropriate as a method of family planning programme evaluation,[14] although some models of the component projection method incorporate features of simulation. But the impact of family planning programmes on fertility has been investigated by means of simulation models, and those investigations have been able to focus on effects attributable to factors other than programme influences.[15] However, their major strength in evaluation research appears to be in determining probable results of alternative programme strategies, in target setting and in testing the validity of results obtained by different evaluation approaches. They are said to approximate only crudely the demographic process[16] and therefore

[10] *Ibid.* See also J. D. Forrest and J. A. Ross, *loc. cit.*

[11] See H. Bradley Wells, "Matching studies", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 215–244.

[12] *Loc. cit.*

[13] "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", *loc. cit.*

[14] *Ibid.*

[15] For references, see John A. Ross and Jacqueline Darroch Forrest, "The demographic assessment of family planning programs: a bibliographic essay", *Population Index*, vol. 44, No. 1 (January 1978), pp. 8–27.

[16] See Jane Menken, "Simulation studies", in C. Chandrasekaran and Albert I. Hermalin, *Measuring the Effect of Family Planning*

are less than satisfactory as means of measuring programme impact.

5. *Availability of data*

It is well established that the developing countries, among which are the majority of countries with national family planning programmes, do not possess adequate demographic and related data. The deficiency of data for family planning evaluation is a part of the general problem of data quality and supply for these countries. Because some or all of the data needed to apply a preferred evaluation method may be lacking or defective, it may be necessary for the researcher to develop estimates or to make assumptions that would otherwise be unnecessary and frequently to do so on a tenuous basis. Often the solution will be recourse to an evaluation approach that is theoretically and technically less suitable but for which most of the required data are available. Consequently, even if all technical conditions for using a given evaluation approach are satisfied, the researcher may be forced to follow an alternative course for want of the necessary data. It is emphasized, however, that only in rare cases will there be such an insufficiency of data that it will not be possible to apply any means of evaluation. In these cases, periodic field surveys and improvements in the quality of the service statistics should be given highest priority.[17]

6. *Independence and reliability of method*

None of the evaluation techniques satisfies all evaluation requirements, and it is not yet known which method yields the most valid results. One study[18] suggests that two or more evaluation approaches should be used and that the replication of results should be taken as evidence of validity; but in certain circumstances, two different methods could yield different results, each of reasonable validity if, for example, there were differences in time span, assumptions, coverage or other important conditions. As a rule of thumb, "... two methods may be viewed as independent if they utilize different frames of reference in assessing programme impact".[19] Considerations in this respect are: (*a*) number and type of assumptions; (*b*) whether the factors utilized were demographic, biological and/or other; (*c*) the estimating technique employed; (*d*) whether the approach assesses programme impact directly or as a residual; and (*e*) whether the method is independent as a coverage.

An outstanding problem in respect to evaluation methodology is whether the evaluation approaches currently employed meet the requirement that they quantify the phenomena which they are designed to measure. The methods outlined in this text are generally thought to be adequate in this respect.[20]

The validity of the results that an approach produces depends not only upon the postulates embodied in the method but upon the assumptions that the researcher makes in order to accommodate data deficiencies and to estimate parameters that are lacking. Users of this *Manual* should therefore pay careful attention to the implications of these assumptions.

Experience has shown that evaluation results cannot necessarily be taken at face value, but must be interpreted in light of: (*a*) the quality and reliability of the statistics used in the evaluation, including biases attributable to sampling and non-sampling sources; (*b*) the methods used to correct unreliable, missing or incomplete data, which may have introduced still other problems; (*c*) the definitions and estimates of variables; and (*d*) all assumptions, as these factors affect the final product. Wherever possible, the researcher should test the effect of alternative definitions, estimates and assumptions as an aid to achieving valid interpretation of evaluation results.

Programs on Fertility, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 351–380.

[17] For a more extensive discussion of this problem, see "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", *loc. cit.*, p. 159.

[18] "Methods of measuring the impact of family planning programmes on fertility: problems and issues", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 35–36.

[19] *Ibid.*, p. 35.

[20] See, for example, *ibid.*; and C. Chandrasekaran and A. I. Hermalin, eds., *op. cit.*; "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", *loc. cit*; and J. A. Ross and J. D. Forrest, *loc. cit.*

Chapter I

STANDARDIZATION APPROACH

*United Nations Secretariat**

The essential feature of the standardization approach, when utilized for evaluating the impact of a family planning programme on fertility, is that it reduces the observed change in the general fertility rate or the crude birth rate to a residue which may be attributed, with corroborative evidence, to the programme. Moreover, unlike other methods, its usefulness lies primarily in its effectiveness in determining whether fertility has changed at all in the area and during the period under study. The standardization approach is a preliminary step in evaluation, in that it may be used to narrow the possible sources of change, if any, in fertility, when the general fertility rate or the crude birth rate is the measure used to indicate fertility. This approach does not and cannot provide a measure of programme impact as such, either in terms of percentage change in the crude birth rate or in terms of births averted. One of the main reasons for focusing on the crude birth rate is that programme impact is often perceived in terms of population growth, of which the crude birth rate is the fertility component. Indeed, this measure is often used, even when other fertility measures are available. It is, of course, the composite nature of the crude birth rate that makes it necessary to sort out or to standardize for the amount of change in it that is due to the influence of either of its four major components: (1) proportion of women of reproductive ages in the total population; (2) age structure of women of reproductive ages; (3) proportion of married women of reproductive ages; and (4) marital age-specific fertility rates.[1]

Thus, standardization determines the contribution of these four demographic components to changes in the magnitude of the observed crude birth rate; in evaluation, the method can be made to yield an estimate of the change in the crude birth rate that is attributable to changes in marital fertility. The role of marital fertility and the changes brought about by this variable may then be attributed to the family planning programme, if evidence is sufficient to warrant such a conclusion. Or further analysis could distinguish the part of the change in marital fertility that could be credited to the programme and the part that may be due to non-programme factors. However, the standardization approach does not go beyond assessing the magnitude of the change in the crude birth rate attributable to changes in marital fertility, and it cannot account for the specific role of the programme. Additional analytical approaches, as seen below in section D, may be used to assess programme impact. Standardization for the effects of socio-economic developments can always be undertaken, although with some inherent computational and theoretical difficulties. Utilized in the sense described, the standardization approach actually deciphers the role of structural factors in determining the magnitude of the crude birth rate, as opposed to evaluating the role of causal factors in fertility change.

In demography, "standardization" has been traditionally utilized to compare the incidence of given demographic occurrences (such as births or deaths) in two or more populations, the purpose being to classify and rank those populations according to the magnitude of the variable studied. In practice, standardization also has often been employed to assess changes in the same variables within a single country over a given interval of time. It is in the latter way that the standardization procedure, sometimes referred to as "decomposition into components", is utilized in evaluation; i.e., it is applied to a time series of birth rates for a single country.

A good number of standardization procedures have been used in the literature and it is not the intention here to review those methods. Neither is the aim to propose any new, sophisticated techniques, nor to discuss and solve theoretical and methodological problems which arise in connexion with the standardization method. Rather, the procedure presented is a classical approach—simple and straightforward—which can be applied easily with the aid of a desk calculator. In the following sections, the method is briefly described, attention is drawn to its significance and problems of interpretation, and a simple algebraic formulation illustrates the application of the method of data for Country A.

A. Description of method

1. *Principles*

Whether the method is applied in comparing the crude

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

[1] Where illegitimacy is widely prevalent, the relative influence on the birth rate of proportions married and of marital fertility is less easily deciphered, and non-marital fertility should be treated as an additional component.

birth rate among several countries or at two points in time for one country, the principles of standardization are the same. The comparison is achieved by selecting a standard population to which the observed rates are compared and specifically by controlling the various components of the crude birth rate one at a time, in order to distinguish the contribution of each component to the magnitude of the crude birth rate.[2] A number of steps are followed to achieve this objective. First, the crude birth rate[3] of the population under study is estimated at two points in time. If a change in the crude birth rate is observed, the next step is to select a standard population, i.e., the population whose characteristics will serve as the term of comparison in the assessment of the role of the selected components.

The next step consists in applying the formula chosen for the study which, in the present case, is the standardization procedure described below. The crude birth rate is expressed as an exact function of the demographic components introduced in the standardization. Then all components except one are simultaneously kept constant in order to compute hypothetical changes in the crude birth rate due to the single varying component. This procedure is repeated for each component and the result yields the amount of change in the crude birth rate that can be accounted for by changes in each of the component factors. The sum of changes contributed by each component is, on the basis of assumptions examined later, expected to account for the observed total change. In the present case, the change in the crude birth rate is assumed to result from changes: (*a*) in the proportion of women of reproductive ages in the total population; (*b*) in the age structure of women of reproductive ages; (*c*) in the proportion married among women of reproductive ages; and (*d*) in age-specific marital fertility. At this point, the preliminary decomposition into factors is terminated and the relative change in the crude birth rate can be translated in number of births "prevented" by each of these factors.

Standardization has a number of advantages over some of the other evaluation methods, one of the major advantages being its simplicity of use and calculation. Another advantage is that standardization of the crude birth rate or the general fertility rate requires demographic data that are more readily available than the data needed for the application of other techniques. A third advantage is that there are no true constraints which impair the results obtained by the method, such as specifications of the relationships (e.g., linearity), nature of the variables (e.g., random), or form of their distribution (e.g., normality). A fourth advantage is that the results are provided in terms of calendar years which conform with the need of programme administrators for information as to programme impact.

Among the limitations is the fact that the impact of the family planning programme cannot be directly assessed by decomposition into components. Thus, the standardization approach equates increases or decreases in annual fertility as a result of rises or falls in birth rates of married women with "real" or "genuine" changes in fertility.[4] Additionally, once an estimate has been made of the number of births that did not occur because there was a decline in legitimate or "genuine" fertility, it remains to determine how many of those births were prevented by the programme. Unfortunately, the standardization approach does not go beyond narrowing what is due to the effect of marital fertility; and, hence, it cannot determine what part of the decline, if any, in marital fertility is due to socio-economic factors and what part to programme activities. Additional analysis is needed at this point in order to ascertain what link may exist between programme acceptors and fertility reduction. The approach is limited also by the fact that it assumes that the components for which standardization is performed are independent of one another.

Another factor is that the estimates of change determined from standardized components are primarily hypothetical information, based on specific assumptions regarding the components chosen and the population selected as a point of reference. Thus, the increase or decrease in the crude birth rate due to movements in the age structure, for instance, is measured by comparing the crude birth rate of an observed population with that of a hypothetical population where it is assumed that all components except that studied remain constant. The effects of the various other components are not actually eliminated but are simply held constant on the basis of an arbitrarily chosen "standard population". This element of the standardization procedure is highly significant, and the arbitrary nature of the process whereby the reference population is chosen should not be underplayed, in particular because any alternative choice would yield different standardization results.

Assuming that it is desired to standardize for population P_1 at time t_1 and population P_2 at time t_2, the questions are what base population should be chosen and what makes one choice less arbitrary than the other. Theoretically, there is no criterion. One might select P_1 or P_2 or $(P_1 + P_2)/2$, or even the population for another year or another country. In the illustration, standardization is undertaken for both population P_1 and P_2 to underline differences in results. The choice of one base population is, of course, sufficient if the assumption is clearly stated and if two bases are not inadvertently mixed during the decomposition into components.

Another characteristic is that the standardization procedure more often yields merely an approximation of the effect that the components have upon the birth rates, a fact underscored in the algebraic presentation given below. Indeed, it frequently occurs that the summation of the relative contribution of each birth rate component

[2] Detailed descriptions of standardization principles are found in various excellent manuals, for instance, Henry S. Shryock, Jacob S. Siegel and Associates, *The Methods and Materials of Demography* (Washington, D.C., United States Department of Commerce, Bureau of the Census, 1971), vol. 2, pp. 418 ff.; and Abram J. Jaffe, *Handbook of Statistical Methods for Demographers* (Washington, D.C., Department of Commerce, Bureau of the Census, 1951), pp. 43 ff.

[3] The general fertility rate may be used instead, but it is important to bear in mind that this measure takes account of the ratio of women of reproductive age to the total population.

[4] A "genuine" change in fertility is defined as one resulting from the use or non-use of birth control methods; other factors, such as migration of spouse or foetal mortality, are not taken into consideration here.

does not account for exactly 100 per cent of the observed change; sometimes more, sometimes less than the total change is accounted for.[5] This situation occurs because the decomposition, as commonly performed, does not take into account the joint effects of the components on the total change, i.e., the influence attributable to the fact that the components are present and operating simultaneously, on the implicit assumptions that these joint effects are negligible. Although this situation may be generally true, there are cases in which these effects are of sufficient magnitude to have an impact on the results.

2. *Quantitative relationships*

As stated above, four components of the crude birth rate have been selected for standardization. The relationship between the birth rate and these components is multiplicative, owing to the basic relationship:

$$CBR = \frac{B}{P} \quad (1)$$

where CBR = crude birth rate;
B = number of births;
P = total population.

In a first step, equation (1) is decomposed into a multiplicative function, where the variables are the four components selected for standardization. In a second step, the multiplicative function is translated into an additive function so that the change in the birth rate can be accounted for by adding the effects of the four components. A formula for computing the role that individual changes of each separate component have in the change of the crude birth rate is derived.

There are a variety of standardization techniques. The procedures followed are more elaborate in some techniques than in others, and some are more appropriate for the present objective than are others. Moreover, data requirements vary among the different techniques.[6] The approach illustrated in this chapter was chosen because of its simplicity and straightforward frame of reference.[7]

Components of crude birth rate

The crude birth rate (CBR), equation (1), can be decomposed into desired components in two successive phases. First, the crude birth rate becomes a function of the general fertility rate (GFR) and the proportion of women of reproductive ages in the total population. Secondly, the general fertility rate is decomposed into its three main elements: age structure; marital status; and marital fertility.

From equation (1) emerges:

$$CBR = \frac{B}{W} \cdot \frac{W}{F} \cdot \frac{F}{P} \quad (2)$$

where W = number of women of reproductive ages;
F = number of females in the total population.

Hence $$CBR = \frac{B}{W} \cdot \frac{W}{P} \quad (3)$$

but $$\frac{B}{W} = GFR \quad (4)$$

thus $$CBR = GFR \cdot \frac{W}{P} \quad (5)$$

whereby the crude birth rate is the cross-product of the general fertility rate and the proportion of women of reproductive ages among the total population.

The point then is to decompose the general fertility rate into its three components. For that purpose, the following values are defined, with i equal to the age groups of women of reproductive ages:

$$B = \sum_i B_i \quad (6)$$

where B_i = number of births to women in age group i:

$$W = \sum_i W_i \quad (7)$$

where W_i = number of women in age group i:

$$F_i = \frac{B_i}{W_i} \quad (8)$$

where F_i = age-specific fertility rate in age group i;

and hence $$B_i = W_i . F_i \quad (9)$$

and $$B = \sum_i W_i . F_i \quad (10)$$

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[5] The practice of assessing the role of one component by subtracting from the total change the contribution made by all other components is deemed inappropriate.

[6] See, for instance, Robert M. Woodbury, "Westergaard's method of expected deaths as applied to the study of infant mortality", *Journal of the American Statistical Association*, vol. 18, Nos. 137–144 (1922–1923), pp. 366–376; John D. Durand, *The Labor Force Change in the United States 1890–1960* (New York, Social Science Research Council, 1948), appendix B, "Methods of analyzing factors of labor force change", pp. 219–236; Peter R. Cox, *Demography*, 4th ed. (Cambridge, Cambridge University Press, 1970), chaps. 10 and 12; Jerzy Berent and P. Festy, "Measuring the impact of some demographic factors on post-war trends in crude birth rates in Europe", in *International Population Conference, Liège, 1973* (Liège, International Union for the Scientific Study of Population, 1974), vol. 2, pp. 99–111; H. S. Shryock, J. S. Siegel and Associates, *op. cit.*; J. Henripin, *Tendances et facteurs de la fécondité au Canada* (Ottawa, Bureau fédéral de la statistique, 1968), annex G, pp. 393–398; Lee-Jay Cho and Robert D. Retherford, "Comparative analysis of recent fertility trends in East Asia", in *International Population Conference, Liège, 1973*, vol. 2, pp. 163–181; Chen-tung Chang, *Fertility Transition in Singapore* (Singapore, Singapore University Press, 1974), appendix A, pp. 209–212; Prithwis Das Guptas, "A general method of decomposing a difference between two rates into several components", *Demography*, vol. 15, No. 1 (February 1978), pp. 99–111; J. F. O'Connor, "A logarithmic technique for decomposing change", *Sociological Methods and Research*, vol. 6, No. 1 (August 1977), pp. 91–102.

[7] Based on "Measuring the impact of socio-economic factors on fertility in the context of declining fertility; problems and issues" (ESA/P/AC. 812), paper prepared by the United Nations Secretariat for the Expert Group Meeting on Demographic Transition and Socio-economic Development, Istanbul, 27 April–4 May 1977; Campbell Gibson, "The U.S. fertility decline, 1961–1975: the contribution of changes in marital status and marital fertility", *Family Planning Perspectives*, vol. 8, No. 5 (September–October 1976), pp. 249–252. See also Evelyn M. Kitagawa, "Components of a difference between two rates", *Journal of the American Statistical Association*, vol. 50, No. 272 (December 1955), pp. 1168–1174; and *idem*, "Standardized comparisons in population research", *Demography*, vol. 1, No. 1 (February 1964), pp. 296–315.

assuming that all births in the population occur to women classified in the i age groups.

Assuming further that the number of illegitimate births is negligible, there is:

$$F_{mi} = \frac{B_i}{N_i} \quad (11)$$

where N_i = number of married women in age group i;
F_{mi} = marital age-specific fertility rate in age group i.

Hence, one has $$B_i = N_i . F_{mi} \quad (12)$$

and $$B = \sum_i N_i . F_{mi} \quad (13)$$

One also has: $$\frac{N_i}{W_i} = M_{pi} \quad (14)$$

where M_{pi} = proportion of married women among all women in age group i.

Thus, from equations (11) and (14):

$$F_{mi} = \frac{B_i}{W_i . M_{pi}} \quad (15)$$

$$B_i = W_i . M_{pi} . F_{mi} \quad (16)$$

and $$B = \sum_i W_i . M_{pi} . F_{mi} \quad (17)$$

assuming that all births are legitimate and occur only to women in the specified age groups i.[8]

Replacing B in equation (1) by equation (17) yields a decomposition of the crude birth rate into three of its components:

$$CBR = \frac{\sum_i W_i . M_{pi} . F_{mi}}{P} \quad (18)$$

and replacing B in equation (4) by equation (17) gives a decomposition of the general fertility rate:

$$GFR = \frac{\sum_i W_i . M_{pi} . F_{mi}}{W} \quad (19)$$

Thus, by substituting equation (19) in equation (5), it is possible to derive:

$$CBR = \frac{\sum_i W_i . M_{pi} . F_{mi}}{W} . \frac{W}{P} \quad (20)$$

or $$CBR = \left(\sum_i A_i . M_{pi} . F_{mi} \right) . \frac{W}{P} \quad (21)$$

where $A_i = \frac{W_i}{W}$ represents the age structure component, i.e., the proportion of women in each age group i among women of reproductive ages.

[8] If illegitimate births have to be taken into account, equation (17) yields legitimate births and a similar equation is utilized to provide the number of illegitimate births. The sum of both will give the total number of births.

Equation (21) is thus the formula for decomposing the crude birth rate into four of its main components: (1) age structure of women of reproductive ages; (2) proportion of married women; (3) marital fertility; (4) proportion of women of reproductive ages out of the total population. This equation also implies that the data utilized in applying the standardization approach must be not only reliable but consistent in terms of their mathematical relationships. In other words, the product of the multiplicative factors is an exact function of the crude birth rate, disregarding possible errors of negligible magnitude due to the rounding of decimals.[9] Equation (21) therefore serves two purposes: it tests the consistency of the data, from a purely algebraic standpoint,[10] and it assesses the portion of change in the crude birth rate that can be accounted for by changes in each component. This second purpose is now examined.

Measurement of change in the standardization approach

Because two points in time constitute the reference for measuring changes in natality, the notations used in the preceding section are somewhat modified to allow for a simpler presentation of the standardization model. Accordingly:

t_1 = initial point in time;
t_2 = end of the time period for which change in the crude birth rate is measured;
CBR_1 = crude birth rate at time t_1;
CBR_2 = crude birth rate at time t_2;
GFR_1 = general fertility rate at time t_1;
GFR_2 = general fertility rate at time t_2;
i = age group of women in their reproductive ages;
A_{1i} and A_{2i} = age structure components in age group i at times t_1 and t_2, respectively;
M_{1i} and M_{2i} = marital status distribution in age group i at times t_1 and t_2, respectively;
F_{1i} and F_{2i} = age-specific marital fertility rates in age group i at times t_1 and t_2, respectively;
$\frac{W_1}{P_1}$ and $\frac{W_2}{P_2}$ = proportion of women in the total population at times t_1 and t_2, respectively.

Equation (21), written for the crude birth rate at times t_1 and t_2, thus becomes:

$$CBR_1 = \left(\sum_i A_{1i} . M_{1i} . F_{1i} \right) \frac{W_1}{P_1} \quad (22)$$

$$CBR_2 = \left(\sum_i A_{2i} . M_{2i} . F_{2i} \right) \frac{W_2}{P_2} \quad (23)$$

Another form of these two latter equations can be thought of whereby the factor $\frac{W}{P}$ is included in the right-

[9] This statement distinguishes further the present function used for standardization from the regression function which can include a disturbance term that accounts for measurement errors and other explanatory variables.

[10] The importance of the problem is described below in section C.

hand part of the equation as follows:

$$CBR = \sum_i A_{1i} \frac{W_1}{P_1} . M_{1i} . F_{1i} \quad (24)$$

where $A_{1i} = \frac{W_{1i}}{W_1}$ and $CBR_1 = \sum_i . \frac{W_{1i}}{P_1} . M_{1i} . F_{1i}$ (25)

The first multiplicative factor of the crude birth rate equation is thus translated from "proportion of women in age group i among all women of reproductive ages" to "proportion of women in age group i among the total population". Although the latter formula has the advantage of decomposing the crude birth rate into three of its main components, it does not distinguish the roles played by the age structure of the women of reproductive ages and the role of the proportion of women of reproductive ages in the total population. In other words, age structure and proportion of women of reproductive ages are merged into one single factor. In order to separate these two factors, the measurement of the changes, based on equations (22) and (23), is given below.

Where a change in the crude birth rate may be formulated[11] as:

$$CBR_2 = CBR_1 + \Delta CBR_1 \quad (26)$$

$$\Delta CBR_1 = CBR_2 - CBR_1 \quad (27)$$

Following equations (5) and (26), one obtains:

$$\Delta CBR_1 = \left(GFR_2 . \frac{W_2}{P_2} \right) - \left(GFR_1 . \frac{W_1}{P_1} \right) \quad (28)$$

and substituting equations (22) and (23) in (26), one obtains:

$$\Delta CBR_1 = \left(\sum_i A_{2i} . M_{2i} . F_{2i} \right) \frac{W_2}{P_2} - \left(\sum_i A_{1i} . M_{1i} . F_{1i} \right) \frac{W_1}{P_1} \quad (29)$$

where the parenthesis term of each right-hand side product represents the general fertility rates at times t_2 and t_1, respectively.

Since $GFR_2 = GFR_1 + \Delta GFR_1$ (30)

and $\frac{W_2}{P_2} = \frac{W_1}{P_1} + \Delta \frac{W_1}{P_1}$ (31)

and substituting equations (30) and (31) in (28), one obtains:

$$\Delta CBR_1 = \left[\left(GFR_1 + \Delta GFR_1 \right) \left(\frac{W_1}{P_1} + \Delta \frac{W_1}{P_1} \right) \right] - GFR_1 . \frac{W_1}{P_1} \quad (32)$$

[11] The algebraic symbol for "increment", which can be positive or negative, is Δ.

and subsequently, $\Delta CBR_1 = GFR_1 . \Delta \frac{W_1}{P_1} + \Delta GFR_1 . \frac{W_1}{P_1} + \Delta GFR_1 . \Delta \frac{W_1}{P_1}$ (33)

whereby the change in the crude birth rate results from a change in the proportion of women of reproductive ages in the total population, $\Delta \frac{W_1}{P_1}$, a change in the general fertility rate, ΔGFR_1, and a change due to the combined effect of the two preceding factors. The change in the general fertility rate can be further decomposed into three of its essential components. Following equation (30), one obtains:

$$\Delta GFR_1 = GFR_2 - GFR_1 \quad (34)$$

Replacing GFR by its components, one has, following equations (22) and (23):

$$GFR_1 = \sum_i A_{1i} . M_{1i} . F_{1i} \quad (35)$$

$$GFR_2 = \sum_i A_{2i} . M_{2i} . F_{2i} \quad (36)$$

and

$$A_{2i} = A_{1i} + \Delta A_{1i} \quad (37)$$

$$M_{2i} = M_{1i} + \Delta M_{1i} \quad (38)$$

$$F_{2i} = F_{1i} + \Delta F_{1i} \quad (39)$$

As a result, equations (37), (38) and (39) can be substituted in equation (36), and equation (34) becomes:

$$\Delta GFR_1 = \sum_i \left[(A_{1i} + \Delta A_{1i})(M_{1i} + \Delta M_{1i})(F_{1i} + \Delta F_{1i}) \right] - \sum_i (A_{1i} . M_{1i} . F_{1i}) \quad (40)$$

After developing the multiplicative terms, the following additive components are obtained:

$$\Delta GFR_1 = \sum_i A_{1i} \cdot M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot \Delta M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot M_{1i} \cdot \Delta F_{1i} + \sum_i \Delta A_{1i} \cdot \Delta M_{1i} \cdot F_{1i} + \sum_i \Delta A_{1i} \cdot M_{1i} \cdot \Delta F_{1i} + \sum_i A_{1i} \cdot \Delta M_{1i} \cdot \Delta F_{1i} + \sum_i \Delta A_{1i} \cdot \Delta M_{1i} \cdot \Delta F_{1i} \quad (41)$$

This means that the change in the general fertility rate can be accounted for by a sum of terms, of which the first three show the independent role of changes in the age structure ΔA_1, in marital status ΔM_1 and in marital fertility ΔF_1; the last four terms show the role of these same three components as joint effects. These joint effects are usually ignored or are assumed to be of negligible magnitude. However, they must be borne in mind to ensure valid interpretation of the results, since, as a rule, the use of the first three terms only does not permit a precise accounting of the total change. Substituting equation (41) for ΔGFR_1 in the second term of (33) putting the joint-effect terms in brackets, at the end of the equation, one obtains:

$$\Delta CBR_1 = GFR_1 \cdot \Delta\frac{W_1}{P_1} + \frac{W_1}{P_1}\left(\sum_i \Delta A_{1i} \cdot M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot \Delta M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot M_{1i} \cdot \Delta F_{1i}\right) + \left[\frac{W_1}{P_1}\left(\sum_i \Delta A_{1i} \cdot \Delta M_{1i} \cdot F_{1i} + \sum_i \Delta A_{1i} \cdot M_{1i} \cdot \Delta F_{1i} + \sum_i A_{1i} \cdot \Delta M_{1i} \cdot \Delta F_{1i} + \sum_i \Delta A_{1i} \cdot \Delta M_{1i} \cdot \Delta F_{1i}\right) + \Delta GFR_1 \cdot \Delta\frac{W_1}{P_1}\right] \quad (42)$$

Or, leaving out the interaction terms which are enclosed in brackets:

$$\Delta CBR_1 = GFR_1 \cdot \Delta\frac{W_1}{P_1} + \frac{W_1}{P_1}\left(\sum_i \Delta A_{1i} \cdot M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot \Delta M_{1i} \cdot F_{1i} + \sum_i A_{1i} \cdot M_{1i} \cdot \Delta F_{1i}\right) \quad (43)$$

whereby the change in the crude birth rate is expressed as a function of the changes occurring in four components of the crude birth rate.

As expressed with the population at t_1 as the base, this equation attempts to answer successively the questions: what the crude birth rate would have been if only the first, the second, the third or the fourth component had changed; how much of the difference can be accounted for by each individual component. The role of each component is then assessed according to the formulae shown below in table 1, with the population P_1 as the standard:

TABLE 1. FORMULAE FOR DECOMPOSITION INTO FACTORS

Change in crude birth rate due to four components	*Procedure*
Proportion of women of reproductive ages in total population	$GFR\left(\frac{W_2}{P_2} - \frac{W_1}{P_1}\right)$
Age structure of women of reproductive ages	$\frac{W_1}{P_1}\left[\sum_i (A_{2i} - A_{1i}) \cdot M_{1i} \cdot F_{1i}\right]$
Marital status distribution	$\frac{W_1}{P_1}\left[\sum_i A_{1i} \cdot (M_{2i} - M_{1i}) \cdot F_{1i}\right]$
Marital fertility	$\frac{W_1}{P_1}\left[\sum_i A_{1i} \cdot M_{1i} \cdot (F_{2i} - F_{1i})\right]$

If population P_2 had been chosen as the standard, the formulae would have remained the same, except for an appropriate interchange of the subscripts in the factors kept constant. The formulae in table 1 permit a quantitative estimation of the role of each individual component of the changing crude birth rate. Theoretically, the sum of the contribution of each component should equal the total change as resulting from $CBR_2 - CBR_1$. This might not be the case because of cumulative small errors due to roundings and especially to the joint effects when they are not taken into account.[12]

Because, as stated earlier, there may be situations in which the interaction terms account for substantial differences, a method of approximating the role of these terms is introduced in the application.[13] It is suggested that such an approximation be undertaken in all cases where the interaction terms in the standardization of crude birth rate or the general fertility are of a magnitude of 0.001 or more.

An alternate approach, which decomposes the number of births rather than the crude birth rate, would have as its elements: (1) the size of the population of women of reproductive ages; (2) the age structure of women in reproductive ages; (3) proportion of married women in reproductive ages; and (4) marital age-specific fertility rates. A formula for achieving this, ignoring the joint effects, is as follows:

$$\Delta B = \sum_i \Delta W_{1i} . A_{1i} . M_{1i} . F_{1i} + \sum_i W_{1i} . \Delta A_{1i} . M_{1i} . F_{1i} + \sum_i W_{1i} . A_{1i} . \Delta M_{1i} . F_{1i} + \sum_i W_{1i} . A_{1i} . M_{1i} . \Delta F_{1i} \quad (44)$$

where $\Delta B = B_2 - B_1$, the difference between the total number of births at two given times; and W_{1i} is the number of women in the reproductive age group i at time t_1.

The advantage of formula (44) is that it decomposes directly the difference in number of births and, with base population W_{1i}, accounts for the actual change in number of births between two given points in time.

Formula (43), instead, decomposes the change in the crude birth rate and, as applied in the illustration, accounts for the difference between the hypothetical number of births and the observed number of births at a single point in time.

In both cases, differences between number of births observed and number of births accounted for by the

[12] This result does not happen, of course, when the components are not estimated independently and when, instead, the role of the last of the n components is obtained as the difference between the total observed change and the sum of the $n-(n-1)$ effects; for instance, if the role of marital fertility were estimated as the difference between total observed change less change due to age structure and marital distribution, a procedure that is not recommended.

[13] What the utilization of the first three terms only means is that the increment of a variable Δy is treated as the differential of that variable dy. The differential of a product $uvw = y$ yields:

$$dy = du \cdot v \cdot w \cdot + u \cdot dv \cdot w + u \cdot v \cdot dw$$

Or, using the notation employed in the text, as applied to the general fertility rate:

$$dGFR = dA \cdot M \cdot F \cdot + A \cdot dM \cdot F + A \cdot M \cdot dF$$

But the differential dy is not the same as the increment Δy, as can be seen from the illustration given below.

For $y = x^2$, $x = 20$ and $\Delta x = 5$, one obtains:

$dy = f'(x)\Delta x$	$\Delta y = (x + \Delta x)^2 - x^2$
$dy = y'\Delta x$	$\Delta y = 2x\Delta x + x^2$
$dy = (x^2)'\Delta x$	$\Delta y = 2(20)(5) + 5^2$
$dy = 2x\Delta x$	$\Delta y = 225$
$dy = 2(20)(5) = 200$	

decomposition procedure must be examined in light of unaccounted joint effects. In some cases, these effects may be negligible, in others not.

3. *Assumptions*

Assumptions relating to decomposition

All assumptions implied in the standardization approach should be made explicit, in so far as possible, and should be borne in mind when results of the evaluation are interpreted. Some of these assumptions relate to the decomposition process itself, others to peculiarities arising in application of this technique to evaluation of programme impact on fertility. The major assumptions underlying this procedure are now examined.

The first assumption that the researcher makes when performing the standardization procedures relates to additivity, or the hypothesis that the four components of the crude birth rate for which standardization is undertaken can be legitimately added (and subtracted) in order to assess the individual effect of each component. However, the fact is that the "true" relationship between the crude birth rate and its components is multiplicative, as is described by the formula:

$$CBR = \frac{W}{P}\left(\sum_i A_1 \cdot M_{pi} \cdot F_{mi}\right) = \text{crude birth rate;}$$

W = number of women of reproductive ages;
P = total population;
i = five-year age groups;
A_i = proportion of women in age group i among all women of reproductive ages;
M_{pi} = proportion of married women of age group i among all women in age group i;
F_{mi} = age-specific marital fertility rate for age group i.

The translation of the multiplicative equation into an additive relationship was described earlier. However, this translation yields an additive relationship of products and not of individual variables, so that the products are additive but not the role of each individual factor. As seen in the algebraic analysis, the role of each component of change in the crude birthrate is obtained as the result of a product.

The second assumption is that of functional independence of the components of the crude birth rate. Specifically, it is that the proportion of women of reproductive ages is not associated[14] with the age structure of women in reproductive ages or with any other component; that age structure is likewise not associated with the other factors etc. This assumption of independence permits the summation of the role of the individual components without too great a risk of adding overlapping effects, but it is not valid under all conditions. For instance, while one assumes independence between the proportion of women married and age-specific marital fertility, there may be cases where particular changes in age at marriage within a five-year age group affect marital fertility through the women's fecundity rather than through family planning.

There are also other interaction factors,[15] which are cross-products of components of change of two or more factors: joint effect of age structure and marital status change; joint effect of age structure and marital fertility change; etc. These interaction terms result from the algebraic manipulation used to translate the multiplicative function into an additive function. But it is not possible to determine which part of the joint effect between, say, age structure change and marital fertility change should be allocated to the age structure effect and which part to the marital fertility effect. These interaction terms are generally assumed to be of negligible magnitude and not taken into consideration. If the interaction terms are taken into account, it is appropriate to allocate the joint effects equally to the pertinent variables.[16] Another type of interaction is the variation of two variables according to the level of a third.[17] This type of interaction is assumed to be absent here.

It may also be assumed, as in this chapter, that illegitimate fertility is of negligible magnitude, so that it will be unnecessary to evaluate its role separately. Of course, whether this assumption is valid depends upon the conditions of the country. In countries with a high rate of illegitimacy, as is often the case when consensual marriage is common, illegitimate and legitimate births can be pooled, and consensual and legal marriages considered to be one category.

A third implied assumption in the standardization procedure is that any component of the crude birth rate that is not standardized for had no role in the observed change. By not including illegitimate fertility as a component, it is automatically assumed that this factor did not contribute to the change in the crude birth rate. Likewise, if marital status had not been included, it would mean that changes in the proportion of women married were considered to be too negligible to have affected the magnitude of the crude birth rate. The implication of this third assumption is particularly important as concerns socio-economic variables, as they are often not standardized for, especially when standardization is undertaken for short periods of time. Although it is true that social change is often slow to affect fertility, that is not always the case. For this *Manual*, it is proposed not to illustrate techniques of assessing effects of social and economic change on fertility. This proposal is owing in part to the data requirements and in part to the fact that it appears more reasonable to identify first that portion of the change due to marital fertility and then to account for

[14] More realistically, one should say, "not too highly correlated", as is stated with problems of multicollinearity, so that it is still possible to disentangle the separate influence of the variables. For instance, it would not be advisable to standardize simultaneously for age and duration of marriage because these two variables are known to be highly associated.

[15] These factors appear in brackets in equation (42).

[16] See illustration in section C.3, where one half of the interaction term is allocated to each of the two interacting components. Allocation can also be done proportionately.

[17] Theoretical problems of interaction in standardization are discussed in T. W. Pullum, *Standardization*, World Fertility Survey technical bulletin No. 3 (London, International Statistical Institute, 1977).

changes in the latter factor by analysing the possible role of such socio-economic factors as urban-rural residence, education or literacy.

Assumptions related to evaluation of programme impact

Because the family planning programme is definable as an undertaking directed to spreading the acceptance and use of efficient family planning methods for the postponement or limitation of births, it is assumed that the programme impact on fertility is through birth control practice. (This assumption is the basis for the definition of "genuine" fertility change given previously.) Specifically, the assumption is that the availability of contraceptives does not affect the couple's decision as to the timing of their marriage. Further, it is postulated that there may be in force other social and population policy measures and cultural practices that could influence fertility. In addition, it is assumed that standardization will not take into account any measures designed to modify the structure of nuptiality. In summary, the family planning programme is assumed to affect age-specific fertility only through birth control and is not assumed to affect any other non-programme factors.

B. Use of method

1. *Standardization for programme evaluation*

An important problem is that of determining the circumstances in which it is appropriate to standardize the crude birth rate. The possibilities are: that (*a*) the crude birth rate did not change; (*b*) the crude birth rate changed. In the present case, it is assumed that there has been a change and that it was a decline. It may be said *a priori* that standardization is appropriate in all cases because one may always assume that in situation (*a*) the effects of the various components are of different signs and that their values cancel each other. The purpose of standardizing the crude birth rate in the absence of an evident change is to avoid misinterpreting the observed data. Indeed, if the effects of the changing components compensate each other, a decline in fertility might pass unnoticed. Instead, if standardization of the birth rate or general fertility rate is undertaken, the conclusion might be reached, for example, that *n* births averted by changing marital fertility were compensated almost exactly by all the other components, making for stability of the observed crude birth rate. Where no change in the crude measures occurred, the results of the standardization should reflect this fact, allowance being made as usual for rounding errors and interaction effects if they are not taken into account. Thus, for evaluation purposes standardization can, and often should, be applied regardless of whether the crude birth rate or the general fertility rate has changed.[18]

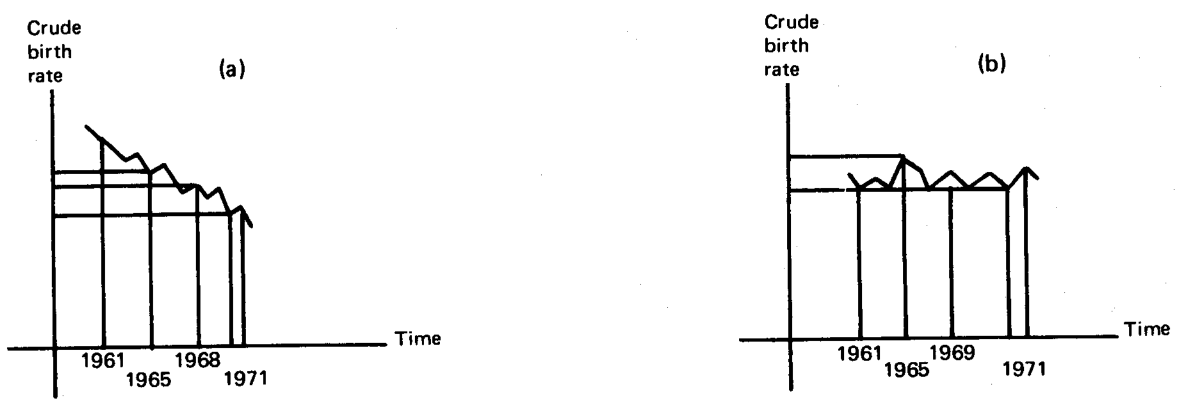
Evaluation of causal factors in short-term trends has many hazards: every effort should be made to determine whether the change is a mere fluctuation. A rule of thumb is to establish a time series of crude birth rates, if possible, extending beyond the time period under study in order to permit a graphic view of that part of the change which appears to reflect a trend and the part which may reflect random factors.

In figure I (*a*) the crude birth rate declines between 1971 and some previous years. In figure I (*b*) the crude birth rate declines between 1965 and 1971 and between 1967 and 1971 but appears unchanged between 1961 and 1971, 1966 and 1971 and 1968 and 1971. The trend analysis shows that in figure I (*a*) the determinants of the decline carry more weight than the annual fluctuations, whereas in figure I (*b*) there is no apparent change over the period 1961-1971.

How much of the fluctuation is random and how much is not constitutes, of course, a problem extending beyond

[18] Where the crude birth rate is concerned, a decline in marital fertility can be masked by an entrance into marriageable age of larger cohorts of women not compensated for by changes in nuptiality patterns. Standardization would reveal that fact, thus permitting the attribution, tentatively at least, of the lower marital fertility to the effects of the programme.

Figure I. Trends in crude birth rate, Country A



the frame of this chapter.[19] The point is that such aspects must be borne in mind so that if there is only a slight decline in a general constant trend of the birth rate, standardization may be attempting to explain a decline which in fact is not genuine. One may add that the problem of random fluctuations is most acute over very short periods of time and that the time interval studied should be as long as possible (five years or more) in order to minimize the effects of these fluctuations.[20] On the other hand, one should remember that a crude birth rate may remain nearly constant because of opposing non-random effects generated by its factors.

If one deals with sample data, both random and non-random errors can be present. If it can be assumed that the non-random errors are of negligible magnitude, it becomes simple enough to undertake a test of significance of the crude birth rate at time t_1 and at time t_2. If the difference is statistically significant, standardization can be undertaken to account for the change. If the difference is not statistically significant, it should be assumed that the crude birth rate did not change; and if standardization is undertaken, its results should account for the absence of change inferred from the test rather than for the decline inferred from the sample data. Generally speaking, if there is evidence of substantial measurement errors due to non-random errors and if those errors cannot be satisfactorily corrected, it is suggested to abstain from utilizing the data, whether or not they are of sample origin. No reliable interpretation and conclusion can be drawn from applying a technique, however good, to unreliable data.

In all circumstances, the results obtained from standardization should be verified. If fertility had been declining prior to initiation of the family planning programme, it would be required to determine the amount of decrease after the programme commenced that was due to the programme and that attributable to changing social and economic conditions or, as they are commonly called, non-programme factors. Where pre-programme fertility was more or less stable and where social change can be assumed not to have affected fertility after programme initiation, this problem does not arise. If this assumption cannot be supported, fertility change must be assumed to result from both non-programme and programme factors. Although standardization for these factors can be undertaken, attribution of the part of the decline due to the programme is allowable only from additional analysis. For instance, the number of births that did not occur may be estimated on the basis of standardization and then matched with the number of births averted estimated by another method of evaluation. Assuming that standardization and the second method are sufficiently independent,[21] there might be an acceptable indication, if not confirmation, that the results obtained by the standardization method are reliable. This indication implies that the estimate, by standardization, of the residual number of births that did not occur made allowance for the role of socio-economic factors as warranted by the specific conditions of the country being studied. Thus, for example, if there is evidence that substantial changes have occurred in education of men or women, or if migration has modified the urban-rural population in such a way as to influence the fertility of the inhabitants, then such factors also should be standardized. Only the residual that cannot be accounted for by such factors can be investigated and attributed to the family planning programme.

2. *Types of data*

The types of statistical data required depend upon the population characteristics for which it is desired to standardize. If confined to the four major components of change in the crude birth rate, standardization requires statistics of the total number of births; births classified by five-year age groups of mother, with subdivisions into legitimate and illegitimate births where indicated; the total population, total number of females, number of women of reproductive ages by marital status and five-year age groups. These statistics are needed for the calendar years t_1 and t_2, where t_1 is the beginning of the period under study and t_2 the last year of that period. If such phenomena as urbanization and increased school attendance, especially of girls, are considered to have taken place on a significant scale during the period covered by the evaluation, standardization should be applied with the view to determining their possible role in the increase of the birth rate or general fertility rate.[22]

In addition to the information covering the years for which evaluation is undertaken, it is helpful to have data also for the periods that precede and follow the time interval under study, so that it can be determined whether the behaviour of the rates during the period under review constitute a trend. Likewise, various additional demographic statistics may be needed to test the accuracy of the data or to facilitate corrections. The specific statistics required for these purposes depend, of course, upon the methods chosen for testing and correcting the data.

3. *Sources and quality of data*

The main sources of data are the population census and

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[19] A quantitative approach to this problem has been undertaken by William Seltzer and R. S. Fand, "A note on the annual variability of the crude birth rate", *Proceedings of the Social Statistics Section, 1973* (Washington, D.C., American Statistical Association, 1974), pp. 386–391. These authors have studied the amount of misinformation generated by estimating changes in the crude birth rate over very short periods of time and attempted to estimate the level of disturbance associated with annual crude birth rates and the stability of these estimates of residual variability. Their basic assumption is that the crude birth rate is the sum of two unobservable components: a polynomial of degree n (or less) and a random disturbance element so that one has $B_y = f(x) + e_y$ where B_y is the observed birth rate in year y, $f(x)$ a polynomial representing the trend, and e_y representing the random fluctuations.

[20] For small changes, a simple test of significance can be undertaken to assess the role of random factors. Results of such test should, however, be taken for what they are: probabilities.

[21] The problem of independence of evaluation methods and the nature of this requirement are briefly examined in "Methods of measuring the impact of family planning programmes on fertility: problems and issues", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 3–42.

[22] Owing to lack of required data, the text does not provide an illustration of the procedures for standardizing for social and/or economic factors that may have influenced the birth rate.

vital statistics. In addition, valuable data may be obtained from fertility and other demographic surveys and from household investigations. The population census returns, as well as vital statistics and survey data, may be impaired by reporting or other errors, so that it may be necessary to evaluate the quality of the data themselves and to correct such errors as methodology and available statistics permit. A good knowledge of the demographic and socio-economic conditions of the country being evaluated is necessary both in detecting data errors and in applying corrective measures.

A number of adjustment procedures have been devised to deal with specific short-comings of demographic data, but these procedures cannot be applied mechanically and require a careful appraisal of all relevant events. Assessing data quality and making corrections thus constitutes a major part of the application of the standardization approach. However, no procedures regarding the testing of accuracy and the correction of demographic data are described in this *Manual*, as a number of manuals have been issued which deal with these problems in considerable detail.[23]

C. Application of method

1. *Data used*

Population data

The data used to illustrate the decomposition of birth rates into components are for Country A and pertain to the period from 1966 to 1971. Population figures for the initial year, 1966, are census returns; those for 1971 are estimates and projections. The figures have been adjusted to incorporate women of unknown age and unknown marital status on the basis of an assumption that unknowns had the same age distribution as the general population and that the distribution of married women was the same among women of unknown marital status as among those of known marital status. An adjustment was also made for an assumed 4 per cent under-enumeration in the 1966 census.

Table 2. Crude birth rates series, Country A, 1963–1973

Year	Estimated series (1)	(2)	(3)	Official series (4)
1963	44.6	44.6	44.3	42.1
1964	46.0	46.2	46.0	45.4
1965	44.0	43.5	43.1	41.8
1966	*44.5*	*43.8*	*43.2*	*43.8*
1967	41.0	40.8	40.9	38.9
1968	40.0	40.3	40.2	38.2
1969	41.0	40.7	41.0	38.8
1970	38.5	38.2	...	36.4
1971	*37.0*	*36.8*	...	*35.1*
1972	39.0	...	...	37.3
1973	38.5	...	...	35.8

Sources: Statistical Office of the country concerned, files of the United Nations Statistical Office and estimates.

[23] See, for instance, *Manual I. Methods of Estimating Total Population for Current Data* (United Nations publication, Sales No. 52.XIII.5); *Manual II. Methods of Appraisal of Quality of Basic Data for Population Estimates* (United Nations publication, Sales No. 56.XIII.2); *Manual III. Methods for Population Projections by Sex and Age* (United Nations publication, Sales No. 56.XIII.3); *Manual IV. Methods of Estimating Basic Demographic Measures from Incomplete Data* (United Nations publication, Sales No. 67.XIII.2); William Brass, *Methods for Estimating Fertility and Mortality from Limited and Defective Data* (Chapel Hill, N.C., University of North Carolina, 1975); Rémy Clairin, *Sources et analyse des données démographiques, vol. II, Ajustement des données imparfaites* (Paris, Institut national d'études démographiques, 1973).

Table 3. Age structure of women of reproductive ages, Country A, 1966

Age group *i*	*Number of women 3 V 1966* (1)	*Number of women corrected for unknown age and adjusted for 4 per cent under-enumeration 3 V 1966* (2)	*Number of women corrected for unknown and adjusted for under-enumeration*[a] *average for 1966* (3)	*Age distribution of women 15–54 in 1966* A_i *(percentage)* (4)
15–19	188 751	196 330	197 056	18.4
20–24	151 018	157 081	157 662	14.7
25–29	154 431	160 631	161 226	15.0
30–34	147 782	153 715	154 284	14.4
35–39	130 005	135 224	135 724	12.7
40–44	99 455	103 448	103 830	9.7
45–49	83 371	86 718	87 039	8.1
50–54	71 983	74 873	75 150	7.0
Subtotal	1 026 796			100.0
Unknown	146			
Total aged 15–54	1 026 942	1 068 020	1 071 971	
Total population	4 533 351	4 714 600	4 732 000	
Proportion of women aged 15–54 in total population			0.2265	

Source: For data in columns (1) and (2), *Demographic Yearbook 1971* (United Nations publication, Sales No. E.72.XIII.1).

[a] Adjusted according to estimates of total number of women aged 15–54; prorating ratios:

$$\frac{1\,072\,000}{1\,068\,020} = 1.0037.$$

The data utilized in the application are described in tables 3–10. The quality of the data was deemed satisfactory for the purpose of illustrating the standardization approach and the only quality test performed was to check the internal consistency of the data as described below. As a result, the crude birth rates chosen for 1966 and 1971 were 43.7 and 36.7 per 1,000, respectively.

Birth data

The registered births were adjusted for under-registration only for the year 1971, for which 95 per cent completeness was assumed. Birth registration in 1966 is assumed to be 100 per cent complete. Births to mothers of unknown age were prorated, and those occurring to women younger than 15 were included in the 15–19 age group, while births to women 55 and over were allotted to women in the 50–54 age group.

Since the crude birth rate is the indicator of fertility that is being standardized, the birth rate trend actually constitutes the frame of reference of the whole procedure. Table 2 shows four series of crude birth rate estimates. These series permit inference as to an acceptable order of magnitude for the crude birth rate of about 43 per 1,000 in 1966 and about 35–37 per 1,000 in 1971. They also allow ascertainment that the observed alterations and, more precisely, that the observed decline in the crude birth rate between 1966 and 1977 reflects genuine changes rather than annual fluctuations. Corroboration of both level and trend by three of the four sources is considered, in the present case, to be sufficient warranty of data reliability and no further tests regarding possible errors are therefore undertaken. In fact, had there been strong disagreement between these estimates, a closer look at the possible measurement errors would have been warranted. In tables 3 to 10, the data needed to undertake the consistency test and to apply the standardization formulas are worked out.

TABLE 4. AGE-SPECIFIC FERTILITY RATES, COUNTRY A, 1966

Age group *i*	Number of births in 1966 adjusted for unknown[a] (1)	Number of women; average for 1966 (2)	Age-specific fertility rates, 1966 (per 1 000) (3)
15–19	14 694	197 056	74.6
20–24	44 697	157 662	283.5
25–29	53 592	161 226	332.4
30–34	46 529	154 284	301.6
35–39	31 372	135 724	231.1
40–44	11 984	103 830	115.4
45–49	2 990	87 039	34.4
50–54	859	75 150	11.4
Total 15–54	206 717	1 071 971	GFR: 192.8 per 1 000 TFR: 6.922 per woman GRR: 3.4

SOURCES: For data in column (1), *Demographic Yearbook 1975* (United Nations publication, Sales No. E. 76. XIII. 1); for column (2), table 3, column (3).

Note: GFR = general fertility rate; TFR = total fertility rate; GRR = gross reproduction rate.

[a] Including all births for ages under 15 years and 55 or over.

TABLE 5. DISTRIBUTION OF MARRIED WOMEN BY AGE, COUNTRY A, 1966

Age group *i*	Number of married women 3 V 1966 (1)	Number of married women corrected for unknown age and under-enumeration 3 V 1966[a] (2)	Number of women with marital status unknown (3)	Number of women with marital status unknown adjusted for under-enumeration[a] (4)	Estimated number of women with unknown marital status assumed to be married (5) = (4) × P_{mi}[b] (5)	Total number of married women 3 V 1966 (6) = (2) + (5) (6)	Total number of married women average for 1966[c] (7) = (6) × 1.0037 (7)	Proportion of married women in each age group, 1966[d] M_{pi} (8)
15–19	34 895	36 292	61	63	12	36 304	36 438	18.5
20–24	107 300	111 595	78	82	58	111 653	112 066	71.0
25–29	136 718	142 191	67	70	62	142 253	142 779	88.6
30–34	136 482	141 945	64	67	62	142 007	142 532	92.4
35–39	119 408	124 188	58	60	55	124 243	124 703	91.9
40–44	87 435	90 936	56	58	51	90 987	91 324	87.9
45–49	68 215	70 946	34	35	29	70 975	71 238	81.8
50–54	50 700	52 730	33	34	24	52 754	52 949	70.5
Sub-total	741 153							
Age unknown	23							
Total 15–54	741 176	770 823	451	469	353	771 176	774 029	

SOURCE: For data in columns (1)–(3), *Demographic Yearbook 1971* (United Nations publication, Sales No. E.72.XIII.1).

[a] Adjustment for 4 per cent under-enumerations.

Age group:	*15–19*	*20–24*	*25–29*	*30–34*	*35–39*	*40–44*	*45–49*	*50–54*
P_{mi}:	0.185	0.710	0.885	0.923	0.918	0.879	0.818	0.704

[b] Same distribution as proportions married in each age group; as computed from table 3, column (2) and from table 5, column (2).

[c] Prorated according to estimates of total number of women aged 15–54; ratio 1.0037.

[d] Computed from table 5, column (7) and from table 3, column (3).

TABLE 6. MARITAL AGE-SPECIFIC FERTILITY RATES, COUNTRY A, 1966

Age group i	Number of births, 1966 (1)	Number of married women, average for 1966 (2)	Marital age-specific fertility rates, 1966 F_{mi} (3)
15-19	14 694	36 438	403.3
20-24	44 697	112 066	398.8
25-29	53 592	142 779	375.3
30-34	46 529	142 532	326.4
35-39	31 372	124 703	251.6
40-44	11 984	91 324	131.2
45-49	2 990	71 238	42.0
50-54	859	52 949	16.2
Total 15-54	206 717	774 029	
Marital general fertility rate			267.1

SOURCES: For data in column (1), table 4, column (1); for data in column (2), table 5, column (7).

TABLE 7. AGE STRUCTURE OF WOMEN OF REPRODUCTIVE AGES, COUNTRY A, 1971

Age group i	Number of women 1 1 1971 (1)	Number of women 1 1 1972 (2)	Number of women; average for 1971[a] (3)	Age distribution of women aged 15-54 in 1971 A_i (percentage) (4)
15-19	287 000	297 300	292 150	23.8
20-24	181 000	201 100	191 050	15.5
25-29	141 000	148 200	144 600	11.7
30-34	146 000	144 300	145 150	11.8
35-39	141 000	141 200	141 100	11.5
40-44	125 000	127 400	126 200	10.2
45-49	99 000	103 300	101 150	8.2
50-54	90 000	90 900	90 450	7.3
Total aged 15-54	1 210 000	1 253 700	1 231 850	100.0
Total population	5 179 000	5 298 000	5 238 500	
Proportion of women aged 15-54 in total population			0.2350	

SOURCES: For data in columns (1) and (2), publications of the Statistical Office of the country concerned.
[a] Arithmetic mean of columns (1) and (2).

TABLE 8. AGE-SPECIFIC FERTILITY RATES, COUNTRY A, 1971

Age group i	Number of births corrected for unknowns and 5 per cent under-registration,[a] 1971 (1)	Number of women, average for 1971 (2)	Age-specific fertility rates, 1971 (per 1 000) (3)
15-19	11 753	292 150	40.2
20-24	48 541	191 050	254.1
25-29	44 752	144 600	309.5
30-34	41 136	145 150	283.4
35-39	29 713	141 100	210.6
40-44	12 977	126 200	102.8
45-49	2 772	101 150	27.4
50-54	832	90 450	9.2
Total 15-54	192 476	1 231 850	GFR: 156.2 per 1 000 TFR: 6,185 per woman GRR: 3.0

SOURCE: For column (1), *Demographic Yearbook 1975* (United Nations publication, Sales No. E.76.XIII.1); for column (2), table 7, column (3).

Note: GFR = general fertility rate; TFR = total fertility rate; GRR = gross reproduction rate.

[a] Including all births to women aged under 15 years and 55 and over.

TABLE 9. DISTRIBUTION OF MARRIED WOMEN, BY AGE, COUNTRY A, 1971

Age group i	Number of women; average for 1971 (1)	Proportion of married women in each age group, 1971 M_{pi} (percentage) (2)	Number of married women, average for 1971 (3)
15-19	292 150	12.0	35 058
20-24	191 050	68.7	131 251
25-29	144 600	85.5	123 633
30-34	145 150	92.1	133 683
35-39	141 000	92.7	130 800
40-44	126 200	89.8	113 328
45-49	101 150	84.2	85 168
50-54	90 450	75.8	67 657
Total 15-54	1 231 850		820 578

SOURCES: For data in column (1), table 7, column (3); for column (2), publications of the Statistical Office of the country concerned.

TABLE 10. MARITAL AGE-SPECIFIC FERTILITY RATES, COUNTRY A, 1971

Age Group i	Number of births 1971 (1)	Number of married women average for 1971 (2)	Marital age-specific fertility rates, 1971 F_{mi} (per 1 000) (3)
15-19	11 753	35 058	335.2
20-24	48 541	131 251	369.8
25-29	44 752	123 633	362.0
30-34	41 136	133 683	307.7
35-39	29 713	130 800	227.2
40-44	12 977	113 328	114.5
45-49	2 772	85 168	32.5
50-54	832	67 657	12.3
Total 15-54	192 476	820 578	
Marital general fertility rate			234.6

SOURCES: For data in column (1), table 8, column (1); for column (2), table 9, column (3).

2. *Consistency test*

For purposes of standardization, the crude birth rate should be compatible with its components, the segments of the total population, i.e., women of various reproductive ages for which standardization is effected must be drawn from precisely the same population represented in the denominator of the crude birth rate. When the researcher calculates the crude birth rate, the components are known and a test for compatibility may not be necessary. Where the reverse is true, compatibility must be investigated by means of a consistency test. Such a test may also be indicated where, as in the case of Country A, the crude birth rate is known only within a reasonable range.

Table 2 gives birth rates that range in value from 44.5 to 43.2 and from 35.1 to 37.0 per 1,000 population for the years 1966 and 1971, respectively. Choice of the crude birth rates to be standardized for 1966 and for 1971 can be determined by a consistency test using the following formula:

$$CBR = \left(\sum_i A_i.M_{pi}.F_{mi}\right)\frac{W}{P}$$

where W = number of women of reproductive ages;
P = total population;
A_i = proportion of women in age group i among all women of reproductive ages;
M_{pi} = proportion of married women of age group i among all women in age group i;
F_{mi} = age-specific marital fertility rate for age group i;
i = five-year age groups.

The test permits selection of a crude birth rate that is an exact mathematical relationship of its components.

Table 11 for 1966 and table 12 for 1971 show that the population characteristics selected for the decomposition

TABLE 11. CONSISTENCY TEST, COUNTRY A, 1966

Age group i	Age distribution of women aged 15–54 A_i (percentage) (1)	Proportion of married women in each age group, 1966 M_{pi} (per 100) (2)	Marital age-specific fertility rates, 1966 F_{mi} (per 1 000) (3)	$A_i \cdot M_{pi} \cdot F_{mi}$ (per 1 000) (4)
15–19	18.4	18.5	403.3	13.7283
20–24	14.7	71.0	398.8	41.6227
25–29	15.0	88.6	375.3	49.8773
30–34	14.4	92.4	326.4	43.7294
35–39	12.7	91.9	251.6	29.3649
40–44	9.7	87.9	131.2	11.1865
45–49	8.1	81.8	42.0	2.7828
50–54	7.0	70.5	16.2	0.7994
TOTAL	100.0			192.7913

$GFR = \sum_i A_i \cdot M_{pi} \cdot F_{mi} = 0.19279$ General fertility rate: 192.8 per 1 000

$CBR = GFR \cdot \frac{W}{P} = 0.19279 \times 0.2265 = 0.043667$ Crude birth rate: 43.7 per 1 000

SOURCES: For data in column (1), table 3, column (4); for column (2), table 5, column (8); for column (3), table 6, column (3).

TABLE 12. CONSISTENCY TEST, COUNTRY A, 1971

Age group i	Age distribution of women aged 15–54, in 1971 A_i (percentage) (1)	Proportion of married women in each age group, 1971 M_{pi} (percentage) (2)	Marital age-specific fertility rates, 1971 F_{mi} (percentage) (3)	$A_i.M_{pi}.F_{mi}$ (per 1 000) (4)
15–19	23.8	12.0	335.2	9.5733
20–24	15.5	68.7	369.8	39.3781
25–29	11.7	85.5	362.0	36.2126
30–34	11.8	92.1	307.7	33.4402
35–39	11.5	92.7	227.2	24.2206
40–44	10.2	89.8	114.5	10.4877
45–49	8.2	84.2	32.5	2.2439
50–54	7.3	74.8	12.3	0.6716
TOTAL	100.0			156.2280

$GFR = \sum_i A_i.M_{pi}.F_{mi} = 0.15622$ General fertility rate: 156.2 per 1 000

$CBR = GFR.\frac{W}{P} = 0.15622 \times 0.2350 = 0.03671$ Crude birth rate: 36.7 per 1 000

SOURCES: For data in column (1), table 7, column (4); for column (2), table 9, column (2); for column (3), table 10, column (3).

into components would account for a general fertility rate of 192.8 per 1,000, which actually equals the general fertility rate computed in table 4 and would be associated with a crude birth rate of 43.7 per 1,000, which is well within the defined acceptable range cited above. As concerns the year 1971, the corresponding figures are a general fertility rate of 156.2 per 1,000 and a crude birth rate of 36.7 per 1,000, both of which are satisfactory. Table 13 presents the basic demographic data utilized for illustrating the decomposition of the crude birth rate into components.

TABLE 13. BASIC DEMOGRAPHIC DATA UTILIZED FOR DECOMPOSITION OF THE CRUDE BIRTH RATE, COUNTRY A

	1966 (*1*)	*1971* (*2*)
Number of births	206 717	192 476
Total population	4 732 000	5 238 500
Female population of reproductive ages	1 071 971	1 231 850
Crude birth rate (per 1 000)	43.7	36.7
General fertility rate (per 1 000)	192.8	156.2
Proportion of women of reproductive ages in the total population (per 100)	22.65	23.50

SOURCES: For number of births in 1966, table 4, column (1); and in 1971, table 8, column (1). For total population, female population of reproductive ages and proportion women of reproductive ages in 1966, table 3, column (3); same data for 1971, table 7, column (3). For crude birth rate and general fertility rate in 1966 and in 1971, tables 11 and 12.

3. *Decomposition: factors affecting the observed change*

Major components

In the illustration given here, changes in both the general fertility rate and the crude birth rate are decomposed into the factors that influence the change. From table 13 it can be seen that the amount of change in the two measures is as follows:

	1966	*1971*	*Amount of change to be accounted for*[a]	*Percentage change*[a]
Crude birth rate (per 1 000)	43.7	36.7	− 7.0	− 16.0
General fertility rate (per 1 000)	192.8	156.2	− 36.6	− 19.0

[a] Negative changes represent declines in rates; positive changes represent increases in rates.

The decomposition is carried out on the basis of the formulae provided in table 1. In the terms of the formulae, subscripts 1 and 2 now stand for the years 1966 and 1971, respectively; and subscript i represents successive age groups from 15–19 to 50–54 years of age. Although in applying the procedure, the use of only one base population is sufficient, this presentation illustrates the decomposition of changes in the crude birth rate and the general fertility rate using first the 1966 and then the 1971 population, in order to underline the differences in results obtained by using different reference populations as seen in tables 14–19. The formulae of table 1 are noted in terms of base population P_1, i.e., the 1966 base population. When using P_2 as the base, i.e., the 1971 population, it suffices to interchange indices 1 and 2 in the constant factors. It is crucial to remember that all factors are kept constant as of the year of reference except the component whose role is sought. In other words, standardizing for a specific factor on the basis of the 1971 population means that all but that factor are held constant as of 1971.

TABLE 14. COMPUTATION OF ROLE OF AGE STRUCTURE IN CHANGES IN CRUDE BIRTH RATE AND GENERAL FERTILITY RATE

(*Base population, 1966*)

Age Group i	*Age structure, 1966* A_{1i} *(percentage)* (*1*)	*Age structure, 1971* A_{2i} *(percentage)* (*2*)	*Change in age structure* $A_{2i}-A_{1i}$ *(percentage)* (*3*)	*Marital status, 1966* M_{1i} *(percentage)* (*4*)	*Marital fertility, 1966* F_{1i} *(percentage)* (*5*)	*Change in general fertility rate due to change in age structure* $(A_{2i}-A_{1i})M_{1i}F_{1i}$ *(per 1 000)* (*6*)
15–19	18.4	23.8	+5.4	18.5	403.3	+4.028967
20–24	14.7	15.5	+0.8	71.0	398.8	+2.265184
25–29	15.0	11.7	−3.3	88.6	375.3	−10.973021
30–34	14.4	11.8	−2.6	92.4	326.4	− 7.841433
35–39	12.7	11.5	−1.2	91.9	251.6	− 2.774644
40–44	9.7	10.2	+0.5	87.9	131.2	+0.576624
45–49	8.1	8.2	+0.1	81.8	42.0	+0.034356
50–54	7.0	7.3	+0.3	70.5	16.2	+0.034263
TOTAL	100.0	100.0				−14.649704

Change in general fertility rate due to age structure change: $\sum_i (A_{2i}-A_{1i})M_{1i}\cdot F_{1i} = -0.01465$

Change in crude birth rate due to age structure change: $\left[\sum_i (A_{2i}-A_{1i})M_{1i}\cdot F_{1i}\right]\frac{W_1}{P_1} = (0.01465)\ (0.2265) = 0.003318$

Change in general fertility rate: − 14.65 per 1 000

Change in crude birth rate: − 3.32 per 1 000

SOURCES: For data in column (1), table 3, column (4); for column (2), table 7, column (4); for column (4), table 5, column (8); for column (5), table 6, column (3).

TABLE 15. COMPUTATION OF ROLE OF MARITAL STATUS DISTRIBUTION IN CHANGES IN CRUDE BIRTH RATE AND GENERAL FERTILITY RATE

(Base population, 1966)

Age group i	Marital status, 1966 M_{1i} (percentage) (1)	Marital status, 1971 M_{2i} (percentage) (2)	Change in marital status $M_{2i}-M_{1i}$ (percentage) (3)	Age structure, 1966 A_{1i} (percentage) (4)	Marital fertility, 1966 F_{1i} (per 1 000) (5)	Change in general fertility rate due to change in marital status distribution $A_{1i}(M_{2i}-M_{1i})F_{1i}$ (per 1 000) (6)
15–19	18.5	12.0	−6.5	18.4	403.3	−4.823468
20–24	71.0	68.7	−2.3	14.7	398.8	−1.348342
25–29	88.6	85.5	−3.1	15.0	375.3	−1.745145
30–34	92.4	92.1	−0.3	14.4	326.4	−0.141004
35–39	91.9	92.7	+0.8	12.7	251.6	+0.255625
40–44	87.9	89.8	+1.9	9.7	131.2	+0.241801
45–49	81.8	84.2	+2.4	8.1	42.0	+0.081648
50–54	70.5	74.8	+4.3	7.0	16.2	+0.048762
TOTAL						−7.430123

Change in general fertility rate due to marital status distribution change: $\sum_i A_{1i}(M_{2i}-M_{1i})F_{1i} = -0.007430$

Change in crude birth rate due to marital status distribution change: $\left[\sum_i A_{1i}(M_{2i}-M_{1i})F_{1i}\right]\frac{W_1}{P_1} = (-0.007430)\ (0.2265) = -0.0016829$

Change in general fertility rate: −7.43 per 1 000
Change in crude birth rate: −1.68 per 1 000

SOURCES: For data in column (1), table 5, column (8); for column (2), table 9, column (2); for column (4), table 3, column (4); for column (5), table 6, column (3).

TABLE 16. COMPUTATION OF ROLE OF MARITAL FERTILITY IN CHANGES IN GENERAL FERTILITY RATE AND CRUDE BIRTH RATE

(Base population, 1966)

Age group i	Marital fertility, 1966 F_{1i} (per 1 000) (1)	Marital fertility, 1971 F_{2i} (per 1 000) (2)	Change in marital fertility $F_{2i}-F_{1i}$ (per 1 000) (3)	Age structure, 1966 A_{1i} (percentage) (4)	Marital status, 1966 M_{1i} (percentage) (5)	Change in general fertility rate due to change in marital fertility $A_{1i}M_{1i}(F_{2i}-F_{1i})$ (per 1 000) (6)
15–19	403.3	335.2	−68.1	18.4	18.5	−2.318124
20–24	398.8	369.8	−29.0	14.7	71.0	−3.026730
25–29	375.3	362.0	−13.3	15.0	88.6	−1.767570
30–34	326.4	307.7	−18.7	14.4	92.4	−2.488147
35–39	251.6	227.2	−24.4	12.7	91.9	−2.847797
40–44	131.2	114.5	−16.7	9.7	87.9	−1.423892
45–49	42.0	32.5	− 9.5	8.1	81.8	−0.629451
50–54	16.2	12.3	− 3.9	7.0	70.5	−0.192465
TOTAL						−14.694176

Change in general fertility rate due to marital fertility change: $\sum_i A_{1i}\cdot M_{1i}(F_{2i}-F_{1i}) = -0.01469$

Change in crude birth rate due to marital fertility change: $\left[\sum_i A_{1i}\cdot M_{1i}(F_{2i}-F_{1i})\right]\frac{W_1}{P_1} = (-0.01469)\ (0.2265) = -0.003327$

Change in general fertility rate = −14.69 per 1 000
Change in crude birth rate = −3.327 per 1 000

SOURCES: For data in column (1), table 6, column (3); for column (2), table 10, column (3); for column (4), table 3, column (4); for column (5), table 5, column (8).

TABLE 17. COMPUTATION OF ROLE OF AGE STRUCTURE IN CHANGES IN CRUDE BIRTH RATE AND GENERAL FERTILITY RATE

(Base population, 1971)

Age group i	Age structure, 1971 A_{2i} (percentage) (1)	Age structure, 1966 A_{1i} (percentage) (2)	Change in age structure $A_{2i}-A_{1i}$ (percentage) (3)	Marital status, 1971 M_{2i} (percentage) (4)	Marital fertility, 1971 F_{2i} (per 1 000) (5)	Change in general fertility rate due to change in age structure $(A_{2i}-A_{1i})M_{2i}.F_{2i}$ (per 1 000) (6)
15–19	23.8	18.4	+5.4	12.0	335.2	2.172096
20–24	15.5	14.7	+0.8	68.7	369.8	2.032420
25–29	11.7	15.0	−3.3	85.5	362.0	−10.213830
30–34	11.8	14.4	−2.6	92.1	307.7	−7.368184
35–39	11.5	12.7	−1.2	92.7	227.2	−2.527372
40–44	10.2	9.7	+0.5	89.8	114.5	0.514105
45–49	8.2	8.1	+0.1	84.2	32.5	0.027365
50–54	7.3	7.0	+0.3	74.8	12.3	0.027601
TOTAL	100.0	100.0				−15.335799

Change in general fertility rate due to age structure change: $\sum_i (A_{2i}-A_{1i})M_{2i}\cdot F_{2i} = -0.015336$

Change in crude birth rate due to age structure change: $\left[\sum_i (A_{2i}-A_{1i})M_{2i}\cdot F_{2i}\right]\frac{W_2}{P_2} = (-0.015336)\ (0.2350) = -0.003604$

Change in general fertility rate = −15.34 per 1 000
Change in crude birth rate = −3.60 per 1 000

SOURCES: For data in column (1), table 7, column (4); for column (2), table 3, column (4); for column (4), table 9, column (2); for column (5), table 10, column (3).

TABLE 18. COMPUTATION OF ROLE OF MARITAL STATUS DISTRIBUTION IN CHANGES IN CRUDE BIRTH RATE AND GENERAL FERTILITY RATE

(Base population, 1971)

Age group i	Marital status, 1971 M_{2i} (percentage) (1)	Marital status, 1966 M_{1i} (percentage) (2)	Change in marital status $M_{2i}-M_{1i}$ (percentage) (3)	Age structure, 1971 A_{2i} (percentage) (4)	Marital fertility, 1971 F_{2i} (per 1 000) (5)	Change in general fertility rate due to change in marital status distribution $A_{2i}(M_{2i}-M_{1i})F_{2i}$ (per 1 000) (6)
15–19	12.0	18.5	−6.5	23.8	335.2	−5.185544
20–24	68.7	71.0	−2.3	15.5	369.8	−1.318337
25–29	85.5	88.6	−3.1	11.7	362.0	−1.312974
30–34	92.1	92.4	−0.3	11.8	307.7	−0.108925
35–39	92.7	91.9	+0.8	11.5	227.2	+0.209024
40–44	89.8	87.9	+1.9	10.2	114.5	+0.221901
45–49	84.2	81.8	+2.4	8.2	32.5	+0.063960
50–54	74.8	70.5	+4.3	7.3	12.3	+0.038609
TOTAL						−7.392286

Change in general fertility rate due to marital status distribution change: $\sum_i A_{2i}(M_{2i}-M_{1i})F_{2i} = -0.00739$

Change in crude birth rate due to marital status distribution change: $\left[\sum_i A_{2i}(M_{2i}-M_{1i})F_{2i}\right]\frac{W_2}{P_2} = (-0.00739)(0.235) = -0.001737$

Change in general fertility rate: −7.39 per 1 000
Change in crude birth rate: −1.74 per 1 000

SOURCE: For data in column (1), table 9, column (2); for column (2), table 5, column (8); for column (4), table 7, column (4); for column (5), table 10, column (3).

TABLE 19. COMPUTATION OF ROLE OF MARITAL FERTILITY DISTRIBUTION IN CHANGES IN CRUDE BIRTH RATE AND GENERAL FERTILITY RATE

(Base population, 1971)

Age Group i	Marital fertility, 1971 F_{2i} (per 1 000) (1)	Marital fertility, 1966 F_{1i} (per 1 000) (2)	Changes in marital fertility $F_{2i}-F_{1i}$ (per 1 000) (3)	Age structure, 1971 A_{2i} (percentage) (4)	Marital status, 1971 M_{2i} (percentage) (5)	Change in general fertility rate due to change in marital fertility $A_{2i} \cdot M_{2i}(F_{2i}-F_{1i})$ (per 1 000) (6)
15–19	335.2	403.3	−68.1	23.8	12.0	−1.944936
20–24	369.8	398.8	−29.0	15.5	68.7	−3.088065
25–29	362.0	375.3	−13.3	11.7	85.5	−1.330465
30–34	307.7	326.4	−18.7	11.8	92.1	−2.032278
35–39	227.2	251.6	−24.4	11.5	92.7	−2.601162
40–44	114.5	131.2	−16.7	10.2	89.8	−1.529653
45–49	32.5	42.0	− 9.5	8.2	84.2	−0.655918
50–54	12.3	16.2	− 3.9	7.3	74.8	−0.212955
TOTAL						−13.395432

Change in general fertility rate due to marital fertility change: $\sum_i A_{2i} \cdot M_{2i}(F_{2i}-F_{1i}) = -0.013395$

Change in crude birth rate due to marital fertility change: $\left[\sum_i A_{2i} \cdot M_{2i}(F_{2i}-F_{1i})\right]\frac{W_2}{P_2} = (-0.013395)\,(0.235) = -0.003147$

Change in general fertility rate: −13.40 per 1 000
Change in crude birth rate: −3.15 per 1 000

SOURCES: For data in column (1), table 10, column (3); for column (2), table 6, column (3); for column (4), table 7, column 4; for column (5), table 9, column (2).

Rounding will affect the results. In these illustrations, one decimal is preserved for rates per 100 or per 1,000; but in the calculations, two decimals or more were retained to illustrate their usefulness in obtaining precision. Where the change in the crude birth rate is small, it may be advantageous to retain more than one decimal in calculating the contribution of each component.

In the further decomposition of changes in the crude birth rate, the role of the proportion of women of reproductive ages in the total population is calculated as follows (see tables 1 and 13):

$$GFR_1\left(\frac{W_2}{P_2}-\frac{W_1}{P_1}\right) \text{ for the 1966 base population; and}$$

$$GFR_2\left(\frac{W_2}{P_2}-\frac{W_1}{P_1}\right) \text{ for the 1971 base population.}$$

One thus has in the first case:

$$0.1928\,(0.2350-0.2265) = +0.0016388$$

and in the second case:

$$0.1562\,(0.2350-0.2265) = +0.001328$$

The resulting role of the changing proportion of women of reproductive ages is thus + 1.64 per 1,000 with the 1966 base population and + 1.33 per 1,000 with the 1971 base population.

The results of the decomposition to determine the role of these four factors in the decline of the crude birth rate and the general fertility rate are summarized in table 20. These results are analysed and interpreted in section D.

TABLE 20. RESULTS OF DECOMPOSITION INTO FACTORS, 1966 AND 1971 BASES

Changes accounted for by:	Absolute change in crude birth rate (per 1 000)	Absolute change in general fertility rate (per 1 000)
Base population, 1966		
Age structure	−3.32	−14.65
Marital status	−1.68	− 7.43
Marital fertility	−3.327	−14.69
Proportion of women of reproductive ages in total population	+1.64	
Base population, 1971		
Age structure	−3.60	−15.34
Marital status	−1.74	− 7.39
Marital fertility	−3.15	−13.40
Proportion of women of reproductive ages in total population	+1.33	

SOURCES: Tables 14–19.

Joint-effects terms

The results of standardization may be effected by errors or biases which arise when no account is taken of the fact that the influence of one or more of the factors being standardized has its impact conjointly with that of another factor. The extent of these joint effects, sometimes referred to as a form of interaction, may be of such proportion that the results of the standardization (formula 43, given above) must be complemented to take them into account. In the illustrative problem presented here for the general fertility rate, base population P_1, the joint effects are only about 0.2 per 1,000:

(1) *Total change in general fertility rate as observed* (*see section C.3*):

$$\sum_i A_{2i}.M_{2i}.F_{2i} - \sum_i A_{1i}.M_{1i}.F_{1i}$$
$$= 156.2 - 192.8 = -36.6 \text{ per } 1{,}000$$

(2) *Total change in general fertility rate as accounted for by standardization* (*1966 base population*):[24]

Accounted for by age structure..........	−14.7
Accounted for by marital status.........	−7.4
Accounted for by marital fertility........	−14.7
Total	−36.8

It is seen that age structure, marital status and marital fertility together account for a slightly greater change in the general fertility rate than actually occurred, 36.8 as compared with the observed decline of 36.6. The residual of 0.2 per 1,000, which is negligible, is attributable to the joint effects of one of the factors with one or both of the others. It is possible to determine which relationships are accountable for this residual by the following procedures:[25]

(3) *Change accounted for by joint effects of age structure and marital status* (see table 21):

(*a*) Combined role of age structure and marital status:[26]

$$\sum_i A_{2i}.M_{2i}.F_{1i} - \sum_i A_{1i}.M_{1i}.F_{1i}$$
$$= 169.7 - 192.8 = -23.1 \text{ per } 1{,}000$$

(*b*) Independent roles of age structure and marital status:[27]

$$-14.7 + (-7.4) = -22.1 \text{ per } 1{,}000$$

(*c*) Amount attributable to the joint effects of age structure with marital status:

$$-22.1 - (-23.1) = +1.0 \text{ per } 1{,}000$$

(4) *Changes accounted for by joint effects of marital status and marital fertility* (see table 22):

(*a*) Combined role of marital status and marital fertility:[28]

$$\sum_i A_{1i}.M_{2i}.F_{2i} - \sum_i A_{1i}.M_{1i}.F_{1i}$$
$$= 171.6 - 192.8 = -21.2 \text{ per } 1{,}000$$

(*b*) Independent roles of marital status and marital fertility:[29]

$$-7.4 + (-14.7) = -22.1 \text{ per } 1{,}000$$

(*c*) Amount attributable to the joint effects of marital status and marital fertility:

$$-22.1 - (-21.2) = -0.9 \text{ per } 1{,}000$$

(5) *Changes accounted for by joint effects of age structure and marital fertility* (see table 23):

(*a*) Combined role of age structure and marital fertility:[30]

$$\sum_i A_{2i} \cdot M_{1i} \cdot F_{2i} - \sum_i A_{1i} \cdot M_{1i} \cdot F_{1i}$$
$$= 163.6 - 192.8 = -29.2 \text{ per } 1{,}000$$

(*b*) Independent roles of age structure and marital fertility:[31]

$$-14.7 + (-14.7) = -29.4 \text{ per } 1{,}000$$

(*c*) Amount attributable to the joint effects of age structure and marital fertility:

$$-29.4 - (-29.2) = -0.2 \text{ per } 1{,}000$$

[24] See table 20; figures have been rounded.
[25] The methodology is based on C. Gibson, *loc. cit.*, p. 250, foot-note.
[26] For first term of this difference, see table 21.
[27] See table 20; figures have been rounded.
[28] For computation of the first term of this difference, see table 22.
[29] See table 20; figures have been rounded.
[30] For computation of the first term of this difference, see table 23.
[31] See table 20; figures have been rounded.

TABLE 21. COMPUTATION OF HYPOTHETICAL GENERAL FERTILITY RATE WITH SIMULTANEOUS CHANGE IN AGE STRUCTURE AND MARITAL STATUS

(*Base population, 1966*)

Age group i	*Age structure, 1971* A_{2i} (*percentage*) (*1*)	*Marital status, 1971* M_{2i} (*percentage*) (*2*)	*Marital fertility, 1966* F_{1i} (*per 1 000*) (*3*)	*Hypothetical general fertility rate* $A_{2i}.M_{2i}.F_{1i}$ (*per 1 000*) (*4*)
15–19......................	23.8	12.0	403.3	11.51824
20–24......................	15.5	68.7	398.8	42.466218
25–29......................	11.7	85.5	375.3	37.543135
30–34......................	11.8	92.1	326.4	35.472499
35–39......................	11.5	92.7	251.6	26.821818
40–44......................	10.2	89.8	131.2	12.017395
45–49......................	8.2	84.2	42.0	2.899848
50–54......................	7.3	74.8	16.2	0.884584
TOTAL	100.0			169.684037

$\sum_i A_{2i}.M_{2i}.F_{1i}$ = hypothetical general fertility rate = 169.7 per 1 000

SOURCES: For data in column (1), table 12, column (1); for column (2), table 12, column (2); for column (3), table 11, column (3).

TABLE 22. COMPUTATION OF HYPOTHETICAL GENERAL FERTILITY RATE WITH SIMULTANEOUS CHANGE IN MARITAL STATUS AND MARITAL FERTILITY

(Base population, 1966)

Age group i	Age structure, 1966 A_{1i} (percentage) (1)	Marital status, 1971 M_{2i} (percentage) (2)	Marital fertility, 1971 F_{2i} (per 1 000) (3)	Hypothetical general fertility rate $A_{1i}.M_{2i}.F_{2i}$ (per 1 000) (4)
15–19	18.4	12.0	335.2	7.401216
20–24	14.7	68.7	369.8	37.345732
25–29	15.0	85.5	362.0	46.426500
30–34	14.4	92.1	307.7	40.808404
35–39	12.7	92.7	227.2	26.748028
40–44	9.7	89.8	114.5	9.973637
45–49	8.1	84.2	32.5	2.216565
50–54	7.0	74.8	12.3	0.644028
TOTAL	100.0			171.564111

$\sum_i A_{1i}.M_{2i}.F_{2i}$ = hypothetical general fertility rate = 171.6 per 1 000

SOURCES: For data in column (1), table 11, column (1); for column (2), table 12, column (2); for column (3), table 12, column (3).

TABLE 23. COMPUTATION OF HYPOTHETICAL GENERAL FERTILITY RATE WITH SIMULTANEOUS CHANGE IN AGE STRUCTURE AND MARITAL FERTILITY

(Base population, 1966)

Age group i	Age structure, 1971 A_{2i} (percentage) (1)	Marital status, 1966 M_{1i} (percentage) (2)	Marital fertility, 1971 F_{2i} (per 1 000) (3)	Hypothetical general fertility rate $A_{2i}.M_{1i}.F_{2i}$ (per 1 000) (4)
15–19	23.8	18.5	335.2	14.758856
20–24	15.5	71.0	369.8	40.69649
25–29	11.7	88.6	362.0	37.525644
30–34	11.8	92.4	307.7	33.549146
35–39	11.5	91.9	227.2	24.011632
40–44	10.2	87.9	114.5	10.265841
45–49	8.2	81.8	32.5	2.17997
50–54	7.3	70.5	12.3	0.633019
TOTAL	100.0			163.620598

$\sum_i A_{2i}.M_{1i}.F_{2i}$ = hypothetical general fertility rate = 163.6 per 1 000

SOURCES: For data in column (1), table 12, column (1); for column (2), table 11, column (2); for column (3), table 12, column (3).

The preceding analysis has yielded three measures of the joint effects of the general fertility rate (per 1,000), namely: age structure and marital status, +1.0; marital status and marital fertility, −0.9; age structure and marital fertility, −0.2.

These results should be allocated to each of the pertinent components. The problem here is that the exact amount to be allocated to each component is not known; the question is how much of the joint effects of age structure and marital status, for instance, is to be allocated to age structure on the one hand and to marital status on the other. In order to calculate the adjusted contribution of each component, it is assumed that these joint effects can be equally allocated to each component.

(6) *Estimate of the contribution made by each component, adjusted for joint-effects terms, with equal allocation to the components involved.* Since the total change accounted for is higher than the observed change, the adjustment must be subtracted from the unadjusted estimate:

(a) *Adjusted role of age structure.* This estimate is obtained as the computed contribution of age structure less one half of the joint effects of age structure and marital status and less one half of the joint effects of age structure and marital fertility:

$$-14.7 - 1/2(+1.0) - 1/2(-0.2) = -15.1 \text{ per } 1{,}000$$

(b) *Adjusted role of marital status.* This is obtained as the computed contribution of marital status distribution less one half of the joint effects of marital status and age structure and less one half of the joint effects of marital status and marital fertility:

$$-7.4 - 1/2(+1.0) - 1/2(-0.9) = -7.45 \text{ per } 1{,}000$$

(c) *Adjusted role of marital fertility.* This is obtained as the computed contribution of marital fertility less one half of the joint effects of marital status and marital fertility and less one half of the joint effects of age structure and marital fertility:

$$-14.7 - 1/2(-0.9) - 1/2(-0.2) = -14.15 \text{ per } 1{,}000$$

In the present case, the amount of adjustment for joint-effects terms is not very significant, as can be seen in table 24.

TABLE 24. UNADJUSTED AND ADJUSTED CONTRIBUTION TO CHANGES IN GENERAL FERTILITY RATE BY THREE COMPONENTS

Changing components	Unadjusted contribution (per 1 000)	Adjusted contribution (per 1 000)
Age structure	−14.7	−15.1
Marital status	− 7.4	− 7.45
Marital fertility	−14.7	−14.15
Total accounted for	−36.8	−36.7
Total change observed	−36.6	

SOURCE: For unadjusted and adjusted contributions, see section C. 3 above.

Indeed, only 0.1 per 1,000 is gained in taking joint-effects terms into account, which leads to the conclusion that in the present case it is not advantageous to give preference to the adjusted rates since they are affected by roundings, are the result of only an approximation and rely upon an assumption of equal allocation of effects. The same reasons may account here for the modification occurring in the individual contribution by each component, and the magnitude of the correction does not warrant the adoption of the adjusted rates.[32]

D. DETERMINING AMOUNT OF IMPACT AND INTERPRETING RESULTS

1. *Changes in fertility*

Changes in rates

As stated at the outset, a major source of variation in standardization results is due to the specific population chosen as a base or standard of comparison. The choice of a base year is therefore very strategic. And the presentation here of decomposition using first 1966 and then 1971 as the base year was designed to emphasize this fact by illustrating the difference that the base year can make. In normal circumstances, one base population is selected, and the standardization exercise is performed only once.

It would ordinarily be sufficient to round to one decimal, but two or more decimals have been preserved here for the purpose of comparing more rigorously the differences in results obtained when the base population was 1966 and when it was 1971. With the 1966 base population, the changes due to change in all four components account for about 95 per cent of the total change observed in the crude birth rate. The difference between the observed changes and the change accounted for by the components are due to the joint-effects terms, which have not been taken into account in the computation. When the amount of change in the general fertility rate attributable to each of three components was calculated, the sum of the individual contributions just barely exceeded the total amount of observed change (tables 25 and 26).

[32] This is especially the case because the 1971 data used are mainly based on projections and estimates of unknown accuracy.

TABLE 25. CHANGES IN CRUDE BIRTH RATE, 1966–1971

(*Base population, 1966*)

Changing components	Absolute change (per 1 000) (1)	Relative change (percentage) (2)
Age structure	−3.32	−47.43
Marital status	−1.68	−24.00
Marital fertility	−3.327	−47.53
Proportion of women of reproductive ages in total population	+1.64	+23.43
Total change explained	−6.687[a]	−95.53[b]
Total change observed	−7.00 [c]	−100.0

SOURCES: For absolute change in age structure, table 14; in marital status, table 15; in marital fertility, table 16; and in proportion of women of reproductive ages, table 20.

[a] The difference between observed and explained changes is due to the neglected interaction terms.

[b] The percentage changes are computed relatively to the observed change in crude birth rate, not to the explained change.

[c] This figure represents a drop of 16.0 per cent during this period. For the rates, see section C.3.

TABLE 26. CHANGES IN GENERAL FERTILITY RATE, 1966–1971

(*Base population, 1966*)

Changing components	Absolute change (per 1 000) (1)	Relative change (percentage) (2)
Age structure	−14.65	−40.03
Marital status	− 7.43	−20.30
Marital fertility	−14.69	−40.14
Total change explained	−36.77[a]	−100.47[b]
Total change observed	−36.6[c]	−100.00

SOURCES: For absolute change in age structure, table 14; in marital status, table 15; and in marital fertility, table 16.

[a] The difference between observed and explained changes is due to the neglected interaction terms.

[b] The percentage changes are computed relatively to the observed change in general fertility rate, not to the explained change.

[c] This figure represents a change of 19 per cent during this period. For the rates, see section C. 3.

In tables 27–29, the results of the standardization are presented with respect to the same rates and the same data presented above, but computations have been carried out with the 1971 population as the base. A comparison of the role of the components in the absolute and relative rates of change as assessed with each base population follows the tables.

Table 29 underscores the difference in standardization results that can occur solely from the choice of population base. Although the difference is rather minor in the present illustration, the possibility exists that such variability could be more substantial, whether standardization is undertaken for the crude birth rate or for the general fertility rate. In fact, it may be seen that these two rates are affected differently by the base population chosen. In the present case, it may be concluded that either base population provides satisfactory estimates of change for both types of fertility indicator. The subsequent analysis is carried out on the basis of results obtained with the 1966 population as the base. The next step consists of translating the amount of decline into number of births that are assumed not to have occurred as a result of the observed decline in the interest of assessing the impact of a family planning programme.

TABLE 27. CHANGES IN CRUDE BIRTH RATE, 1966–1971

(*Base population, 1971*)

Components kept constant	Absolute change (per 1 000) (1)	Relative change (percentage) (2)
Age structure	−3.60	−51.43
Marital status	−1.74	−24.86
Marital fertility	−3.15	−45.0
Proportion of women of reproductive ages in total population	+1.33	+19.0
Total change explained	−7.16[a]	−102.29[b]
Total change observed	−7.0[c]	−100.0

SOURCES: For absolute change in age structure, table 17; in marital status, table 18; in marital fertility, table 19; and in proportion of women of reproductive ages, table 20.

[a] The difference between explained and observed change is due to the neglected interaction terms.

[b] The percentage changes are computed relatively to the observed change in crude birth rate, not to the explained change.

[c] This figure represents a decrease of 16 per cent during this period. For the rates, see section C. 3.

TABLE 28. CHANGES IN GENERAL FERTILITY RATES, 1966–1971

(*Base population, 1971*)

Components kept constant	Absolute change (per 1 000) (1)	Relative change (percentage) (2)
Age structure	−15.34	−41.91
Marital status	− 7.39	−20.19
Marital fertility	−13.40	−36.61
Total change explained	−36.13[a]	−98.71[b]
Total change observed	−36.6[c]	−100.0

SOURCES: For absolute change in age structure, table 17; in marital status, table 18; and in marital fertility, table 19.

[a] The difference between the observed and explained changes is due to the neglected interaction terms.

[b] The percentage changes are computed relatively to the observed change in general fertility rate, not to the explained change.

[c] This figure represents a drop of 19 per cent during this period. For the rates, see C. 3.

Number of births estimated not to have occurred

The number of births calculated not to have occurred over any given period of time, as a result of changes in specified demographic factors, is a hypothetical estimate based on the assumptions made in the course of standardization. It should be emphasized that this estimate does not account for the total births not having occurred between 1966 and 1971, but rather presents hypothetical figures for a given calendar year. In the present case, calculations are made for 1971, showing the (hypothetical) number of births for the year 1971 that would have occurred had the specified components not changed but remained as in 1966. The estimated number of births that would not have occurred due to change in each component can now be calculated. First, an estimate is made of the hypothetical total number of births that would have occurred in 1971, had the 1966 level of the crude birth rate not changed. Then, the number of births that did not occur as a result of changes in individual components can be derived. These estimates are computed in the next paragraphs and in table 30.

Given the assumption of unchanged components between 1966 and 1971, the crude birth rate in 1971 and 1966 would have been the same. The hypothetical number of births that would have occurred in 1971 is thus obtained as follows:

Crude birth rate in 1966	0.0437
Hypothetical crude birth rate in 1971	0.0437
Total population in 1971	5 238 500
Hypothetical number of births in 1971 under unchanged conditions (5,238,500 × 0.0437 = 228,922 births)	228 922
Number of births observed in 1971	192 476
Number of births assumed not to have occurred as a result of changes in age structure, marital status, marital fertility and proportion of women of reproductive ages in the total population[a]	36 446

[a] The 1971 crude birth rate utilized in the standardization is 36.7 per 1,000, which results from rounding 36.74, the actual birth rate computed from 192,476 ÷ 5,238,500. The number of births corresponding to a birth rate of 36.7 is: 0.0367 × 5,238,500 = 192,253 births.

If this figure is utilized instead of the observed 192,476 births, the adjusted number of births assumed not to have occurred as a result of changing components becomes: 228,922 − 192,253 = 36,669.

The effect of rounding the 1971 crude birth rate to one decimal accounts for a difference of 36,669 − 36,446 = 223 births.

TABLE 29. COMPARISON OF RESULTS OBTAINED WITH 1966 AND 1971 AS THE BASE POPULATION YEARS, COUNTRY A

Change in crude birth rate accounted for by:	Absolute change[a] 1966 (per 1 000)	Absolute change[a] 1971 (per 1 000)	Relative change[a] 1966 (percentage)	Relative change[a] 1971 (percentage)
	Crude birth rate[b]			
Age structure	−3.32	−3.60	−47.43	−51.43
Marital status	−1.68	−1.74	−24.00	−24.86
Marital fertility	−3.327	−3.15	−47.53	−45.0
Proportion of women of reproductive ages in total population	+1.64	+1.33	+23.43	+19.0
Total change accounted for	−6.687	−7.16	−95.53	−102.29
	General fertility rate[b]			
Age structure	−14.65	−15.34	−40.03	−41.91
Marital status	− 7.43	− 7.39	−20.30	−20.19
Marital fertility	−14.69	−13.40	−40.14	−36.61
Total change accounted for	−36.77	−36.13	−100.47	−98.71

[a] Dates refer to the base population year. [b] See tables 25–28.

TABLE 30. INFLUENCE OF CHANGE IN SPECIFIED COMPONENTS UPON THE NUMBER OF BIRTHS IN 1971, COUNTRY A

(Base population, 1966)

Change accounted for by:	Change (per 1 000)	Contribution to the hypothetical number of births in 1971: Number[a]	Percentage
	Crude birth rate[b]		
Age structure	−0.00332	−17 392	−49.6
Marital status	−0.00168	− 8 801	−25.1
Marital fertility	−0.003327	−17 428	−49.8
Proportion of women of reproductive ages in total population	+0.00164	+ 8 591	+24.5
TOTAL		−35 030	−100.0
	General fertility rate[c]		
Age structure	−0.01465	−17 382[d]	−39.8
Marital status	−0.00743	− 8 816[d]	−20.2
Marital fertility	−0.01469	−17 430[d]	−40.0
TOTAL		−43 628	−100.0

[a] The hypothetical number of births is obtained as the product of the amount of change per 1 000 multiplied by the total population in 1971: 5,238,500. The "minus" sign characterizes a decline, the "plus" sign an increase.

[b] Amount of decline taken from table 25.

[c] Amount of decline taken from table 26.

[d] The number of births prevented is obtained as the product of the amount of change per 1,000 and the total number of women in reproductive ages, corrected for $\frac{W_1}{P_1}$, i.e., 1 186 520 as shown below.

The question is how the various components account for the number of births assumed not to have occurred in 1971 as a result of changes in these components. Table 30 presents these estimates obtained on the basis of the 1966 base population.

As in the computation only one component at a time is allowed to change, it is erroneous to multiply the amount of decline in the general fertility rate by the number of women of reproductive ages enumerated in 1971, as this figure does reflect the increase in the proportion of that category of women. A more appropriate course is to keep that component constant by estimating the number of women in the reproductive ages in 1971 with the proportion observed in 1966, as follows:

$$\frac{P_2(W_1)}{P_1}$$

thus, 5,238,500 × 0.2265 = 1,186,520. It is this latter figure multiplied by the amount of decline in the general fertility rate that yields the number of births prevented given in table 30.

How does one account for the difference between the adjusted 36,669 births assumed not to have occurred (see section D.1) and the 35,030 births accounted for by the various components. In the present case, failure to make allowance for the joint-effects terms accounts for most of the difference. From table 25, it may be seen that the part not accounted for amounts to: 7.0 − 6.687 = 0.313 per 1,000. In other words, the number of births not accounted for because of the procedure is: 0.000313 × 5,238,500 = 1,640 births. The total number of births prevented amounts to 36,670, comprising:

(*a*) Number of births accounted for: 35,030;

(*b*) Number of births not accounted for: 1,640.

Indeed, the total amount of decline in the crude birth rate is 0.007 and the corresponding number of births not having occurred is: 0.007 × 5,238,500 = 36,669.5.

Table 30 presents the major results of the standardization. It can be seen that the number of births assumed to have been prevented by changes in age structure, marital status and marital fertility are similar whether computed on the basis of the crude birth rate or on the general fertility rate. The only difference is that the general fertility rate does not make allowance for the proportion of women of reproductive ages in the total population, thus affecting the estimate of total number of births not having occurred. As far as assessment of programme impact on fertility is concerned, table 30 shows that the number of births accounted for by the change in marital fertility is greater than that attributable to other factors so that, whereas age structure played a role of nearly equal importance, the control of fertility within marriage was somewhat more influential.

A number of concluding remarks can now be made with respect to the interpretation of the results presented in the preceding tables:

(*a*) Results differ according to the base population chosen; this factor should be borne in mind and particular care given to the choice of a population base to permit a single standardization;

(*b*) The evaluator of the programme is interested foremost in births that did not occur, as a result of changes in marital fertility. As such, the standardization of the general fertility rate is sufficient as both that rate and the crude birth rate yield very similar results;

(*c*) If an assessment of the total number of births assumed not to have occurred is sought, it should be noted that the total estimated on the basis of the general fertility rate is, in the present case, higher than the estimate based on the crude birth rate because the latter rate takes into consideration the proportion of women of reproductive ages in the total population;

(*d*) The hypothetical number of births assumed not to have occurred because of changes in individual components refers to a specified calendar year (1971 in the present case) and not to the whole period under study (i.e., from 1966 to 1971);

(*e*) The hypothetical number of births computed by the standardization approach assumes, in the present case, that all factors are constant as of 1966 (because of the 1966 base population) except the component whose role is being assessed and which is given its 1971 value;

(*f*) The major outcome of this standardization is an estimated 17,428 births which did not occur as a result of changes in the marital fertility component. The question is then to determine how many of those births did not take place as a result of other non-programme factors and how many can be credited to the programme;

(*g*) Although it is usually simpler to utilize numbers rounded to one decimal, it should be recalled that differences are magnified when rates thus rounded are translated into number of births. Such a bias is likely when the rounding encompasses an adjustment of the largest magnitude. In other words, if 0.796 is rounded to 0.80 the bias is small, but if 0.751 is rounded to 0.80, the effect of the rounding, in terms of number of births, may be quite substantial;

(*h*) Differences that should be attributed to the joint-effects terms may also play a substantial role in particular cases, and this factor also should be borne in mind when interpreting results. Small joint effects, say of less than 0.001 in absolute value, may be assumed to be negligible.[33] In other cases, their role should be assessed. If, however, the evaluator wants to ascertain whether the individual contribution of each component is modified by the joint-effects terms, then the role of these terms must be measured.

2. *Programme impact on fertility*

Assessing programme impact

The following example illustrates one practical means of estimating births averted following standardization. It uses data that are limited in detail and is, in fact, a rather rough means of obtaining births averted. Among other things, it does not include the usual discounts for intra-uterine device (IUD) use time. Since it is assumed that the impact of a family planning programme on fertility is achieved only through the ability of the programme to influence married women to practice family planning,[34] the starting-point for analysing programme effect on fertility is the estimation of the number of births assumed not to have occurred as a result of changes in marital fertility. For Country A (1971), this number, estimated by standardization, amounts to 17,430 births which, theoretically, were avoided as a result of both programme and non-programme factors. The problem is to determine how many of these births can be accounted for by programme activities. Various approaches can be utilized in such an analysis, but the approach followed here is the direct computation of the number of births averted in 1971 based upon statistics of programme acceptance and use, which is then compared to the hypothetical number of births estimated by the standardization method. If the two figures are close, it may be concluded that the programme has had an important role in the marital fertility decline. If the direct estimate of births prevented is smaller than the estimate obtained by standardization, the difference may be attributed to the role of non-programme factors. Should the direct estimate be larger than the total number obtained through standardization, the data, procedures and assumptions should be reviewed in aid of an explanation for such an unlikely occurrence.

The validity of the assessment described above rests, *inter alia*, upon the quality of the data and the strength of the assumptions. In this connexion, it may be noted that statistics maintained by programmes on acceptors and users of family planning methods are almost invariably inaccurate, while statistics obtained from surveys may possibly be impaired by both sampling and non-sampling errors. In addition, simplifying assumptions for estimating births averted affect results.

The procedure utilized below for estimating births averted directly from programme acceptance data is directed to providing only annual approximations when limited data are available and is not a substitute for the other, more sophisticated procedures which are explained in this *Manual* and which can be applied when more detailed data are at hand. This method yields an order of magnitude; there is no pretense at estimating the exact numbers of births averted.

Methodology

The number of births prevented in 1971 by the family planning programme results from the application of birth control between 1 April 1970 and 1 April 1971, allowance being made for the nine-month pregnancy period. In applying the method, it was assumed that contraceptive use was 100 per cent effective, that users were uniformly distributed during 1970 and 1971 and, in order to simplify computations further, that the number of family planning users as of 1 October 1970 represented the average number over the period from 1 April 1970 to 1 April 1971 (see figure II). In other words, births prevented in 1971 result from the estimated number of users as of 1 October 1970.

Once the number of users has been calculated, the number of births prevented in 1971 by these users is obtained as a product of the estimated number of users and their potential fertility.[35]

For Country A and generally for most countries, there is no information that would permit a distinction of programme acceptors who would have practised family planning in the absence of the programme and programme acceptors who would have remained unprotected against pregnancy in the absence of the programme. Thus, in this example, it is assumed that all programme acceptors would have been exposed to the risk of pregnancy had there been no family planning programme.[36] It is also postulated that in the absence of the programme, the fertility of the acceptors would have remained constant.

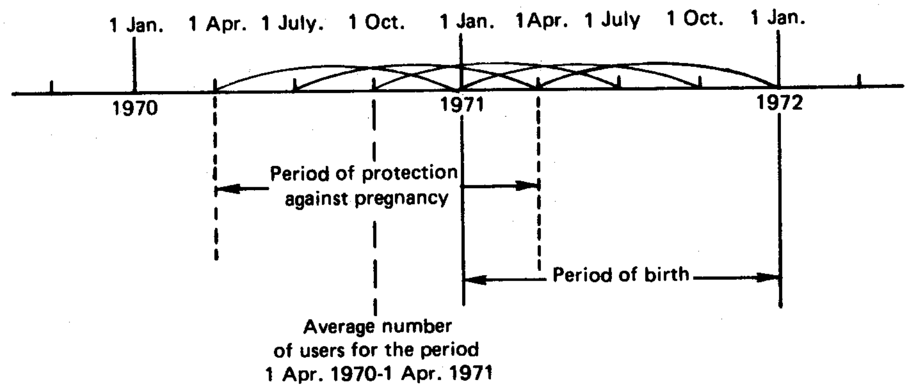
[33] The joint effects are obtained as the difference between the amount of change accounted for by the standardization and the amount of change observed.

[34] Such factors as foetal mortality and temporary sterility can also effect marital fertility, but those factors are not taken into account in this procedure.

[35] "Potential fertility" has been defined as "the fertility a population subjected to a family planning programme would have experienced in the absence of this programme". Methodological issues related to this concept and its estimation are discussed in "Methods of measuring the impact of family planning programmes on fertility: problems and issues", *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication Sales No. E.78.XIII.2), pp. 23–27.

[36] There is evidence, however, that although there was a potential for family planning acceptance prior to the programme, there was at the time a relatively low degree of family planning practice and low use-effectiveness. It appears reasonable to assume that in the absence of the programme, this situation would have prevailed, at least in the short run. When birth control is widespread and effective prior to a programme, it is safe to assume that some pre-programme family planners would have practised birth control even in the absence of the programme.

Figure II. Period of birth control and period of birth



Although there are no data on acceptors or on marital fertility to support this assumption, the birth rate series presented in table 2 suggests that prior to 1966 fertility had not changed, at least for some time. For present purposes, therefore, it was postulated that this stability would have continued in the absence of the family planning programme.

Derivation of estimates

Description of programme conditions

To obtain the number of births averted, two values are thus necessary: the number of users as of 1 October 1970; and an estimate of potential fertility. As regards the latter value, and on the basis of the assumptions previously made, the 1966 marital general fertility rate is taken as the potential level, i.e., 267.1 per 1,000 married women aged 15–54 years.[37]

The family planning methods offered by the programme of Country A are: intra-uterine devices; oral contraceptives; condoms; jellies; female sterilizations; and abortions. The major part of all family planning contraceptive methods is provided by official family planning units hosted in hospitals, clinics and maternal and child health centres. The role of the private sector, limited mostly to contraceptive pills, is small; and, given the prevailing socio-cultural conditions, it is assumed that private-sector contraception can be credited to non-programme factors. The data on contraceptive acceptance and abortions are drawn from service statistics records of generally good quality.

Estimating number of users

Intra-uterine devices. Statistics were available of first and subsequent insertions of intra-uterine devices but without information regarding contraceptive practice prior to enrolment in the programme. To prevent the double-counting of acceptors, only first insertions were taken into account. No provision was made for acceptors who shifted from one method to another in the programme or for those who complemented contraceptive failure with abortion. It was assumed that acceptance occurs uniformly during the calendar year and that protection lasts for an average of six months during the year of acceptance.

Thus, the number of users as of 1 October 1970 is estimated by applying the appropriate retention rates to the annual number of acceptors in the years 1966–1969 and for 1970, to the number of acceptors from 1 January to 1 October, i.e., the first nine months of 1970.[38] In the method of estimation, the annual numbers of acceptors are represented as being of 1 July in that year, except for 1970, when the representation is of 15 May.

It should be noted that the number of users may be underestimated in this way, as women who accepted before 1966 may have continued use. The estimation may include as many earlier years as available data permit.

The number of IUD acceptors was translated into the number of IUD users on the basis of retention rates computed from results of a follow-up study of programme acceptors.[39] The retention rates used are as

[37] In the present case, it is the marital fertility of all married women that is chosen (acceptors as well as non-acceptors). In certain cases, all women, married and non-married, are taken into consideration; in other cases, the fertility of acceptors prior to acceptance only is taken into consideration for estimating potential fertility. See "Methods of measuring the impact of family planning programmes on fertility: problems and issues", *loc. cit.* It should also be noted that use of the age group 50–54 depresses the general fertility rate used.

[38] Women protected as of 1 October 1970 must necessarily have accepted a contraceptive prior to that date.

[39] Although continuation rates can be computed from detailed clinical records through decremental life-table techniques, the rates so obtained do not account adequately for women lost to follow-up, nor for those who do not come back for check-ups but remain protected against pregnancy. For impact measurement, follow-up studies provide more satisfactory information on continuation of contraceptive use than do clinical records, provided that the sample is representative. For life-table methods see, notably, Robert G. Potter, "Application of the life-table technique to the measurement of contraceptive effectiveness",

follows:[40]

Number of months after acceptance	Retention rates[a] (per 100 acceptors)
0	100.0[b]
6	84.9
12	74.6
24	58.5
36	46.7
48	38.3

[a] Retention rates refer to all intra-uterine device (IUD) segments. A "segment" is defined as "a period of use starting with a first or later insertion and either terminated by an event such as accidental pregnancy, expulsion of IUD, removal of IUD, or loss to follow-up, or continuing as of cut-off date." See Christopher Tietze, "Intra-uterine contraception: recommended procedures for data analysis", *Studies in Family Planning*, vol. 1, No. 18 (supplement) (April 1967), p. 1. Each reinsertion constitutes one addition segment. All rates are obtained from a follow-up survey and cover the acceptance years 1969–1972. These rates are assumed to be valid for the period 1966–1970.

[b] A retention rate of 100 per cent applies to day of acceptance only.

The number of IUD users as of 1 October 1970 can then be computed (table 31).

TABLE 31. NUMBER OF WOMEN PROTECTED BY INTRA-UTERINE DEVICES AS OF 1 OCTOBER 1970

Year of insertion	number of acceptors as of 1 July	Duration of use as of 1 October 1970 (months)	Retention rates[a] (per 100)	Number of women protected as of 1 October 1970
1966	12 077	51	35.975	4 345
1967	9 657	39	44.600	4 307
1968	9 304	27	55.550	5 168
1969	8 696	15	70.575	6 137
1970	7 229[b]	4.5	88.675	6 410
TOTAL	46 963			26 367

SOURCE: Data on acceptors obtained from the service statistics records of Country A. Except for 1970, the data relate to annual numbers of acceptors, assumed to represent the number of acceptors as of 1 July.

[a] Obtained by linear interpolation of rates shown in the text table given above.

[b] The 7 229 acceptors represent three quarters of the annual number of first insertions in 1970 and cover the period from 1 January to 1 October. Hence, the figure of 7 229 is the nine-month average as of 15 May.

Oral contraceptives. The average number of visits that women made each month to family planning clinics for supplies during the year 1970 is taken to be the same as the number of pill users as of 1 October 1970, thus implying that: (*a*) pill use is uniformly distributed over the 12-month period; (*b*) all women receive supplies to cover one menstrual cycle only; (*c*) over-estimation of the number of users results from the fact that some women may obtain the supplies from clinics twice in one month; and (*d*) underestimation and over-estimation resulting from the last two assumptions cancel each other. It is also assumed that all supplies received are correctly and fully utilized.

Condoms and jellies. The number of condom and jelly users was estimated by the same procedure and on the same assumptions as those used for oral contraceptives. However, much less confidence can be placed in these estimates; the assumption that one visit to the clinic ensures one month of supplies cannot be supported by available information. As the number of acceptors resorting to these two family planning methods are comparatively small, it was assumed that possible biases would not affect unduly the over-all estimate of contraceptive users. According to service statistics records of Country A, the number of pill, condom and jelly users as of 1 October 1970 was estimated to be: pill, 6,285; condom, 2,254; and jelly, 340. The data are monthly averages obtained by dividing the annual number of visits by 12.

Female sterilization. Sterilization is a permanent birth limitation method, and it is required to determine for a given group of women[41] who have been sterilized for birth control purposes what number of surviving, cohabiting couples would not have become sterile from other causes, but are still protected against pregnancy at a given point in time. The rates used to compute the residual number of cohabiting couples protected against pregnancy *n* months after sterilization were as follows:

Number of months (p) after sterilization	Proportion of sterilized women still protected against pregnancy p months after sterilization (per 1 000)
12	933.0
24	867.0
36	793.0
48	718.0
60	645.0

SOURCE: Rates are taken from, "Births averted by tubal ligations in Tunisia", prepared by L. Behar, in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 102–106. This procedure, applied to a group of women sterilized at ages 25, 30, 35, 40 and 45, takes into consideration mortality, widowhood, divorce, sterility and the probability that the women might have resorted to another method of contraception if not sterilized.

These proportions are applied in this example only to complete the illustration of the impact evaluation procedure. When utilized, they should always represent the

Demography, vol. 3, No. 2 (1966), pp. 297–304; Christopher Tietze and Sarah Lewit, "Recommended procedures for the statistical evaluation of intrauterine contraception", *Studies in Family Planning*, vol. 4, No. 2 (February 1973), pp. 35–42; Robert G. Potter and Roger C. Avery, "Use-effectiveness of contraception", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 133–162.

[40] It has been shown that the proportion of women retaining their intra-uterine device may be estimated with at least a fair degree of precision with the formula:

$$R = ae^{-rt}$$

where R = retention rate at time t;
a = a constant that allows for immediate expulsion;
e = the natural logarithm base;
r = the constant annual rate of decline;
t = time.

See W. Parker Mauldin, "Births averted by family planning programs", *Studies in Family Planning*, vol. 1, No. 33 (August 1968), p. 6. See also P. M. Kulkarni and R. G. Potter, "Extrapolation of IUD continuation curves", *Population Studies* (London), vol. 30, No. 2 (July 1976), pp. 353–368 and chapter V of this *Manual*, especially section B.2 and Section C, as regards the effect of marriage dissolution.

[41] In this illustration, only female sterilization is accounted for. This is because sterilization of males is not provided for in the family planning programme of Country A. If evaluation is being performed for a programme that provides male sterilization, this factor must be taken into account in calculating the proportions of sterilized women still protected against pregnancy *p* months after sterilization.

experience of the country under study. As treated here, the estimation of the number of women protected against pregnancy as of 1 October 1970 assumes that sterilization is accepted uniformly over 12 months of a given year; that, on the average, the woman is in the sterilized state only six months of the year in which she accepts it; and that the annual number of sterilizations is the average as of 1 July. As stated above, an exception is made for the year 1970 for which only the first nine months of the year are taken into consideration. Women protected as of 1 October must necessarily have been sterilized prior to that date. Hence, the annual number of sterilizations is assumed to have been that accepted as of 15 May, i.e., midway between 1 January and 1 October.

The number of women protected by sterilization as of 1 October 1970 can now be estimated (see table 32).

TABLE 32. NUMBER OF WOMEN PROTECTED BY STERILIZATION AS OF 1 OCTOBER 1970

Year of sterilization	Number of women sterilized as of 1 July	Number of months after sterilization p	Proportion of sterilized women still protected against pregnancy p months after sterilization[a] (per 1000)	Number of women protected by sterilization as of 1 October 1970
1966	766	51	699.75	536
1967	742	39	774.25	574
1968	1 627	27	848.50	1 381
1969	2 513	15	916.50	2 303
1970	1 904[b]	4.5	974.88	1 856
TOTAL	7 552			6 650

SOURCE: Data on number of women sterilized as of 1 July taken from the service statistics of Country A.

[a] Obtained by linear interpolation of proportion of sterilized women still protected against pregnancy from 12 to 60 months after sterilization.

[b] These sterilizations represent three quarters of the annual number of sterilizations performed in 1970 and cover the period from 1 January to 1 October 1970. Hence, the figure of 1,904 is the nine-month average as of 15 May.

Abortions. In computations of the number of births averted by abortions, the present procedure relies on research by Potter[42] who, on the basis of simulation models, concluded that one abortion can be worth less than 0.5 birth in the absence of contraception, but that it can be equivalent to more than 0.8 birth averted if efficient contraception is used. Assuming that an equal number of abortions is performed in cases where contraception was not used and where it was used but failed, the abortion/births averted ratio would be: $(0.5 + 0.8)/2 = 0.65$.

In order to estimate the number of births averted by abortions in 1971, the number of abortions that would have resulted in births in 1971 has to be multiplied by 0.65. Since, for the country under study, there is some evidence that the average duration of pregnancy prior to the performance of an abortion is two months, the births averted in 1971 are assumed to result from abortions performed between 1 June 1970 and 31 May 1971. There were 2,705 abortions in 1970, and 3,197 abortions in 1971 within the family planning programme. It is assumed that abortions are uniformly distributed during a calendar year and the number of abortions performed between 1 June 1970 and 31 May 1971 may be estimated as follows: $2{,}705 \times (7/12) + 3{,}197 \times (5/12) = 2{,}910$ abortions.

[42] Robert G. Potter, "Births averted by induced abortion: an application of renewal theory", *Theoretical Population Biology*, vol. 3, No. 1 (March 1972), pp. 69–86.

Computation of number of births averted

The hypothetical number of births averted in 1971 by all contraceptive methods offered by the programme can now be estimated as described in table 33.

TABLE 33. NUMBER OF BIRTHS AVERTED IN 1971 BY METHODS OFFERED IN THE FAMILY PLANNING PROGRAMME

Type of family planning method	Number of women protected against pregnancy as of 1 October 1970	Potential fertility (per 1 000)	Hypothetical number of births prevented in 1971
Intra-uterine device ...	26 367	267.1	7 043
Pills	6 285	267.1	1 679
Condoms............	2 254	267.1	602
Jellies..............	340	267.1	91
Sterilization..........	6 650	267.1	1 776
TOTAL	41 896		11 191

SOURCES: For number of women protected as of 1 October 1970 by intra-uterine devices, table 31; by pills, condoms and jellies, section D.2 of this chapter; and by sterilization, table 32.

The number of births averted by programme contraceptive methods is thus estimated at 11,191. The number of births averted by the 2,910 programme abortions discussed above is estimated as: $2{,}910 \times 0.65 = 1{,}891$.

The total hypothetical number of births averted by the family planning programme for the calendar year 1971 resulting from programme activities during the period 1966–1971 is thus estimated at: $11{,}191 + 1{,}891 = 13{,}082$.

An approximate appraisal of the programme impact on fertility suggests that, of the 17,430 births which did not occur in 1971 as a result of changes in marital fertility, about 13,000 births can be accounted for by family planning programme activities.

3. *Interpretation of results*

Broadly interpreted, the results of both evaluation procedures (standardization and impact evaluation) can be summarized as follows:

(*a*) Total number of births not having occured in 1971, 17,430;

(*b*) Births prevented by family planning programme services, 13,082;

(*c*) Births that did not occur due to non-programme factors, 4,348.

These estimates are hypothetical, in that they are based on a large number of adjustments and assumptions which were introduced in the preceding sections. However, the results appear to be sufficiently reasonable and thus may provide programme evaluators with satisfactory approximations of programme impact on fertility. A first step in relating more precisely programme activities to fertility changes would require both monthly acceptance data and monthly continuation rates. Data on acceptance and use of programme methods by single year of age or for, at least, five-year age groups would have made it possible to introduce helpful refinements, including the linkage of acceptance of family planning and fertility decline according to age.

It is difficult, if not impossible, to assess the over-all weight of each particular assumption in the evaluation results; however, they should be borne in mind. For Country A, at least, the assumption that much of the change in legimate fertility has been due to family planning practice is evidently correct, but other factors, such as foetal mortality, post-partum amenorrhoea and migration of spouse, may interfere. Likewise, when estimated on the basis of the general marital fertility rate, births averted by sterilization may be over-estimated, as average age at acceptance is much higher for sterilization than for other contraceptive methods. The assumption that family planning is practised with 100 per cent use-effectiveness is, of course, also a source of over-estimation, especially in respect of methods other than sterilization. Two other sources of over-estimation and underestimation need to be borne in mind. One may result from the fact that a certain proportion of acceptors participating in the programme would have practised family planning even in the absence of the programme and hence, by being considered as genuine programme acceptors, they inflate the estimated effect of the programme. On the other hand, the occurrence of what has been known as "indirect programme effects" tends to underestimate programme effect. These effects occur when couples are genuinely motivated by the existing family planning programme, but do not resort to the programme services to meet their family planning needs. In both cases, gathering evidence in support of the assumptions made is very difficult.

The potential fertility estimate utilized may also be a source of bias. It may over-estimate the number of births averted to the extent that some of the programme acceptors were users prior to the programme and simply shifted from private to official family planning. This bias is, however, considered negligible in the country under review because pre-programme contraception was very low. On the other hand, underestimation of births averted can result from using a potential fertility indicator related to all married women because this group is likely to include a proportion of women who are sterile and thus would not have gone to the programme for family planning services. In addition, sterility may also affect women after their acceptance either as a result of age; or temporarily as a result of a birth, an abortion or simply through breast-feeding.

A major problem in interpretation of the results is that of assessing the validity of the potential fertility estimate. Where pre-programme fertility was constant, it could reasonably be assumed that fertility would have remained constant in the absence of the programme, as was done here. However, this assumption is not completely accurate, for it is likely that fertility would have declined to some extent in response to the socio-economic changes that made possible both the inauguration of the programme and its success.[43] Generally speaking, it can be said that the various assumptions made in assessing fertility changes and family planning programme impact on fertility are expected to produce slight over-estimations and underestimations of births averted. As it cannot be established that these biases cancel one another, the results must be regarded as, at best, approximations.[44]

[43] In certain countries, development and modernization may cause a temporary rise in fertility due to better nutrition, decline of communicable and debilitating diseases, decline of breast-feeding, disruption of the largely rural practice of prolonged post-partum abstinence and so on.

[44] It remains difficult, at this point, to interpret the observed fertility decline in terms of changes in family size. The proportions of family planning practice motivated by the desire to limit the number of births or to postpone a birth cannot be assessed with the available data and over a short time span.

Chapter II

STANDARD COUPLE-YEARS OF PROTECTION

Martin Gorosh and David Wolfers***

It is now generally accepted that evaluation of national family planning programmes must be directed to determining achievements and assessing strategies on a number of levels, including the administrative, demographic, financial and political levels. Furthermore, the results of these assessments must be represented in a convenient form for annual or other appropriate periods. What a family planning programme accomplishes may be measured in many ways. For example, programme achievements may be represented by a mass of statistics on such topics as acceptors by age, parity and method; continuation rates, pregnancy rates, conversions between methods and so on. But in such cases, the larger the number of different indices displayed, the more hopeless becomes the task of drawing comparisons between years or between programmes.[1]

It was to overcome this problem of interpreting achievements from service statistics and clinical records that Wishik[2] introduced the concept of combining the incidence of long-term contraceptive methods with the prevalence of short-term methods into a single index known as couple-years of protection (CYP). This index summarizes the total achievement of a year's programme work into a single figure, satisfying at least some of the needs which demand such an assessment. For the most important tasks, however, it has very serious deficiencies.[3]

It cannot be used to compare successive years or different areas in terms of the impact of the programme on fertility. This limitation exists because, in terms of birth-preventing effect, the couple-years of protection summed to yield the accomplishment index are a mixture of many different values, specifically:

(*a*) Contraception by women of all different ages is given equal weight. Evidence suggests that contraceptive use by parous women under 18 years of age is about 17 times as productive in avoiding births as use by women over 43, with a steeply sliding scale between the groups.[4] Shifts in the age distribution of acceptors from year to year can therefore outweigh changes in the number of acceptors;

(*b*) The physiological state of women at the time of acceptance is not taken into account. In all programmes, it has been found that a large proportion of acceptors adopt contraception shortly after the birth of a child. Of these acceptors, a high proportion may not at the time of acceptance be susceptible to impregnation; they are in a state of post-partum amenorrhoea or anovularity. The first few months of use by such women are without birth-preventing value. There is, furthermore, great variation from time to time within programmes, and always between programmes in the importance of this consideration, particularly where post-partum programmes form different proportions of the total family planning programme effort. The basic assumption of the CYP methodology, that x months of use by y women is equivalent to y months of use by x women, is invalid where use in the post-partum state of anovularity is included in the sum;

(*c*) The quality of contraception is not taken into account. With pregnancy rates (use-effectiveness) varying from zero per 1,000 for sterilization to perhaps 400 per 1,000 in some circumstances for rhythm, one again sees that a shift in the contraceptive mix can be as significant as a change in contraceptive prevalence, or more so;

(*d*) Fertility levels, and thus fertility expectations, are not taken into account. There is wide variation not only between countries in fertility levels but within countries, usually on a rural-urban basis of division. Certainly for international comparison it is necessary to incorporate this parameter into calculations.

Are these four rather serious defects of the CYP methodology remediable? The present authors believe that they are and that within the limitations of the data usually available in such settings, it is possible to devise a

* Assistant Professor, Center for Population and Family Health, Columbia University, New York; and

** Consultant on Family Planning, Ministry of Health, Israel.

[1] This problem arises especially where statistics are not available to support evaluation of the demographic impact of the programme.

[2] Samuel M. Wishik, "Indexes for measurement of amount of contraceptive practice", (SD/Dem/AFPM/14) paper prepared for a meeting of the Expert Group on Assessment of Acceptance and Use-effectiveness of Family Planning Methods, Economic Commission for Asia and the Far East, Bangkok, 11–21 June 1968.

[3] Lee L. Bean and William Seltzer, "Couple years of protection and births prevented: a methodological examination", *Demography*, vol. 5, No. 2 (1968); pp. 947–959; C. Chandrasekaran and K. Srinivasan, "Evaluation of family planning programmes", in *Evaluation of Family Planning Programmes, Report of a Regional Seminar*, Bangkok, 24 November – 12 December 1969 (United Nations publication, Sales No. E.70.II.F.20), pp. 42–55; W. H. Mosley, "Application of demographic methods in population planning", *International Journal of Health Services*, vol. 3, No. 4 (1973), pp. 601–609.

[4] David Wolfers, "Birth averted: important unresolved problems", in *International Population Conference, Liège, 1973* (Liège, International Union for the Scientific Study of Population, 1974), vol. 2, pp. 233–245.

procedure which will yield a single summary figure to describe the annual accomplishment of a programme sufficiently accurately to serve all the purposes described above. What such an index cannot do, however, is to provide a predictor of the time pattern of demographic change that will follow from a year of programme activities. This value is precluded by the nature of the CYP index, which gives credit to the year assessed both for contraceptive use in that year and for the projected effects of the long-term contraceptive use (and sterilization) initiated in that year. The prediction of the time curve of demographic change is a different exercise not considered here.

A. Standard couple-years of protection approach and formulation

The approach adopted is to express all contraceptive use in terms of a standard couple-year of protection (SCYP). The quantity, arbitrarily selected, is the perfect practice of a 100 per cent effective contraceptive method over a period of one susceptible year by a couple representative of a group with an expected fertility rate[5] of 400 per 1,000 women.

Simple, or crude, couple-years of protection (CCYP) are subjected to a series of modifications based on the age-specific fertility rate applicable during the time of use, the proportion of that time spent in a non-susceptible state, the probability that the user is sterile and the probability of pregnancy developing during use. The effect of these modifications is to render comparable, or commensurate, periods of contraceptive use by different women in different settings with different methods and to generate an index which measures programme accomplishment in a way which has appropriate significance for the objectives of a population programme and does not vary in significance over time and in place.

The data requirements for these computations are naturally more onerous than for the calculation of crude couple-years of protection, but they are not beyond the resources nor outside the routine data collection systems of the average national programme. In certain cases (most importantly, the incorporation of compensation for post-partum amenorrhoea on an age-specific basis), the use of standard tables is recommended. Although inaccuracy is inevitably introduced by such a procedure, the two alternatives, that of generating local data and that of omitting any correction for these factors, are very much less satisfactory. Local data on age-specific mean post-partum amenorrhoea (PPA) or of its age-specific distribution, are obtainable only after laborious long-term prospective studies which do not justify their expense by general utility, while the omission of any correction for post-partum amenorrhoea may, in the case of short periods of contraceptive use, lead to errors as high as 50 per cent. Any reasonably plausible schedule of correction is therefore likely greatly to enhance the accuracy of the calculations, and it is the authors' belief that the procedures recommended here for allowing for this factor are accurate within an error of about 20 per cent, i.e., they eliminate at least 80 per cent of the error that arises from neglect of this factor.

[5] For a definition of expected fertility rate, see section B. 1 below.

The procedures for calculating couple-years of protection (hereafter termed crude couple-years of protection or CCYP) are fully described in Wishik and Chen,[6] and illustrated in a recent United Nations publication.[7]

The general formula (not applicable to abortions and sterilizations) for transforming CCYP into SCYP is:

$$SCYP = \frac{E\left[CCYP\left(\frac{100-P}{100}\right)-\frac{NA}{12}\right]}{400}$$

The formula must be applied separately for each method and each age group within a method.

In this formula, E is the expected fertility (see section B.1) so that $\frac{E}{400}$ standardizes the couple-year of protection for age and the prevailing fertility rates. If the expected fertility of the users in question is 400 per 1,000, i.e., standard, then each crude couple-year of protection is, as far as the fertility parameter is concerned, equivalent to one standard couple-year of protection. If, however, the expected fertility is only 200 per 1,000, the value of the protection for demographic purposes is halved and it requires two crude couple-years of protection to equal one standard couple-year of protection.

P is the penalty applied for pregnancies and is related to the age-specific pregnancy rate for the method, expressed as a rate per 100 crude couple-years of protection.

N is the number of new acceptors of specific age for a particular method during the year. Alhough continuing users of short-term contraceptive methods are included in the annual accounting, their number does not contribute to N.

A is the allowance, in months per new acceptor, for overlap between contraceptive use and post-partum amenorrhoea.

$\frac{NA}{12}$ therefore yields the total period of overlap in years, which is subtracted from the CCYP values.

B. Derivations

The methods by which E (expected fertility), P (penalty for pregnancy) and A (allowance for overlap between contraceptive use and post-partum amenorrhoea) are derived are discussed below.

[6] Samuel M. Wishik and Kwan-hwa Chen, *Couple-Year of Protection: A Measure of Family Planning Program Output*, Manuals for Evaluation of Family Planning and Population Programs, No. 7 (New York, Columbia University, International Institute for the Study of Human Reproduction, 1973).

[7] *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2).

1. *Expected fertility*

The calculation of E[8] rests on a number of differences between the potential or expected fertility of a group of contraceptive acceptors or users and the age-specific marital fertility rates of the population from which they come.

Age-specific fertility rates are generated by the women giving birth at a given age. Women who do not give birth at that age cannot properly be assigned these rates. A group of contraceptive acceptors at age 30 would not, if they had not accepted contraception, have given birth at age 30; nor would they have exhibited the probabilities of miscarriage, stillbirth, live birth and sterility appropriate to and calculable for women aged 30. On average, they would have been subjected to the probabilities applicable to women aged 32 years—the average age that they would have attained when they next gave birth. This figure is, of course, only an average and the two-year differential will be seen to increase for older women and to decrease for younger women. To avoid complications, however, a general two-year discrepancy is computed. The first step in the calculation of expected fertility then is to obtain the age-specific marital fertility rate of women two years older than the group of acceptors. By far the simplest practical way of doing this task is to assemble acceptors in age groups two years younger than those for which age-specific marital fertility rates are available. Thus if, as is standard, rates are available for ages 15–19, 20–24, 25–29 etc., acceptors should be grouped 13–17, 18–22, 23–27 etc., with exact correspondence between the two sets of groups.

The second step is to discount, in the value for age-specific marital fertility rate, the contribution made by first births to elevating it above the level at which it corresponds to the notion of reciprocal duration per birth. As contraception is only rarely used in family planning programmes (in developing countries) to delay a first birth, and as the duration between marriage and first birth is very significantly shorter than for any inter-birth interval, the average duration, if calculated directly from age-specific marital fertility rates, is likely to be shorter than that which is properly applicable to contraceptive acceptors. A correction is applied based on the proportion, N, of all births at the appropriate age (age $j+2$ for acceptors at age j) that are first births. This correction has the value $\frac{3-N_{j+2}}{3}$ implying a duration per birth for first births of two thirds the length of others. This correction for births is clearly most important in the younger age groups.

The final correction to age-specific marital fertility rates is designed to eliminate the depressing effects of sterility, on the reasonable assumption that contraception will be accepted primarily by women who have had recent evidence of their continued fertility. This correction consists of the division of age-specific marital fertility rates by the proportion of non-sterile $(1-S_j)$ at the time of acceptance. These values must necessarily be taken from standard tables, for there are almost no contemporary useful data. Table 34 is derived from the work of Henry,[9] which is suggested as the most useful source.

TABLE 34. STANDARD DISTRIBUTIONS OF PROPORTION OF STERILE WOMEN BY AGE

S_i	*Age group*
0.03	13–17
0.03	18–22
0.06	23–27
0.10	28–32
0.16	33–37
0.31	38–42
0.60	43–47
0.98	48+

SOURCE: Derived from Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. VIII, No. 2 (1961), pp. 81–91.

The sterility correction is most important for older age groups. The final formula for E is:

$$E_j = \frac{B_{j+2}(3-N_{j+2})}{3(1-S_j)}$$

where B_{j+2} = marital fertility rate, age $j+2$
N_{j+2} = proportion of births at age $j+2$ which are first births;
S_j = proportion of women at age j who are sterile.

Where data on acceptors are available only grouped in conventional age groups, a process of interpolation may be used to reassemble them into the groups required—13–17, 18–22, 23–27 etc.[10]

2. *Penalty for pregnancy*

The calculation of P, the penalty for pregnancy, is based on the work of Potter,[11] who showed that each pregnancy occurring during contraceptive use "wasted" a period of use equivalent (in the absence of contraception) to the mean period of ovulatory exposure required to yield one pregnancy. To obtain this value, it is necessary first to change expected fertility into duration per birth in months—$\left(\frac{12{,}000}{E}\right)$ and then deduct from it nine months for pregnancy, the appropriate duration of post-partum amenorrhoea (section B.3) and an allowance (F) for the contribution of foetal loss to duration per birth. The remainder is the desired penalty; i.e., the mean exposure time required to become pregnant.

[8] This method was originally published in D. Wolfers, *loc. cit.*

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

[10] This process is fully described in Martin Gorosh and David Wolfers, *Standard Couple-Years of Protection: A Methodology for Program Assessment*, Manuals for Evaluation of Family Planning and Population Programs, No. 10 (New York, Columbia University, Center for Population and Family Health, 1977).

[11] Robert G. Potter, "Estimating births averted in a family planning program", in S. J. Behrman, Leslie Corsa, Jr. and Ronald Freedman, eds., *Fertility and Family Planning; A World View* (Ann Arbor, University of Michigan Press, 1969), pp. 413–434.

Thus, ovulatory exposure $= \frac{12{,}000}{E} - 9 - PPA - F$

and the penalty for pregnancies is

$$P_j = \frac{PR_j}{100\,CCYP} \times \frac{\left[\frac{12{,}000}{E} - 9 - PPA_j - F_j\right]}{12} LBP_j$$

where $\frac{PR_j}{100\,CCYP}$ = pregnancy rate per 100 $CCYP$ at age j; and LBP_j = proportion of pregnancies at age j expected to proceed to a live birth.

Tables 35 and 36 give standard distributions of values of F_j and LBP_j. Table 35 is derived from direct observation of the differences between live-birth intervals at Guayaquil, Ecuador.[12]

TABLE 35. STANDARD DISTRIBUTION OF CONTRIBUTION OF FOETAL LOSS TO DURATION PER BIRTH BY AGE

Age group	*Months contributed*
13–17	0.9
18–22	1.5
23–27	1.9
28–32	2.8
33–37	3.0
38–42	3.3
43+	3.3

SOURCE: David Wolfers and Susan Scrimshaw, *Child Survival and Interval Between Births in Guayaquil, Ecuador* (New York, Columbia University, International Institute for the Study of Human Reproduction, 1975).

NOTE: For derivation of tables, see foot-note 12 and tables 37–39.

TABLE 36. STANDARD DISTRIBUTION OF LIVE-BIRTH PROPORTION BY AGE

Age group	*Proportion of live births*
13–17	0.833
18–22	0.818
23–27	0.805
28–32	0.791
33–37	0.777
38–42	0.765
43+	0.752

SOURCE: Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. VIII, No. 2 (1961), pp. 81–91.

3. *Overlap with post-partum amenorrhoea*

To make an accurate estimate of overlap between contraceptive use and post-partum amenorrhoea (which is contraceptive waste-time), it is necessary to know not only the distribution of acceptors by open interval to acceptance (i.e., delivery-to-acceptance intervals) but the age-specific distribution of the duration in months of post-partum amenorrhoea in the population. The latter distributions are so rarely available and so difficult to collect that it is necessary almost everywhere to simulate them. To do this task, one value must be known or estimated, and that value is the mean period in months of post-partum amenorrhoea for the population. Given this value, one then wants to know the mean for each separate age group, which is provided in table 37.

Next, taking each age group with its specific mean, one obtains the distribution of post-partum amenorrhoea durations from table 38.

From these two distributions a very accurate estimate of overlap with post-partum amenorrhoea can be made by using the method described by Wolfers.[13] Since this calculation is tedious (with many different calculations of overlap being needed to account for the age-specific distribution of post-partum anovularity, the method-specific distribution of open interval to acceptance, and the method-specific continuation rate), an abbreviated method is required. This abbreviated method is described below in section E. Its use requires reference to table 39.

The next step is to adjust the number of months of overlap between post-partum amenorrhoea and contraceptive use for discontinuation taking place prior to the end of post-partum amenorrhoea. This procedure is achieved by obtaining the continuation rate for the method for month $\frac{M}{2}$, where M is the mean post-partum amenorrhoea used for the calculation of overlap. (The continuation rate for month $\frac{M}{2}$ is an estimate of the point in time at which one half of the acceptors under consideration discontinue.) The number of months of overlap

[12] David Wolfers and Susan Scrimshaw, *Child Survival and Interval Between Births in Guayaquil, Ecuador* (New York, Columbia University, International Institute for the Study of Human Reproduction, 1975). In the course of this analysis, intervals were computed by age of mother at delivery of the later child, separately restricted by the condition that both pregnancies demarcating the interval should have terminated in live births and for intervals of which only the later pregnancy was required to fulfil this condition. The former set of intervals therefore included, and the latter set excluded, intervals with intervening foetal loss. The difference in months by age of mother between the means of the two types of intervals as found in this population are shown below in the original table (intervals being "termination-to-conception" intervals):

DIFFERENCE IN MONTHS BY AGE OF MOTHER BETWEEN LIVE-BIRTH AND PREGNANCY-TO-LIVE-BIRTH INTERVAL

Age *(1)*	*Live-birth intervals* *(2)*	*Pregnancy-live-birth intervals* *(3)*	*Difference* *(4)*
15	15.5	15.1	0.4
15–19	12.4	11.5	0.9
20–24	17.3	15.8	1.5
25–29	20.2	18.3	1.9
30–34	24.1	21.3	2.8
35–39	26.2	23.2	3.0
40–45	27.4	24.1	3.3

[13] David Wolfers, "Contraceptive overlap with post-partum anovularity", *Population Studies*, vol. XXII (1971), p. 535–536; and *idem*, "Births averted", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 163–214.

is multiplied by the continuation rate to obtain the mean overlap per acceptor, specific for method continuation and mean post-partum amenorrhoea for age.

To obtain the continuation rate for month $\frac{M}{2}$, the following procedure is used:

(*a*) If life-table continuation rates are available, where M is an even number of months, read off the cumulative continuation rate for month $\frac{M}{2}$. Where M is an odd number, just read off the cumulative continuation rates for months $\frac{(M-1)}{2}$ and $\frac{(M+1)}{2}$, sum them and divide by two;

TABLE 37. STANDARD DISTRIBUTION OF AGE-SPECIFIC MEAN POST-PARTUM AMENORRHOEA BY GENERAL MEAN POST-PARTUM AMENORRHOEA

(*Months*)

Age group	*General mean* 3	4	5	6	7	8	9	10	11	12	13	14
13–17	3	3	3	3	3	4	5	6	7	8	10	12
18–22	3	3	3	4	5	6	7	8	9	10	12	13
23–27	3	4	5	6	7	8	9	10	11	12	14	14
28–32	4	6	7	8	9	10	11	12	13	14	14	14
33–37	5	8	9	10	11	12	13	13	14	14	14	14
38–42	6	9	10	11	12	13	14	14	14	14	14	14
43 + ...	6	9	10	11	12	13	14	14	14	14	14	14

SOURCE: Based on pattern of increase given in Anrudh K. Jain and others, "Demographic aspects of lactation and postpartum amenorrhoea", *Demography*, vol. 7, No. 2 (May 1970), pp. 255–271.

Note: Post-partum amenorrhoea increases with maternal age. Jain and others show that the increase is about two months for each five years of age between ages 20 and 35 and one month for each five years thereafter. Taking the age distribution of mothers at the time of birth of their children in eight countries in Africa, Asia, Latin America and the Middle East, means were disaggregated according to this pattern of increase. Although the distributions of births by mothers' ages differed greatly among countries, the age distributions of post-partum amenorrhoea (rounded to whole number of months) were identical for all the countries considered. Table 37 gives the results of this exercise, constrained so that no mean age-specific post-partum amenorrhoea would be less than three or more than 14 months.

TABLE 38. STANDARD DISTRIBUTION OF PROPORTION PER 1 000 POPULATION OVULATING, BY NUMBER OF MONTHS AFTER DELIVERY, BY MEAN MONTHS OF POST-PARTUM AMENORRHOEA

Month	*Mean months of post-partum amenorrhoea* 3	4	5	6	7	8	9	10	11	12	13	14
2	444	250	160	111	82	63	49	40	33	28	24	20
3	740	500	352	259	199	157	126	104	87	74	64	55
4	888	688	525	407	324	262	216	181	153	132	115	100
5	954	813	663	539	443	367	309	263	225	196	172	151
6	981	891	767	649	549	466	399	345	299	263	233	206
7	992	938	842	737	640	555	483	424	372	330	295	263
8	996	965	894	805	716	633	560	497	441	395	356	320
9	998	981	930	857	778	700	628	564	506	457	415	376
10	999	990	954	896	828	756	688	624	566	515	471	430
11		995	970	925	868	803	739	678	620	569	524	481
12		998	981	946	899	842	783	725	669	618	573	529
13		999	988	961	923	874	820	766	713	663	618	574
14		1 000	993	972	942	900	851	802	752	704	659	616
15			996	980	956	921	877	833	786	740	697	655
16			998	986	967	938	899	859	816	772	731	690
17			999	990	975	951	917	882	842	801	762	722
18			1 000	993	981	962	932	901	865	827	790	751
19				995	986	970	944	917	885	850	815	778
20				997	990	977	954	931	902	870	837	802
21				998	993	982	962	943	917	887	857	824
22				999	995	986	969	953	930	902	875	844
23				1 000	997	989	975	961	941	915	891	862
24+...........					1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000

SOURCE: Derived from J. C. Barrett, "A Monte-Carlo simulation of human reproduction", *Janus* (France), vol. 25 (1969), pp. 1–22; and Robert G. Potter and G. S. Masnick, "The contraceptive potential of early versus delayed insertion of the intrauterine device", *Demography*, vol. 8, No. 4 (November 1971), pp. 507–517. For mean months of post-partum amenorrhoea, see table 37.

Note: Following Barrett and also Potter and Masnick, Pascal distributions were fitted to mean post-partum amenorrhoeas so that the proportion experiencing exactly $n+1$ months of anovularity was:

$$n\left(\frac{2}{a}\right)^2\left(1-\frac{2}{a}\right)^{n-1}$$

where a = mean post-partum amenorrhoea in months.
Table 38 shows these proportions cumulated to give the proportion ovulating by month after delivery.

TABLE 39. VALUES OF ΣZ_i BY MONTH AND MEAN POST-PARTUM AMENORRHOEA WHERE Z_i IS PROPORTION OVULATING i MONTHS AFTER DELIVERY

Month	Mean post-partum amenorrhoea value											
	3	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	8.992	11.008	14.012	18.002	18.031	17.054	16.080	15.193	14.320	13.508	12.774	12.049
2	8.992	11.008	14.012	18.002	18.031	17.054	16.080	15.193	14.320	13.508	12.774	12.049
3	8.548	10.758	13.852	17.891	17.949	16.991	16.031	15.153	14.287	13.480	12.750	12.029
4	7.808	10.258	13.500	17.632	17.750	16.834	15.905	15.049	14.200	13.406	12.686	11.974
5	6.920	9.570	12.975	17.225	17.426	16.572	15.689	14.868	14.047	13.274	12.571	11.874
6	5.966	8.757	12.312	16.686	16.983	16.205	15.380	14.605	13.822	13.078	12.399	11.723
7	4.985	7.866	11.545	16.037	16.434	15.739	14.981	14.260	13.523	12.815	12.166	11.517
8	3.993	6.928	10.703	15.300	15.794	15.184	14.498	13.836	13.151	12.485	11.871	11.254
9	2.997	5.963	9.809	14.495	15.078	14.551	13.938	13.339	12.710	12.090	11.515	10.934
10	1.999	4.982	8.879	13.638	14.300	13.851	13.310	12.775	12.204	11.633	11.100	10.558
11	1.000	3.992	7.925	12.742	13.472	13.095	12.622	12.151	11.638	11.118	10.629	10.128
12		2.997	6.955	11.817	12.604	12.292	11.883	11.473	11.018	10.549	10.105	9.647
13		1.999	5.974	10.871	11.705	11.450	11.100	10.748	10.349	9.931	9.532	9.118
14		1.000	4.986	9.910	10.782	10.576	10.280	9.982	9.636	9.268	8.914	8.544
15			3.993	8.938	9.840	9.676	9.429	9.180	8.884	8.564	8.255	7.928
16			2.997	7.958	8.884	8.755	8.552	8.347	8.098	7.824	7.558	7.273
17			1.999	6.972	7.917	7.817	7.653	7.488	7.282	7.052	6.827	6.583
18			1.000	5.982	6.942	6.866	6.736	6.606	6.440	6.251	6.065	5.861
19				4.989	5.961	5.904	5.804	5.705	5.575	5.424	5.275	5.110
20				3.994	4.975	4.934	4.860	4.788	4.690	4.574	4.460	4.332
21				2.997	3.985	3.957	3.906	3.857	3.788	3.704	3.623	3.530
22				1.999	2.992	2.975	2.944	2.914	2.871	2.817	2.766	2.706
23				1.000	1.997	1.989	1.975	1.961	1.941	1.915	1.891	1.862
24					1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

SOURCE: Table 39 is obtained directly from table 38 by reverse cumulation of values, i.e., from the bottom of table 38 upwards.

(*b*) Where only continuation rates for, say, month a $\left(\text{being less than } \frac{M}{2}\right)$ and month n $\left(\text{being greater than } \frac{M}{2}\right)$ are available, divide the n^{th} continuation rate by the a^{th} continuation rate, take the $\left(\frac{\frac{M}{2}-a}{n-a}\right)^{\text{th}}$ power of the quotient (using logarithm tables or a modern calculator) and multiply this power by the a^{th} continuation rate:

$$R_{\left(\frac{M}{2}\right)} = R_a\left(\frac{R_n}{R_a}\right)^{\left(\frac{\frac{M}{2}-a}{n-a}\right)}$$

This formula can be illustrated with the data from table 53, row 1 (see section E.3). Continuation is known to be 0.799 at one month (i.e. $a = 1$) and 0.739 at two months (i.e., $n = 2$). With $M = 3$, then

$$R_{3/2} = 0.799\left(\frac{0.739}{0.799}\right)^{\left(\frac{3/2-1}{2-1}\right)}$$

so $R_{1.5} = 0.799\ (0.925)^{0.5}$
$R_{1.5} = 0.769$

Thus, continuation as of 1.5 months is 0.769;

(*c*) Where only one continuation rate for any month n $\left(\text{whether greater or less than } \frac{M}{2}\right)$ is available, take the $\left(\frac{M}{2n}\right)^{\text{th}}$ power of the nth month continuation rate as the $\left(\frac{M}{2}\right)^{\text{th}}$ month continuation rate, this rate is expressed as:

$$R_{\frac{M}{2}} = Rn^{\frac{M}{2n}}$$

To illustrate, suppose one knows that continuation is 0.552 at eight months (i.e., $n = 8$). With $M = 11$, then:

$$R_{11/2} = 0.552^{\frac{11}{(2)(8)}}$$

so $R_{5.5} = 0.665$

Thus, continuation as of 5.5 months is 0.665.

C. Birth control methods

1. *Classes of methods*

For the purposes of computing couple-years of protection, birth control methods are classified into four types: recurrent; semi-permanent; permanent; and abortion. Recurrent methods are those for which each prescription is effective only for a limited period of time or number of coitions, e.g., oral contraceptives, condoms, spermicides or injections. Semi-permanent methods are those for which use begins with a single acceptance and supply and which are then assumed to continue for a period of time thereafter as estimated from client follow-up data of some type, e.g., intra-uterine devices (IUD), rhythm or diaphragm. Permanent methods are those which cannot be reversed save by surgical means, e.g., male and female sterilization.

2. *Computation of crude couple-years and standard couple-years of protection for classes of methods*

The computation of CCYP with recurrent methods is made by using the quantities distributed (to users not retailers) during the year as the primary source of data. Estimates are made of the proportions of each device or medicament that are wasted, that is to say, dispensed but not used, and of the mean length of time for which each prescription gives protection. From these three quantities, the total number of couple-years of protection provided is computed.

For the semi-permanent methods, apart from the number of persons adopting the method during the year, the essential quantity required is the mean duration of use. In the original CYP manual, use of the median duration for certain methods was recommended; but no unique advantage attaches to this procedure and it is suggested that mean duration of use be computed for all methods in this class. This value is calculated from life tables of continuation based on data derived usually from surveys.

The simplest available formula for calculating mean duration of use (M) is $M = a/r$, where a is the proportion of devices retained (or adopters still practicing) "initially", and r the (presumed constant) annual rate of attrition thereafter.

The quantity r is obtained from $R(t_2)/R(t_1) = e^{(t_1-t_2)r}$, $R(t_2)$ being the proportion retained at time t_2 after insertion, either one year[14] or two years[15] or other appropriate duration; and $R(t_1)$ is the proportion retained after a shorter duration t_1 (not zero months), either one month[16] or six months[17] or other appropriate duration. The quantity a is then obtained from $a = e^{rt_1}[R(t_1)]$. Simple methods of performing these calculations are presented in Gorosh and Wolfers.[18]

Note that for age specificity of fertility expectation in SCYP calculations, the ages of acceptors of these three methods should be increased by $\frac{M}{2}$ years to ensure that the most appropriate fertility expectations shall be employed. (With M denoting mean duration of use, this correction helps reflect the age at which most use actually occurs.) Whole numbers only should be considered.

Thus, where age data are available by single years of

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[14] S. M. Wishik and K. H. Chen, *op. cit.*

[15] Robert G. Potter, "A technical appendix on procedures used in manuscript 'Estimating births averted in a family planning program'", paper prepared for Major Ceremony V, University of Michigan Sesquicentennial Celebration, 1 June 1967.

[16] S. M. Wishik and K. H. Chen, *op. cit.*

[17] R. G. Potter, "A technical appendix on procedures . . .".

[18] *Op. cit.*, p. 8.

age, if $M = 2.5$ years, the acceptors should be assigned fertility rates applicable after $2.5/2 = 1$ year of use. Then, instead of using age groups 13–17, 18–22, 23–27 etc., use groups 12–16, 17–21, 22–26 etc. to correspond to age-specific marital fertility rates at 15–19, 20–24, 25–29 etc.

To avoid excessive complexity, only one uniform age shift should be made, applicable to all age groups and based on the mean duration of use (M) for the entire batch of acceptors of each method.

Standard couple-years of protection for permanent methods (sterilization) are calculated directly without an intervening calculation of CCYP. Although this method alters the symmetry of calculations, the authors believe that it is the most straightforward approach to handling sterilizations. CCYP may be derived from SCYP if there is a need to present programme achievement in terms of CCYP:

$$SCYP = \sum \frac{E_i \text{ (total)}}{0.4} \times N_i$$

where N = number of acceptors in age group i;
0.4 = standard future births averted per woman per year;
E_i (total) = total future expected fertility of an acceptor in age group i.

E_i (total) is the key to the SCYP approach for sterilization. For each age group at acceptance, the estimated future fertility of one woman in that age group is computed by "aging" the woman through 45 and in so doing subjecting her serially to the remaining age-specific "expected" fertility rates modified by the probability that both the woman and her husband will survive to the next age group. Because the age-specific values of E are obtained from a formula that rests on the assumption that all women are fertile at the time they adopt a fertility regulating method, it is necessary to compensate for this factor in assessing a long-term method. E(total) is therefore computed from E_j values multiplied by $(1 - S_j)$, the whole being divided by the sterility proportion applicable to the age at sterilization. The formula for E_i (total) is:

$$E_i \text{ (total)} = \frac{2.5\, E_i (1 - S_i)(P'_{i-i+5} \cdot P''_{i+5-i+10}) + 5 \Sigma_{j=i+5}^{j=48+} E_j (1 - S_j)(P'_{j-j+5} \cdot P''_{j+5-j+10})}{1{,}000 (1 - S_i)}$$

where P'_{j-j+5} = probability of a female dying between the ages j and $j + 5$;
$P''_{j+5-j+10}$ = probability of a male dying between ages $j + 5$ and $j + 10$.

The result is the expected fertility averted as a consequence of the sterilization. This quantity (births averted) is divided by 0.4 to obtain the number of standard couple-years of protection provided to each acceptor in the particular age group. This number multiplied by the total acceptors in each age group equals the total number of standard couple-years of protection for all acceptors in the age group.

Adjustments for overlap between sterilization and post-partum amenorrhoea and for the post-vasectomy fertile period are accomplished by appropriately reducing the exposure time of the couple under the expected fertility rate for the wife's age as of sterilization (i.e., by varying the figure 2.5 (years) in the first term of the equation).

The SCYP approach for abortion is based on the differences between abortion and delivery as they affect certain components of the duration per birth:

(*a*) Duration per birth $= \frac{12{,}000}{E}$ months

(*b*) Duration per abortion = the duration per birth minus the differences in gestation and post-partum amenorrhoea associated with births and abortions, respectively;

(*c*) Duration per abortion = CCYP per abortion, which, when modified by expected fertility, live-birth proportion and the standard, equals SCYP per abortion or:

$$\text{CCYP per abortion} = \frac{\frac{12{,}000}{E} - [(GD_B - GD_A) + (PPA_B - PPA_A)]}{12}$$

and $\text{SCYP per abortion} = \text{CCYP per abortion} \times \frac{E}{400} \times \frac{LBP + 1}{2}$

Where $\frac{12{,}000}{E}$ = duration per birth;
GD_B = gestation duration, birth (nine months);
GD_A = gestation duration, abortion (two or three months);
PPA_B = post-partum amenorrhoea, birth;
PPA_A = post-partum amenorrhoea, abortion (one month);
E = expected fertility;
LBP = live-birth proportion.

D. Data requirements and sources

For the calculation of programme achievement in terms of standard couple-years of protection, reasonably accurate knowledge of certain data is essential. These data requirements and their sources are given in table 40.

E. Application

This section is intended to illustrate the steps to be followed in applying the SCYP method. The illustration is based on actual data on population characteristics and oral contraceptive acceptors from Country B.

1. *Data base*

New acceptors of oral contraceptives by age

The age distribution of new acceptors of oral contraceptives is as follows:

Age group	*New acceptors*
13–17	396
18–22	3 737
23–27	6 002
28–32	4 851
33–37	2 265
38–42	1 189
43–47	321
48 +	94
TOTAL	18 855

Population characteristics

The data on population characteristics are:

(*a*) Mean population post-partum amenorrhoea equals six months, based on data for Thailand;[19]

[19] Jeroen K. Van Ginneken, "Prolonged breastfeeding as a birth-spacing method", *Studies in Family Planning*, vol. 5, No. 6 (June 1974), pp. 200–206.

TABLE 40. DATA REQUIRED TO CALCULATE PROGRAMME ACHIEVEMENT

Data requirements	*Sources of data*
1. Distribution of acceptors by method and age of wife at acceptance	1. Should be available from routine service statistics. If age data are not available, they can be obtained by sample survey. Efforts should be made to obtain age data by single year of age.
2. Acceptors by open interval at acceptance	2. Either by routine statistics or by sample survey. It is desirable that this item be made specific, where possible, for method and age.
3. One-month and 12-month (or similar pair of observations) continuation rates for semi-permanent methods of contraception	3. Follow-up studies are required to determine continuation rates for intra-uterine device, diaphragm (if used) and rhythm.
4. "Wastage" proportions of recurrent methods of contraception together with an estimate of continuation rate at least at one point in time. (Coital frequency by age may be used as a less satisfactory alternative)	4. See procedure described above in section C and in sources given at end of table.
5. Quantities of recurrent contraceptives provided to intending users	5. Routine service statistics.
6. Age-specific marital fertility rates (ASMFR)	6. Calculated from statistics frequently provided by government statistical departments. Where only age-specific fertility rates (ASFR) are available, they may be combined with most recent census data on proportion of women married by age to give marital fertility rates i.e., ASFR ÷ proportion married in age group = ASMFR.
7. Proportions of births that are first births by age of mother	7. May be available from government statistics (if birth registration is well observed and records age of mother and birth order of child). Otherwise, they may be rapidly computed by numerator analysis of a sample of births from hospital records (e.g., labour-ward books).
Additionally required data that may be derived from local sources or "borrowed" from standards available in the literature	
8. Age-specific mortality rates or, preferably, recent mortality life table	8. Government statistical record. Where no figures are available, the appropriate model life table should be used (see end of this table).
9. Mean duration of post-partum amenorrhoea	9. Not generally available. A number of values for different populations have been published (see end of table) and estimates may be made on judgement, taking into account breast-feeding habits. Accurate measurement is a complex and expensive task involving prospective study of a national sample of births.
10. Age-specific mean durations of post-partum amenorrhoea	10. Use table 37[a] in the absence of survey data.
11. Distribution of durations of post-partum amenorrhoea	11. Use table 38[a] in the absence of survey data.
12. Pregnancy rates by method and age	12. If available, use life-table results from programme. Where not available, use method-specific rates from literature (see end of table).
13. Ages of husbands of sterilization acceptors at acceptance	13. Should be available in routine records and may easily be added. As a stopgap may be simulated by adding mean husband-wife age difference to wife's age.
14. Age-specific prevalence of female sterility	14. Use table 34.
15. Contributions of foetal loss to duration per birth by age of woman	15. Use table 35.[a]
16. Proportion of (diagnosable) pregnancies proceeding to live births by age of mother	16. Use table 36 in the absence of survey data.

SOURCES: For No. 4, Martin Gorosh and David Wolfers, *Standard Couple-Years of Protection: A Methodology for Program Assessment*, Manuals for Evaluation of Family Planning and Population Programs, No. 10 (New York, Columbia University, Center for Population and Family Health, 1977); and Jeroen K. Van Ginneken, "Prolonged breastfeeding as a birth-spacing method", *Studies in Family Planning*, vol. 5, No. 6 (June 1974), pp. 200–206. For No. 7, R. T. Ravenholt and H. Frederiksen, "Numerator analysis of fertility patterns", *Public Health Reports*, No. 83 (June 1968), pp. 449–458. For No. 8, *Manual IV. Methods of Estimating Basic Demographic Measures from Incomplete Data* (United Nations publication, Sales No. E.67.XIII.2). For No. 9, J. K. Van Ginneken, *loc. cit.* For No. 12, Frederick S. Jaffe, "Commentary: some policy and program implications of 'Contraceptive failure in the United States'", *Family Planning Perspectives*, vol. 5, No. 3 (Summer 1973), pp. 143–144; K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (1969), pp. 1–9; Norman B. Ryder, "Contraceptive failure in the United States", *Family Planning Perspectives*, vol. 5, No. 3 (Summer 1973), pp. 133–144; Christopher Tietze and Sarah Lewit, "The IUD and the pill: extended use-effectiveness", *Family Planning Perspectives*, vol. 3, No. 2 (April 1971), pp. 53–55.

[a] For derivations of tables, see foot-note 12 and tables 37–39.

TABLE 41. OPEN INTERVAL TO ACCEPTANCE, ORAL CONTRACEPTIVES

	Months													
	1	2	3	4	5	6	7	8	9	10	12	15	18	24+
Oral contraceptives..........	0.2	0.01	0.03	0.01		0.2		0.1		0.05	0.1	0.05	0.05	0.2

(*b*) With respect to open interval to acceptance, oral contraceptives were assigned a hypothetical distribution as shown in table 41;

(*c*) Age-specific marital fertility rates using unpublished data for Country B are as shown in table 42;

(*d*) Proportion of births that are first births, by age of mother, are given in table 43.

TABLE 42. AGE-SPECIFIC MARITAL FERTILITY RATE PER 1 000 WOMEN

Age group	Fertility rate
15–19	609
20–24	452
25–29	331
30–34	209
35–39	121
40–44	58
45–49	11

SOURCE: Unpublished data of David Wolfers, 1966.

TABLE 43. PROPORTION OF FIRST BIRTHS, BY AGE OF MOTHER

Age group	Proportion of first births
15–19	0.745
20–24	0.472
25–29	0.222
30–34	0.069
35–39	0.017
40–44	0.010
45–49	0.0

SOURCE: David Wolfers, ed., *Postpartum Intra-uterine Contraception in Singapore* (Amsterdam, Excerpta Medica Foundation, 1970).

Rates

Pregnancy and continuation rates are given in tables 44 and 45.

TABLE 44. PREGNANCY RATE BY AGE, ORAL CONTRACEPTIVES

Age group	Pregnancy rate
13–17	9.00
18–22	9.00
23–27	7.00
28–32	4.50
33–37	1.00
38–42	1.00
43 + ...	1.00

SOURCE: K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (December 1969), pp. 1–9.

TABLE 45. CONTINUATION RATES, ORAL CONTRACEPTIVES

One month	Six months	Twelve months	Eighteen months
0.799	0.627	0.531	0.448

SOURCE: K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (December 1969), pp. 1–9.

Quantities of oral contraceptives distributed

It is reported that 233, 176 cycles of oral contraceptives were distributed.[20]

Sample data

On the basis of hypothetical sample data, oral contraceptive wastage amounted to 1,392 cycles wasted out of 25,277 cycles distributed.

Standard data

Standard data, such as proportion of women becoming sterile by age, contribution of foetal loss to duration per birth, live-birth proportion and overlap with post-partum amenorrhoea, were taken from tables 34–39 in section B.

2. *Expected fertility*

The first step in applying SCYP methodology is the calculation of E, or the expected fertility of acceptors (table 46), as follows:

$$E_j = \frac{B_{j+2}(3 - N_{j+2})}{3(1 - S_j)}$$

TABLE 46. EXPECTED FERTILITY (E) OF ACCEPTORS

Age group (1)	B_{j+2} (2)	N_{j+2} (3)	S_j (4)	E (5)
13–17	609	0.745	0.03	471.9
18–22	452	0.472	0.03	392.7
23–27	331	0.222	0.06	326.1
28–32	209	0.069	0.10	226.9
33–37	121	0.017	0.16	143.2
38–42	58	0.010	0.31	83.8
43–47	11	–	0.60	27.5
48 + ...	–	–	0.98	

SOURCES: For data in column (3), David Wolfers, ed., *Postpartum Intra-uterine Contraception in Singapore* (Amsterdam, Excerpta Medica Foundation, 1970); for column (4), Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. VIII, No. 2 (June 1961), pp. 81–91.

[20] K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (December 1969), pp. 1–9.

Attention is called to the novel age groupings used in this and other SCYP calculations. As explained above, these groupings are used to facilitate the calculation of expected fertility from the conventional age groupings for which fertility rates are usually available. Thus, for the 13–17 age group, B_{j+2} is the 15–19 age group; for the 18–22 age group, B_{j+2} is the 20–24 age group; etc.

3. *Oral contraceptives*

Crude couple-years of protection

CCYP calculations are based on the following formula (table 47):

$$CCYP = \frac{C(1-W)}{13}$$

where C = number of cycles distributed to individuals (not to distributors);

W = proportion considered to have been wasted.[21]

TABLE 47. CALCULATION OF CRUDE COUPLE-YEARS OF PROTECTION, ORAL CONTRACEPTIVES

Age group (1)	*Number of new acceptors*[a] (2)	*Number of cycles*[a] (3)	$CCYP = \frac{C\left(1-\frac{1\,392}{25\,277}\right)^{a}}{13}$ (4)
13—17	396	4 902	356.3
18—22	3 737	46 215	3 359.1
23—27	6 002	74 224	5 395.0
28—32	4 851	59 986	4 360.1
33—37	2 265	28 009	2 036.0
38—42	1 189	14 705	1 069.0
43—47	321	3 968	288.4
48 + ...	94	1 167	85.0
Unknown	–	–	–
TOTAL	18 855	233 176	16 948.9

SOURCE: For columns (2) and (3), K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (December 1969), pp. 1-9.

[a] Published data not sufficient for computing age group-specific (W) values.

[b] See section E.1 of this chapter.

Calculation of penalty (P) per 100 crude couple-years of protection—oral contraceptives

The calculation of penalty (P) first requires conversion of pregnancy rates to pregnancy rates per 100 crude couple-years of protection. A 12-month cumulative pregnancy rate of 61/1,000 has been reported.[22] The rate includes both intended and unintended pregnancies. It was assumed that 0.5 (3.05 per cent) of the rate was attributable to unintended pregnancies. The same study showed pregnancy rates by age groups as shown in table 48.

TABLE 48. PREGNANCY RATES, ORAL CONTRACEPTIVES

Age group (1)	*Pregnancy rate* (2)	*0.5 of pregnancy rate* (3)
Under 25	18	9
25–29	14	7
30–34	9	4.5
35 and over	2	1

SOURCE: K. Kanagaratnam and Khoo Chian Kim, "Singapore: the use of oral contraceptives in the national program", *Studies in Family Planning*, vol. 1, No. 48 (December 1969), pp. 1-9.

From the data given in table 48, table 49 was constructed. The crude couple-years of protection (see column (2) of table 49) were obtained from age groups two years younger given in table 47.

The values for column (4) of table 49 are obtained by solving the following equation:

$$k = \frac{3.05}{\left[\dfrac{9a+7b+4.5c+1d}{a+b+c+d}\right]} \qquad (1)$$

$$k = \frac{3.05}{\dfrac{(9\times 3{,}715.4)+(7\times 5{,}395)+(4.5\times 4{,}360.1)+(1\times 3{,}393.4)}{3{,}715.4+5{,}395+4{,}360.1+3{,}393.4}} \qquad (2)$$

$$k = 0.5459 \qquad (3)$$

Having derived pregnancy rates per 100 crude couple-years of protection, the penalty for pregnancies per 100 crude couple-years of protection for oral contraceptives (table 50) is calculated as follows:

$$P = \frac{PR}{100\,CCYP} \times \left[\frac{\dfrac{12{,}000}{E} - 9 - PPA - F}{12}\right] \times LBP$$

[21] M. Gorosh and D. Wolfers, *op. cit.*, p. 6.

[22] K. Kanagaratnam and K. C. Kim, *loc. cit.*

TABLE 49. CALCULATION OF PREGNANCY RATES PER 100 CRUDE COUPLE-YEARS OF PROTECTION, ORAL CONTRACEPTIVES

Age group (1)	*Crude couple-years of protection* (2)	*Pregnancy rate* (3)	*Pregnancy rate per 100 crude couple-years of protection* (4)
Under 25	a = (356.3 + 3 359.1)	9k	4.91 (9 × 0.5459)
25–29	b = (5 395.0)	7k	3.82 (7 × 0.5459)
30–34	c = (4 360.0)	4.5k	2.46 (4.5 × 0.5459)
35 or over	d = (2 036.0 + 1 069.0 + 288.4)[a]	1k	0.55 (1 × 0.5459)

[a] Excluding women over 48 years of age.

TABLE 50. CALCULATION OF PENALTY (P) FOR ORAL CONTRACEPTIVES

Age group *(1)*	*Pregnancy rate per 100 crude couple-years of protection* *(2)*	*Duration per birth 12 000[a] E* *(3)*	*Nine months gestation (−9)* *(4)*	*Post-partum amenorrhoea[b] (−6)* *(5)*	*Foetal loss* *(6)*	*Live-birth proportion* *(7)*	*Penalty in years per 100 crude couple-years of protection* *(8)*
13–17......	4.91	25.4	9	3	0.9	0.833	4.26
18–22......	4.91	30.6	9	4	1.5	0.818	5.39
23–27......	3.82	36.8	9	6	1.9	0.805	5.10
28–32......	2.46	52.9	9	8	2.8	0.791	5.37
33–37......	0.55	83.8	9	10	3.0	0.777	2.20
38–42......	0.55	143.2	9	11	3.3	0.765	4.20
43–47.......	–	–	–	–	–	–	4.20
48 + ...	–	–	–	–	–	–	–

SOURCES: For data on post-partum amenorrhoea in Thailand, Jeroen K. Van Ginneken, "Prolonged breastfeeding as a birth-spacing method", *Studies in Family Planning*, vol. 5, No. 6 (June 1974), pp. 200–206; for contribution of foetal mortality to duration per birth, David Wolfers and Susan Scrimshaw, *Child Survival and Interval Between Births in Guayaquil, Ecuador* (New York, Columbia University, International Institute for the Study of Human Reproduction, 1975); for live-birth proportions, Robert G. Potter, Jr., "Estimating births averted in a family planning program", in S. J. Behrman, Leslie Corsa, Jr. and Ronald Freedman, eds., *Fertility and Family Planning: A World View* (Ann Arbor, University of Michigan Press, 1969), pp. 413–434.

[a] See calculation of E (expected fertility) illustrated in section E. 2.

[b] Data were not available for the mean duration of post-partum amenorrhoea for Country B. It was estimated that available data for Thailand approximated the reality of Country B. This mean was then disaggregated into age-specific means by reference to table 37.

TABLE 51. COMPUTATION OF MEAN OVERLAP WITH POST-PARTUM AMENORRHOEA (A), CONSTRUCTED FOR $M = 3$, ORAL CONTRACEPTIVES

Month i *(1)*	Y_i[a] *(2)*	ΣZ_i[b] *(3)*	$Y_i \Sigma Z_i$[c] *(4)*	$Y_i(i-1)$[d] *(5)*
1	0.2	8.992	1.7984	0
2	0.01	8.992	0.08992	0.01
3	0.03	8.548	0.25644	0.06
4	0.01	7.808	0.07808	0.03
5		6.920		
6	0.2	5.966	1.1932	1.0
7		4.985		
8	0.1	3.993	0.3993	0.7
9		2.997		
10	0.05	1.999	0.09995	0.45
11 (n).........................	0.4	1.000	0.4	4.0
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
TOTAL			4.31529	6.25

$$n - \Sigma Y_i(\Sigma Z_i) - \Sigma Y_i(i-1) = 0.43471 = A'$$

[a] Y_i = proportion of acceptors accepting i months after last delivery. The last value includes all acceptors adopting i months or later after delivery.

[b] From table 39.

[c] The product of columns (2) and (3).

[d] The product of column (2) and $i-1$.

Calculation of overlap between contraceptive use and post-partum amenorrhoea (A) for oral contraceptives

The calculation of overlap between contraceptive use and post-partum amenorrhoea (A) for oral contraceptives, which is for new acceptors only, is illustrated in table 51. The illustration is for mean $PPA = 3$.

The steps of the calculation are given below:

1. The distribution of ΣZ_i that corresponds to a mean post-partum amenorrhoea of three months is copied from table 39 into column (3) of table 51;

2. The distribution for open interval to adoption is entered into column (2) of table 51. The last entry in column (2) should coincide with the last entry in column (3). Add any subsequent distribution of column (2) to the entry that coincides with the last entry in column (3). That is Y_n, where n is the month of the last value of ΣZ_i in $Y_{i=n}^{i=\infty}$. In this example (section E.1), the distribution of open interval to acceptance covers $1-24+$ months. The last entry in column (3) is at 11 months. Add all values of column (2) beyond 11 months $(0.1+0.05+0.05+0.2 = 0.4)$ and enter the total in column (2) opposite month 11;

3. Entries for columns (2) and (3) are cross-multiplied for each month and the products are entered in column (4);

4. Each column (2) entry is then multiplied by the value of $i-1$ and the product entered in column (5). On line 1, for example, i is 1, and $i-1$ is zero. Therefore, column (5) is also zero;

5. Columns (4) and (5) are summed;

6. The sums of columns (4) and (5) are added together and subtracted from n, the number of entries in column (3). In the example, this is $11-(4.31529+6.25)$ or 0.43471;

7. The quantity obtained in step 6 is designated A'—the number of months of overlap between post-partum amenorrhoea and contraceptive use.

Steps 1–7 are repeated for overlap with post-partum amenorrhoea where values for $M = 4$, 6, 8, 10 and 11. Values of A' are summarized in table 52.

TABLE 52. VALUES OF POST-PARTUM OVERLAP (A') IN THE ABSENCE OF DISCONTINUATION

Mean post-partum Amenorrhoea (M) (months)	*A' values*
3	0.43471
4	0.72000
6	1.52973
8	2.52324
10	3.62444
11	4.16449

The A' values are now corrected for observed continuation rates. (See section B.3 for the methodology of calculating continuation rates.) In table 53, the continuation rate in column (4) is multiplied by the A' value in column (5) to obtain A (column (6)), the mean overlap with post-partum amenorrhoea per acceptor, specific for method continuation and mean post-partum amenorrhoea for age.

Calculation of standard couple-years of protection for oral contraceptives

The basic SCYP formula is:

$$SCYP = \frac{E\left[CCYP\left(\frac{100-P}{100}\right) - \frac{NA}{12}\right]}{400}$$

The calculation of SCYP for oral contraceptives is given in table 54.

F. CONCLUSION

A method is presented with which it is possible to summarize, in a single annual figure, the accomplishments of a birth control programme. Based on the couple-year of protection procedures developed by Wishik, it provides a methodology for rendering commensurable periods of contraceptive protection provided by different methods of contraception, sterilization and abortion, and their use by couples of different ages and therefore of different fertility expectations. Overlap between contraceptive use and post-partum amenorrhoea is also considered.

Although inevitably the data requirements of this method are more comprehensive than those of the original CYP methodology, there are no data requirements which cannot be readily met by the average programme or filled in by standard data and tabulations as substitutes for locally derived values with little loss of accuracy.

This method reduces the value of programme acceptances to a single measure in the face of diverse method and age mixes and expected fertility levels. Value gained is stated in terms of births averted and also in terms of the standard unit described. Although these effects are not scheduled by calendar year, the over-all method mix tells the basic picture: if the programme relies predominantly

TABLE 53. CORRECTION OF MEAN OVERLAP WITH POST-PARTUM AMENORRHOEA FOR CONTINUATION RATES, ORAL CONTRACEPTIVES

Age group (1)	*M*	*Continuation rate (a) ((a) = months) (2)*	*Continuation rate (n) ((n) = months) (3)*	*Continuation rate (M/2) (4)*	*Values of post-partum overlap A (5)*	*Mean overlap with post-partum amenorrhoea A (6)*
13–17	3	0.799 (a = 1m)	0.739 (n = 2m)	0.769	0.43471	0.334
18–22	4			0.739	0.7200	0.532
23–27	6			0.699	1.52973	1.069
28–32	8			0.672	2.53234	1.702
33–37	10			0.648	3.62444	2.349
38–42	11	0.648 (a = 5m)	0.627 (n = 6m)	0.6375	4.16449	2.655
43–47	11			0.6375	4.16449	2.655

upon condoms and oral contraceptives, the benefits are realized chiefly in that year (or nine months later); but if sterilization is the main method the benefits come over many years, descending towards the end. Intra-uterine devices are intermediate. Moreover, in a stable programme, the character of which changes little over several years, the calendar scheduling of births averted becomes in one sense unimportant because the cumulative effect of past activity upon this year's births will about equal the total future contributions of the new programme work in this year. In other words, in a stable state, the benefits felt in each year become constant, and equal the total future effects from the new programme input for each year.

Of course, few active programmes can be safely considered stable. The technique proceeds on a method and age-specific basis and thus is sensitive to changes tied to them as concerns expected fertility and other measures. These measures are then reflected in the estimate of the standard units of protection and in births averted.

As a final form of overview and as a rough methodological comparison, this method was applied to programme data previously published for Country B[23] to obtain results that may be expressed as the number of births averted per acceptor of each method. These results were then put alongside comparative results from other locations, obtained by various adaptations of births averted approaches. The comparative picture appears in table 55.

[23] One modification was used to adapt these heavily post-partum data to the longer open-interval distribution found in most national programmes.

TABLE 54. CALCULATION OF STANDARD COUPLE-YEARS OF PROTECTION, ORAL CONTRACEPTIVES

Age group (1)	*Crude couple-years of protection* (2)	*Penalty for pregnancy P* (3)	*Number of new acceptors per annum N* (4)	*Mean overlap with post-partum amenorrhoea A* (5)	*Total overlap in years NA/12* (6)	*Expected fertility E* (7)	*Standard couple-years of protection* (8)
13–17	356.3	4.26	396	0.334	11.02	471.9	389.4
18–22	3 359.1	5.39	3 737	0.532	165.67	392.7	2 957.4
23–27	5 395.0	5.10	6 002	1.069	534.68	326.1	3 738.1
28–32	4 360.1	5.37	4 851	1.702	688.03	226.9	1 950.2
33–37	2 036.0	2.18	2 265	2.349	443.37	143.2	554.1
38–42	1 069.0	4.20	1 189	2.655	263.06	83.8	159.4
43–47	288.4	4.20	321	2.655	71.02	27.5	14.1
48 + ...	85.0	–	94	2.655	20.80	–	–
TOTAL	16 948.9		18 855				9 762.6

Births averted (SCYP × 0.4) = 3 905.0

TABLE 55. COMPARISONS OF STANDARD COUPLE-YEARS OF PROTECTION AND OTHER BIRTHS AVERTED CALCULATIONS BY CONTRACEPTIVE METHODS

A. *Births averted per acceptor*

Contraceptive method	*Standard couple-years of protection*	*Other approaches*
Intra-uterine device	0.62	0.54 (Country F) 0.70 (Country F) 0.75 (Country F) 0.50–0.79 (Country B) 0.33 (Country E) 0.43–0.65–0.94 (Country E)
Sterilization	1.98	2.35 (Country F) 2.39 (Country F) 2.48 (Country G) 2.50 (Country H) 1.23–1.64 (Country F)
Condom	0.10	0.14 (Country F) 0.16 (Country F)
Abortion...........	0.67	0.4–0.9
Oral contraceptives ..	0.21	0.21

B. *Births averted per intra-uterine device by age, Country E; and standard couple-years of protection for Country B*

	Age group 20–24	25–29	30–34	35–39	40–44
Country E	0.54	0.68	0.72	0.54	–
Country B	0.70	0.57	0.55	0.40	–

C. *Births averted per sterilization by age, Country F; and standard couple-years of protection for Country B*

	20–24	*25–29*	*30–34*	*35–39*	*40–44*
Country F	4.24	3.02	1.83	0.92	0.29
Country B	4.44	2.83	1.58	0.74	0.28

SOURCES: Compiled from John A. Ross and others, *Findings from Family Planning Research*, Reports on Population/Family Planning, No. 12 (New York, The Population Council, 1972); A. K. Jain, "Relative effectiveness of different fertility control methods in reducing community reproduction rates", in *International Population Conference, Liège, 1973* (Liège, International Union for the Scientific Study of Population, 1974), vol. 2, pp. 209–224; and Kap Suk Koh and Douglas J. Nichols, "Measurement of the impact of the national family planning program on fertility in Korea: 1960–1975", Seoul, Republic of Korea, Korean Institute for Family Planning, 1977 (unpublished).

Chapter III

COMPONENT PROJECTION APPROACH I: A COMPUTERIZED MODEL

*Dorothy Nortman**

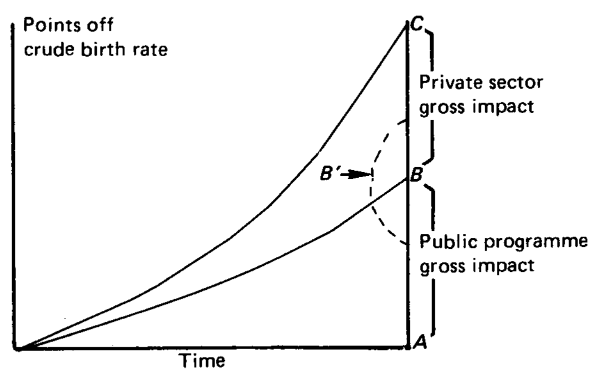
CONVERSE is a macro-deterministic, one-sex, computerized, age-component population projection model, which yields the impact on the crude birth rate and other demographic measures of an annual stream of acceptors of birth control methods.[1] The techniques employed are the ordinary demographic procedures for projecting specific age groups of a population over time under prescribed schedules of fertility and mortality. The essential difference is that the fertility trend is not postulated in advance, but it unfolds in CONVERSE as a consequence of modification of its initial level by the acceptance and use of various methods of birth control.

Articulation of two basic features will help the reader to understand the methodology and analyze the output. The first feature involves the treatment of public *versus* private sector sources of family planning services and supplies; the second, the frame of reference from which births averted by contraception are measured for the impact of fertility. With regard to the first feature, if the input data on number of acceptors recruited relate only to the public programme, then clearly the output reflects only this programme and not the total impact of both public and private sector birth control practice. Thus, in instances where private sector practice is extensive, an empirical crude birth rate found in a survey or based on vital register data, should be considerably below the CONVERSE finding. On the other hand, if estimates of all acceptors—public and private—comprise the CONVERSE input data, then the resulting output should be compatible with empirical findings.

It should also be appreciated that public programme acceptor data taken from service statistics will rarely (if ever) have been adjusted to exclude people switching from the private sector or people likely to have become contraceptors through the private sector in the absence of the public programme. Thus, when the input acceptor data relate only to the public programme, the output measures the gross, not the net impact of the public programme. Although estimates of net programme impact are important to justify public expenditures on these programmes, for example, the question is clearly speculative, involving not only the points already mentioned but the catalytic effect of the public programme in enhancing contraceptive practice at private expense and effort.

Schematically, this discussion can be summarized as shown in figure III.

Figure III. Sectoral composition of family planning programme impact on the crude birth rate



CONVERSE measures *AB* or *AC* depending upon the composition of the acceptor data. *B*′ is depicted as a floating, speculative point to denote *AB*′ equal to the net impact of the public programme. Whether *B*′ would fall below or above *B* depends upon whether the public programme substitution exceeds its catalytic effect, or vice versa, respectively. (For insight into techniques to answer this question, the reader is referred to other chapters in this *Manual.*)

As for the frame of reference for measuring averted births, CONVERSE takes it to be the natural fertility

* Staff Associate, The Population Council, Inc., New York.

[1] The term CONVERSE was ascribed to this model because it is the converse of an earlier methodology, TABRAP, which was developed to yield the number of acceptors required for a designated decline in the birth rate. TABRAP is an acronym for TArget Birth Rate Acceptor Program. For a full discussion of the TABRAP/CONVERSE methodology, including a mathematical exposition, see Dorothy L. Nortman and others, *Birth Rates and Birth Control Practices: Relations Based on the Computer Models TABRAP and CONVERSE* (New York, The Population Council, 1978), chap. V.

level, that is, expected fertility in the absence of a deliberate attempt to control childbirth. Not only does this assumption bear a logical relation to the measurement of gross rather than net demographic impact of the input acceptor data, but by equating the potential fertility of acceptors with the (fecund) natural level of the society, the speculative nature of this question is considerably reduced. It is not that natural fertility is visible or easily measured, for a total absence of any birth control, including abortion, is most unlikely in any society. However, given fairly reliable information on current use, observed fertility rates are readily converted into natural fertility rates, as is discussed and illustrated in section D.1, which concerns potential fertility of acceptors.

CONVERSE can be used retrospectively or prospectively. If the former, the family planning input data are likely to be limited to acceptors recruited by the public programme. Information on private sector contraceptive acceptance and use is necessarily derived from private hospital, clinic and physician records, pharmacies, contraceptive inventories, imports and exports, and sample survey findings. If these data can be converted into an annual schedule of acceptors over the retrospective projection interval, two separate runs of CONVERSE could be prepared, one yielding the public programme gross impact, the other the private sector impact. Alternatively, one run utilizing acceptors in both sectors would yield the total demographic impact. In the latter case, sectoral distinction by method is still possible from an analysis of some of the 10 auxiliary computerized FORTRAN programs which were designed as analytical or input aids.

If CONVERSE is used prospectively, again the acceptor input data can relate to the public or private sector or both, with varying mixes per run of age and methods. The resulting output can suggest an optimal public programme strategy with respect to methods offered and age groups to attract in order to reach desired demographic ends.

The basic procedure of the CONVERSE model can be summarized in three steps. The first is to project the one-sex initial population under the assumption of no birth control acceptance over the projection interval (although allowance is made for contraceptive use by initial users). Independent of step one, step two calculates annual births averted by a family planning acceptor of given age. This computation is done by: (*a*) converting the acceptor into a time schedule of protection from the risk of birth nine months later; and (*b*) multiplying the total protection (couple-years of use) obtained in (*a*) by the risk of birth (potential fertility), and summing over age groups. Step three is a second projection of the population, identical to step one except that the annual births produced are the difference between the number expected without acceptors and the number averted by birth control users. Because of its age specificity, the methodology yields a full array of demographic variables with programme impact measured by the difference between corresponding variables in the two projections. A point to note is that even though the two projections make the same mortality assumptions, slight differences emerge in the crude death rate because the different birth rates produce a different age structure.

The CONVERSE FORTRAN program is available in the form of a computer tape and accompanying documentation. Once the FORTRAN statements are compiled and linked in a computer, runs can be easily made if the input requirements are satisfied, at a cost that thus far has averaged about $5 per run. At a nominal cost, the tape and necessary documentation can be procured by completing a photocopy of the computer configuration form provided in figure IV and sending it to the author.

A. Advantages and disadvantages of CONVERSE methodology

CONVERSE is an elaborated methodology of the component approach to measure the demographic impact of a family planning programme, which was first suggested by Lee and Isbister[2] in 1966 in an analysis of intrauterine contraception in the Republic of Korea. In the interim, there has been considerable elaboration with respect to both methodology and factors considered to have an important bearing on results. CONVERSE represents a level of sophistication that, in the judgement of its developers,[3] will yield reliable orders of magnitude of the demographic impact of family planning programme acceptors, subject as always to the degree of reliability of the input data. This condition can be a serious limitation, but the trade-off between heavy data demands and refinement of results cannot be avoided. CONVERSE is considered a happy compromise—comprehensive enough to yield meaningful results, yet sufficiently simple and economical to warrant its use for the purpose it was designed to serve.

1. *Advantages of CONVERSE*

The positive features of CONVERSE include:

(*a*) Capacity to handle a multimethod family planning programme in one run;

(*b*) Analysis of acceptors as a percentage of couples not using contraception (eligibles) as well as a percentage of married women of reproductive age;

(*c*) Aging of continuing users over time so as to vary their potential for averting births;

(*d*) Ability to cope with the speculative question of the potential fertility of acceptors with a clear-cut definition that potential fertility equals natural fecund fertility;

(*e*) Deduction of the period of overlap between contraceptive use and post-partum amenorrhoea from time protected against the risk of conception (although the

[2] B. M. Lee and John Isbister, "The impact of birth control programs on fertility", in Bernard Berelson and others, eds., *Family Planning and Population Programs: A Review of World Development* (Chicago, Ill., University of Chicago Press, 1966), pp. 737–758. The early Lee-Isbister model has been refined to permit estimates of births averted.

[3] Four principals are the developers of CONVERSE: Dorothy L. Nortman and John Bongaarts of The Population Council, Inc., New York; and Robert G. Potter and Sharon Kirmeyer of Brown University, Providence, Rhode Island.

Figure IV. Computer configuration form

1. Computer Manufacturer ____________________
(i.e.: I.B.M.; C.D.C.; I.C.L.; D.E.C.; etc.)

2. Model of Computer ____________________
(i.e.: 360-30; 1130, 1901, 11/45, 8e, etc.)

3. Character coding for tape: ____________________
EBCDIC / BCD / ASCII

4. If 7 track tape, parity: ____________________
Even/Odd

5. Type of Operating System ____________________
(i.e.: DOS, OS/360, BATCH, etc.)

6. Is FORTRAN available NO __________ YES __________ Level of Compiler(s) __________
(i.e.: E,F,G,H, Version 10)

7. Available Memory ____________________ Indicate base (decimal, octal) and units (words, bytes...).
(i.e., i.e.: 16K decimal words; 100K octal bytes; etc.)

8. Are 7 track tape drives available NO __________ YES __________

Check all Available B.P.I. ___ 228 ___ 556 ___ 800

9. Are 9 track tape drives available NO __________ YES __________

Check all Available B.P.I. ___ 800 ___ 1600 ___ 6250

10. Is disk storage available NO __________ YES __________

Disk Model Number ____________________

11. What is the character width of the Line Printer ____________________
(i.e.: 80, 120, 132, etc.)

12. TABRAP/CONVERSE Tape to be sent to

Name and title ____________________

Institution ____________________

Address ____________________

____

13. Order from: The Population Council, Inc.
1 Dag Hammarskjöld Plaza
New York, New York 10017
USA

device whereby this procedure is done is admittedly crude);

(*f*) To allow for gestation, assignment of a precise nine-month lag between contraceptive use and averted births;

(*g*) Partitioning of lifetime averted births per acceptor into annual time units over the projection interval;

(*h*) Accommodation of abortion as a method and of initial users at the beginning of the projection;

(*i*) Flexibility over the projection interval with respect to changes in nuptiality (proportions married by age class), mortality, natural fertility and methods adopted;

(*j*) Definition of method by an analytical mathematical expression that is easily handled by the computer.

2. *Disadvantages of CONVERSE*

The disadvantages, limitations and simplifying assumptions of CONVERSE are as follows:

(*a*) Requirement of some data that are not readily available; e.g., proportions by age group sterile or using a method for the first time, and the need to estimate it or to substitute data from another population;

(*b*) Assumption that population is closed to migration, which renders the model unsuited to subnational units with significant in- or out-migration;

(*c*) Disregard for method effectiveness, which creates an upward bias in contraceptive use effective in averting births (this feature is not thought to affect results significantly but to compensate for this bias, it is recommended that care be taken not to underestimate the method discontinuation rate);

(*d*) The simplifying assumption that annual acceptors enter simultaneously as a cohort in mid-year instead of continuously over time;

(*e*) Failure (because of lack of empirical data) to overlap method use with post-partum amenorrhoea and age or the latter and use of specific methods;

(*f*) Treatment of data on method used by a simple mathematical expression which has the virtue of simplifying the algebra but which may not yield the most precise calculation of ongoing contraceptive use;

(*g*) Extensive data requirements involving knowledge of the age structure of the population, details about mortality and nuptiality trends, the current fertility level, awareness of methods that have been (retrospective projection) or will be (prospective projection) accepted and their discontinuation rate (first segment) by age class, and so on. (These heavy demands are both the strengths and weaknesses of the model—its strengths because a good model must incorporate these factors, its weaknesses because many of the empirical data are not readily available.)

Assessment of these limitations indicates that the findings lack precision but are not impaired as orders of magnitude. Moreover, given the quality of the input data, an order of magnitude is the best one could hope for, even with the most refined and sophisticated methodology.

B. CONVERSE INPUT REQUIREMENTS AND OUTPUT

1. *CONVERSE input requirements*

Input requirements fall into two categories—demographic variables and family planning variables—of which a listing follows.

Demographic variables

The demographic variables required are:

(*a*) Length of projection period: five or 10 years;

(*b*) Fertility: observed age-specific marital fertility rates for first year and for final year, with final year different from first year only for reasons other than a change in deliberate birth control. (Possible important reasons are reduced breast-feeding and changes in marital coital frequency.) Rates for intervening years are linear interpolations between first and final years;

(*c*) Mortality trend: option (i) or (ii) may be used:

(i) Model life table (based on the Coale-Demeny regional model life tables[4]), specifying annually life expectancy at birth;

(ii) Empirical data on first-year age-specific death rates, for ages 0–1 and 1–4, and in five year age groups thereafter. (Because of data considerations, a time trend over the projection period is optional under (i) but not under (ii).);

(*d*) Sex ratio at birth;

(*e*) Population (female) size and age structure: option (i) or (ii) may be used:

(i) Stable: requires total female population size in first year:

(ii) Real: requires first-year population size in five-year age groups;

(*f*) Nuptiality: proportions married (cohabitating) for each of the six five-year age groups among women aged 15–44 years, both for the first year and for the final year. Proportions for intervening years are linear interpolations between first and final year;

(*g*) Sterility: proportion sterile for each of the six five-year age groups among women aged 15–44. (If empirical data are not available, the following figures are suggested: 0.02, 0.045, 0.08, 0.13, 0.235, and 0.455 for the six age groups, respectively.[5])

Family planning variables

The family planning variables required are:

(*a*) Annual inputs on acceptors, by age group, with a choice of one of six options as follows:

(i) Acceptance rate as a percentage of total married for the composite age group 15–44;

(ii) Number of acceptors, by five-year age groups;

(iii) Acceptance rate as a percentage of the total

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

[5] Louis Henry, "Some data on natural fertility", *Eugenics Quarterly*, vol. VIII, No. 2 (June 1961), pp. 81–92.

eligible, i.e., married currently not using contraception, for the composite age group 15–44;

(iv) Acceptance rate as a percentage of eligibles, by five-year age groups;

(v) Acceptance rate as a percentage of all women, married or not, by five-year age groups;

(vi) Acceptance rate as a percentage of total married, by five-year age groups;

(*b*) If there are initial users, input of the proportion of each age class using all methods combined and the total number of women using each method;

(*c*) For each method, input to specify:

(i) Name;

(ii) Overlap of use with post-partum amenorrhoea (as a proportion of the first 12 months following acceptance);

(iii) Values of the parameters a and r in the method continuation schedule $C = ae^{-rt}$, specific by age (computation of these values is discussed in section E);

(iv) Annual distribution of methods among acceptors: if static, proportion of each acceptor age group adopting the method; if changing, for each year, the percentage distribution of acceptors by method.

The above-listed variables are embodied in 18 input groups, illustrated by the following data based on the experience of Country D. A summary coding sheet indicating how the data are to be key-punched into the IBM cards is given in table 56.

TABLE 56. SUMMARY CODING SHEET FOR CONVERSE INPUT

Input No. 1. Parameters for this job

Card	Item
1	Number of methods: 4
1	Years of projection period: 10
1	Initial year: 1971
1	Code for changes in method over time: 2
1	Code for presence of initial users: 1
1	Code for absence of abortion: 0
1	Program name: INDONESIA-LIKE DATA

Input No. 2. Methods by name

Card	Item
1	Intra-uterine device
2	Pills
3	Condoms
4	Sterilization

Input No. 3. Overlap of use, in years, with post-partum amenorrhoea

Card	Item
1	Intra-uterine device: 0.275
1	Pills: 0.175
1	Condoms: 0.200
1	Sterilization: 0.167

Input No. 4. Proportion of acceptors who initiate use of method (the a value in $a \exp(-rt)$

		Age-group					
Card	Item	15–19	20–24	25–29	30–34	35–39	40–44
1	Intra-uterine device	0.985	0.985	0.985	0.985	0.985	0.985
2	Pills	0.838	0.838	0.838	0.838	0.838	0.838
3	Condoms	0.612	0.612	0.612	0.612	0.612	0.612
4	Sterilization	0.980	0.980	0.980	0.980	0.980	0.980

Input No. 5. Annual rate of discontinuation

		Age group					
Card	Item	15–19	20–24	25–29	30–34	35–39	40–44
1	Intra-uterine device	0.108	0.108	0.108	0.108	0.108	0.108
2	Pills	0.238	0.238	0.238	0.238	0.238	0.238
3	Condoms	0.560	0.560	0.560	0.560	0.560	0.560
4	Sterilization	0.080	0.080	0.080	0.080	0.080	0.080

Input No. 6. Proportion of acceptors by method each year

Card	Year	Intra-uterine device	Pills	Condoms	Sterilization	Total
1	1 (1971)	0.410	0.440	0.140	0.010	1.00
2	2	0.345	0.490	0.153	0.012	1.00
3	3	0.280	0.540	0.165	0.015	1.00
4	4	0.215	0.590	0.178	0.017	1.00
5	5	0.150	0.640	0.190	0.020	1.00

TABLE 56 (*continued*)

Input No. 6 (*continued*)

Card	Year	Intra-uterine device	Pills	Condoms	Sterilization	Total
6	6	0.170	0.612	0.192	0.026	1.00
7	7	0.190	0.584	0.194	0.032	1.00
8	8	0.210	0.556	0.196	0.038	1.00
9	9	0.230	0.528	0.198	0.044	1.00
10	10 (1980)	0.250	0.500	0.200	0.050	1.00

	Input No. 7. Marital fertility rates		*Input No. 8* Proportions married		*Input No. 9.* Proportions sterile
Age group	Year I	Year II	Year I	Year II	
15–19	0.488	0.488	0.363	0.303	0.020
20–24	0.364	0.364	0.752	0.732	0.045
25–29	0.298	0.298	0.869	0.879	0.080
30–34	0.241	0.241	0.871	0.891	0.130
35–39	0.173	0.173	0.834	0.855	0.235
40–44	0.106	0.106	0.746	0.786	0.455
	Card 1	Card 1	Card 1	Card 1	Card 1

Input No. 10. Mortality schedule and age structure

Card	Item
1	Code for life-table mortality rates: 1
1	Code for stable population age structure: 1

Input No. 11. Life expectancy at birth

Card	Item
1	Code for region in Coale-Demeny models: 1(West)
1	Life expectancy at birth

Year	e_0^o
1 (1971)	45.0
2	45.5
3	46.0
4	46.5
5	47.0
6	47.5
7	48.0
8	48.5
9	49.0
10	49.5
11 (1981)	50.0

Input No. 12. Population parameters

Card	Item
1	Total female population size, mid-year 1971: 39 913 722
1	Sex ratio at birth: 1.06

Input No. 13. Table printing option

Card	Item
1	Code for print-out of tables: 0 for "no", 1 for "yes"

Input No. 14. Year 1 percentage age distribution of acceptors by method

Age group	Intra-uterine device	Pills	Condoms	Sterilization
15–19	5	7	7	0
20–24	25	28	28	0
25–29	29	32	32	0
30–34	25	20	20	10
35–39	13	11	11	47
40–45	3	2	2	43
15–45	100	100	100	100
	Card 1	Card 2	Card 3	Card 4

TABLE 56 (*continued*)

Input No. 15. Option to choose one of six annual acceptors model type: 2

Input No. 16. Annual acceptors (corresponding to option selected in input No. 15)

Card	*Year*	*Total acceptors*
1	1	380 514
1	2	229 632
1	3	494 714
1	4	485 613
1	5	690 201
1	6	679 256
1	7	809 543
1	8	908 893
1	9	1 051 773
1	10	1 156 307

Input No. 17. Number of initial users by method

Card	*Item*	
1	Intra-uterine device:	82 000
1	Pills:	88 000
1	Condoms:	28 000
1	Sterilization:	2 000

Input No. 18. Proportion of married women of each age group using all methods combined

Card	*Age group*	*Proportion*
1	15–19	0.0028
1	20–24	0.0141
1	25–29	0.0198
1	30–34	0.0226
1	35–39	0.0198
1	40–44	0.0141

No matter how good a model is, its output is no better than its input. In addition to number of acceptors, items that greatly influence the results include the age ascribed to acceptors, the discontinuation rate assigned to each method and observed marital age-specific fertility rates. If there is a significant number of initial users of a method at the date for which the projection is begun, it is important to have a fairly accurate assessment of them by age group because, in addition to the dependence of births averted on age, the conversion of observed into natural fertility also hinges on age. Regrettably, information on the age of users is often of uncertain quality, and appropriate adjustments are necessary if the reported age of the users is to be made to yield a plausible age pattern of natural fertility. On the other hand, incompatibility between the proportions using a method and the observed fertility rates may be because the latter, rather than (or as well as) the former, is at fault. Clearly, good judgement and discretion must be exercised in analyzing and tailoring the input data for plausible relations and levels.

Another major test of consistency in the input data is to reconcile age-specific fertility rates with crude birth rates. That is, the births produced by each age group summed over the age groups must, when divided by the total population, equal the crude birth rate. Empirical data often do not meet this test of consistency. An auxiliary FORTRAN program, ADJUST, performs the reconciliation giving two outputs: (1) an adjusted set of age-specific fertility rates consistent with the observed crude rate (the adjustment can consist of an equal proportionate change in all age groups or be made according to a prescribed curve); and (2) a crude birth rate consistent with the observed age-specific fertility rates. The CONVERSE user selects one of these two options for the required input data.

An input item not likely to be empirically available is the proportion sterile of each age group. As the increase in sterility with age is a natural, biological phenomenon, it is not thought to vary greatly over time, space or culture.[6] Hence the recommendation is to use Henry's[7] data given in the illustration when empirical data are uncertain or unavailable.

The demographic requirements presuppose the usual knowledge about the age structure, sex ratio at birth, death rates, nuptiality and so on of the population. There is no escaping these requirements for a component projection. Even though a country may lack precise information on these matters, given the inertia and interrelations of a demographic system, qualitative judgements are readily transformed into quantitative estimates through the use of population models published by the United Nations[8] or other sources.

2. *CONVERSE output*

The CONVERSE model produces 27 tables, with headings as shown in table 57.

TABLE 57. CONVERSE OUTPUT

Heading	*CONVERSE table No.*
Echo check of input data (repeats all input)	1
For initial users, projected births averted in programme year, couple-years of use and mid-year users	2, 3
Life table – year 1	4
Reproduction rates for year 1	5
Initial population distribution	6
Life table—years other than year 1 (not generated if the data are the same as in year 1)	7
Population projection under assumption of no acceptors	8
Married population, crude birth rate, crude death rate, crude rate of natural increase—under assumption of no acceptors	9

[6] John Bongaarts, "Why high birth rates are so low", *Population and Development Review*, vol. 1, No. 2 (December 1975), pp. 289–296.

[7] *Loc. cit.*

[8] *Manual IV. Methods of Estimating Basic Demographic Measures from Incomplete Data* (United Nations publication, Sales No. E.67.XIII.2).

TABLE 57 (*continued*)

Heading	*CONVERSE table No.*
Worksheet of the multiplicative approach to derive births averted per acceptor and the following measures:	
Contraceptive use interval affecting programme year births (expressed in years from acceptance, set back nine months from programme years)	
Per acceptor (by age), couple-years of use affecting births (U)	
Potential fertility of acceptor nine months after use interval (F)	
Births averted per acceptor nine months after use ($U \times F$)	
Couple-years of use per acceptor during programme year (not to be confused with interval affecting programme year births)	
Proportion of acceptors still using a method exactly y years after acceptance (y indicated from O to last acceptance years)	10
Programme results for each year except the last year: age-specific fertility rates; births averted by users; births expected without the programme; births under programme accumulated by age. For changing method mix also printed is age-specific disposition to accept	11
Results for last programme year (same items as table 11)	12
Population projection taking impact of acceptors into account	13
Married population, crude birth rate, crude death rate and crude rate of natural increase—taking acceptors into account	14
Number and percentage distribution of acceptors in each programme year, by age and method accepted	15
Births averted in programme year by those accepting M years ago, by age in year M	16
Acceptors as a percentage of married non-users (eligibles), by age	17
Acceptors as a percentage of married women, by age	18
Percentage age distribution of acceptors	19
Couple-years of use as a percentage of married women, by age (corresponding to survey findings on proportion of couples using a method)	20
Mid-year users as a percentage of married women, by age[a]	21
Percentage distribution of mid-year users, by age[a]	22
Percentage distribution of averted births, by age at acceptance (not to be confused with current age in indicated programme year)	23
Annual acceptors, by age	24
Annual number of women eligible for acceptance, by age	25
Reproduction rates for terminal year of programme	26
Annual number of mid-year users, by age[a]	27

[a]This output is an artifact of the methodology, without practical significance.

C. FAMILY PLANNING PROGRAMME PARAMETERS IN CONVERSE METHODOLOGY

An overview of the family planning programme to which the CONVERSE methodology relates will help the reader to understand it. The projection starting-point is called "programme year 1" whether the programme is new or several years old. Ideally, the demographic base-line data relate to the mid-point of programme year 1.

A simplifying assumption that greatly facilitates the algebra is that annual acceptors enter the programme as a simultaneous cohort, once a year at mid-year, over the projection period. As the projection is of a one-sex population, acceptors are called "female". This term does not exclude males but when they accept, the wife's age is required because calculations are based on it.

All acceptors are considered to be drawn from a pool of eligibles who are all married females in the age range 15–44 not currently using a method as of the mid-point of each programme year. The importance of drawing acceptors from non-users lies in the fact that even with modest continuation rates, an assumption of a fixed age distribution of acceptors is unrealistic and can lead to the contradiction of more users than women in one or more age groups.

Acceptors are aged over time, one fifth of each age group passing into the next higher age group each year. This identification of users by their current age is important for proper assignment of potential fertility rates for averting births in each programme year. A second important advantage of keeping track of the ages of users is that upon discontinuing, they re-enter the correct age class of the pool of eligibles. On the other hand, it should be mentioned that among eligibles no distinction is made between ever-acceptors and never-acceptors. As a result, the models fail to recognize that discontinuers return to the non-user base with greater susceptibility to the risk of pregnancy than their never-acceptor age counterparts (a factor that affects the timing of births, although increases in one year are compensated for the following year, with diminishing magnitudes). Also, no mechanism is provided for a count over time of individual women entering the programme because non-users, from whom annual acceptors are drawn, consist of both discontinuers and never-acceptors without distinction.

Although the duplication of individuals in summing acceptors over time is not methodologically important (because births averted are a function of birth control use per unit of time, not of numbers ever accepting), to assess facilities, personnel, supplies and ultimately cost, programme administrators are interested both in the number of persons currently being served and in the total number ever served. However, as family planning programmes mature, no matter how well designed and efficiently executed their record-keeping systems, it becomes increasingly difficult to keep track of individuals on a longitudinal basis, weeding out the duplications over time, place and method.[9]

[9] Cumulative acceptance rates are subject to wide margins of error in

1. *Estimation of continuing use of specific contraceptive methods*

The component projection method requires, for each acceptor, data on continuation of use of each contraceptive method. These data are usually not accurate or available in programme records or even from follow-up surveys. These values may preferably be derived separately from the CONVERSE procedure, as described below.

Although theoretically any smooth mathematical function that depicts a continuation schedule could have been used, incorporated into the present CONVERSE FORTRAN program is the modified decay curve, $C = ae^{-rt}$. The parameter r is the rate at which the method is discontinued per unit of time, t; a is the proportion of the acceptor cohort that initiates use of the method (meaning that $(1-a)$ accepts but does not use); e is the natural logarithm number 2.718 . . . . ; and C is the resulting proportion of an acceptor cohort still using the method at time t from acceptance (not to be confused with projection duration). Each method is assigned its own set of a and r values; and for a particular method, say intra-uterine device (IUD) or pills, these values can also vary by age in recognition of the fact that different age groups are known to discontinue use of the same method at different rates.

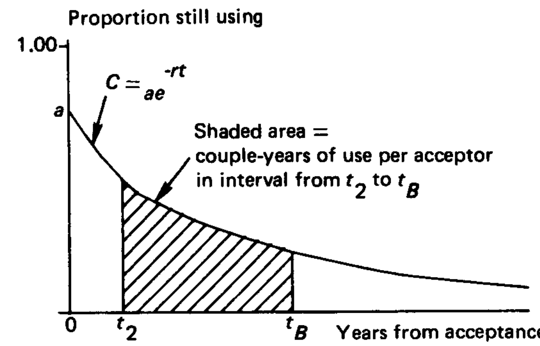
The a and r parameters are not empirically visible, but are easily derived mathematically by fitting a linear least-squares line to the (natural) logarithms of the observations on proportions of a cohort still using the method at various time intervals after acceptance. To avoid the tedium of the procedure, two auxiliary FORTRAN programs perform the operations: CONTINUE when only two observations are available; CONTINU2 with any number of observations.

The reason for not generating the a and r values in the main CONVERSE methodology, using the observations instead of the a and r values as input, is to avoid the possibility of generating and therefore unknowingly using an a greater than 1. This situation sometimes occurs when the observed proportions still continuing are high within short durations from acceptance but fall off more rapidly after three or six months. By determining the a and r values in advance of the CONVERSE operation, they can be generated to ensure an a less than one by discarding, if necessary, the observations at one or two months from acceptance.

The $C = ae^{-rt}$ curve of continuation is useful for two major reasons: it gives a fairly good fit to empirical observations on proportions of an acceptor cohort with uninterrupted use of the method at various points in time following acceptance; and it is easily handled mathematically (integrated) to get total use over specified time intervals. Figure V is a graphic presentation of both these measures.

both numerator and denominator. Accuracy entails an unduplicated count of acceptors over time for the numerator, and inclusion in the denominator, of women who have left the reproductive ages in the time interval under consideration.

Figure V. Method continuation schedule



Clearly, the validity of the output depends heavily upon the validity of the a and r values assigned to the parameters for each method. Care should be exercised not to over-estimate a because pills, condoms, foams, jellies and other such contraceptive supplies are subject to waste in a variety of ways; and, in community-based distribution programmes, many people accept supplies that they do not intend to use. As for the attrition rate r, it must be understood to represent over-all discontinuation for all possible reasons combined, including contraceptive failure, switching of methods, wanting a child, and marriage dissolution due to separation, divorce or death of either spouse.

2. *Contraceptive use*

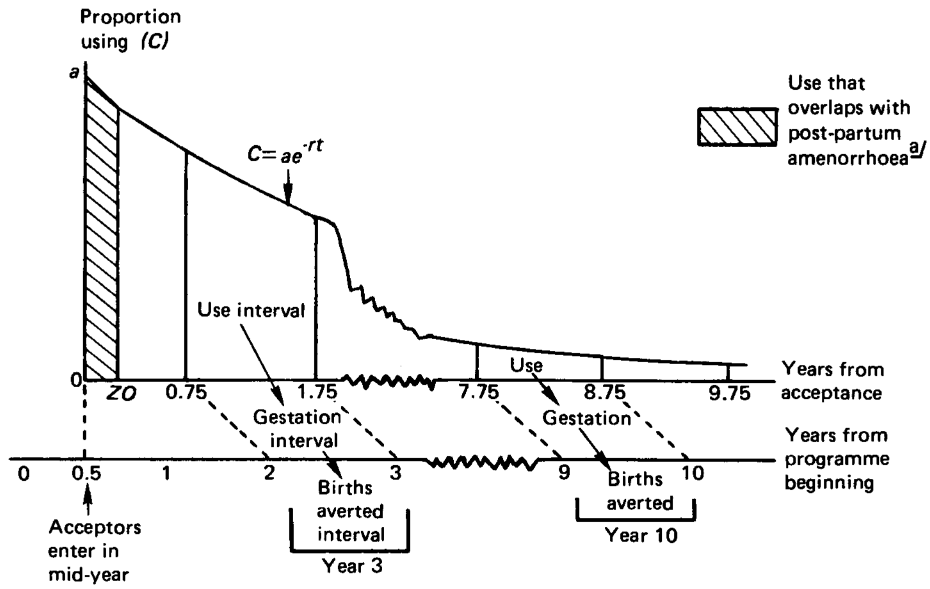
The CONVERSE model computes three types of statistics relating to contraceptive use, each serving a different purpose. For each type, use relates to users' current age, a relationship made possible by the aging of acceptors over time. These statistics are:

(a) *Mid-year users.* This concept is a methodological artifact necessitated by the stipulation that recruitment occurs at one point in time per year, at mid-year. Although artificial, the array by current age of previous annual acceptor cohorts still using their method precisely at mid-year of each year, subtracted from the total married of the age group, provides the eligible base for annual acceptors;

(b) *Programme year use.* This measure is simply the total couple-years of use complied during the 12 months of each programme year by all acceptors. Not all of this use averts births, because some of it overlaps with post-partum amenorrhoea or pregnancy and some is contributed by women who have become sterile. This use plays no important methodological role but it tends to correspond to survey findings on proportion of couples practising fertility control (under a family planning programme defined by the sectoral composition of the acceptor input data);[10]

[10] By sectoral composition is meant acceptance of methods under the public programme or obtaining them from the private sector, i.e., commercial or private outlets, as described at the beginning of this chapter.

Figure VI. Relation between use interval and corresponding births averted interval per acceptor entering in year 1



[a] This period represents, on average, for the cohort, the time span between acceptance and the onset of menstruation. Except in a post-partum family planning programme, this period will not generally exceed three months.

(c) *Use that averts births in programme years.* This use differs from programme year use in two respects. First, to allow for the gestation period, it is set back nine months from the programme year. Secondly, it discounts use that overlaps with post-partum amenorrhoea, a period labelled *ZO* in the FORTRAN program, specific by method (but not by age).[11] Thus, since entry is at mid-year, with nine months allowed for gestation, no births are averted in the year of acceptance but some are averted every year thereafter. Another way to state this is that during every programme year births are averted by continuing use of all acceptor cohorts except the cohort of the year in question. Figure VI clarifies for women accepting in year 1 the relation between use interval and the corresponding interval during which births were averted.

D. Other parameters

1. *Potential fertility*

As previously mentioned, CONVERSE uses natural fertility as the yardstick for calculating averted births. With initial users present, the FORTRAN program computes natural fertility internally by dividing the observed marital rate (provided as input data) by the proportion of fecund non-users in each age group and then multiplying the result by the proportion of women fecund in the age group. (The proportion fecund is of course one minus the input item, proportion sterile.) This procedure is illustrated as follows:

	Proportion of age group	*Fertility rate*
Sterile	0.10	0
Fecund	0.90	
User	0.20	0
Non-user	0.70	(x = 300)
Total	1.00	210 = observed

On the assumption that all users are fecund and that use is 100 per cent effective, with an observed fertility rate of 210 and 70 per cent of an age group consisting of fecund non-users, the fertility rate of fecund women and hence their potential fertility is $x = 210/0.7 = 300$. Natural fertility is simply fecund fertility multiplied by the proportion fecund or $(300)\cdot(0.9) = 270$.

An option structured into the methodology allows for a change in natural fertility (brought about, for example, by a decline in breast-feeding or a change in marital coital frequency) by requiring as input data both the initial and terminal-year marital fertility rates. It should be understood that the latter rates represent a modification of the former only for reasons other than deliberate fertility control. (Rates for intervening years between the initial and terminal years are linearly interpolated.)

[11] Refinement of the methodology to incorporate age-specific post-partum amenorrhoea was not considered warranted, because empirical data on this subject are generally lacking. For a discussion of the relation among post-partum amenorrhoea, potential fertility and effective use, see David Wolfers, "Births averted", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organization for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 163–214.

TABLE 58. POTENTIAL FERTILITY OF ACCEPTORS

Age group (1)	Marital rate (2)	Percentage fecund (3)	Potential fertility rate of acceptors[a]: At acceptance (4)	Five years later (5)	Ten years later (6)
15–19	498	98	508	541	448
20–24	530	95.5	555	460	357
25–29	439	92	477	370	291
30–34	341	87	392	308	187
35–39	268	76.5	350	213	0
40–44	163	54.5	299	0	0
45–49	0	0	0	0	0

[a] Regressed, with the passage of time from acceptance, at the same rate as the marital fertility schedule; acceptors assumed fecund at acceptance. Rates for years between acceptance and five years later, and between five and 10 years later are obtained by linear interpolation.

As illustrated in table 58, when moved through time, continuing users are subject to an annually changing potential fertility that reflects their advancing age. The schedule calls for the same proportionate change in five-year periods as is found in going from one to the next five-year age group in the initial natural fertility schedule, with rates in intervening years linearly interpolated. By age 45, zero potential fertility is assumed. This procedure reconciles the decline through time in acceptor potential fertility with that of the general population while letting potential fertility of acceptors begin from the higher level reflected by their composition of fecund women only.

The assumption of fecundity at acceptance combined with failure to exclude the sterile from the pool of eligible recruits creates the possibility of generating negative age-specific fertility rates. This possibility may be explained as follows. Suppose only half the women of some age group are estimated to be fecund. Then, according to the procedure, acceptors have a potential fertility at acceptance that is twice the average of their age group. If they accept in high proportions of their age group and adopt a method, such as sterilization, that has a high continuation rate, after a few years the non-users will consist primarily of sterile women. However, defining all non-users as eligible to accept could result in recruitment of some who are sterile, with assignment to them of a fecund potential fertility schedule. When this happens, users are estimated to avert more births than the age group as a whole produces, an anomaly that shows up in the CONVERSE output as a negative fertility rate. Input of a suitable adjustment in any of the parameters at work – lower estimate of percentage sterile, lower method of continuation or fewer accepting – will avoid encroachment of acceptors among the sterile. Another alternative to dispel the anomaly would be to restructure the methodology to exclude the sterile from those defined as eligible to accept.

2. *Births averted*

On a per acceptor basis, births averted in a given programme year are simply the product of potential fertility at current age of user and average (mean) duration of contraception in the 12-month interval nine months prior to programme year (discounted for any post-partum amenorrhoea in the use interval). Ignored are method failure and overlap of pregnancy while using a method. With modern methods, these deficiencies are not considered serious; and regardless of method, the upward bias they introduce in the estimate of averted births can be compensated for by a conservative continuation method schedule. Secondary sterility, considered structured into the waning potential fertility schedule, is not discounted from the use that averts births, although effective use, i.e., use that averts births, would exclude use by women no longer fertile.

E. CONVERSE METHODOLOGY

With the background given above, the following exposition of the CONVERSE methodology should be adequate for a comprehension of how the model works.

1. *Steps in the methodology*

Step one

In step one, which projects the initial population on the premise of no family planning acceptors, age-specific survivorship rates survive the initial population over the projection interval, in five-year age groups, five years at a time, with linear interpolation for programme years between 1 and 6 and between 6 and 11. The initial population aged 0–4, however, is survived by single years of age over the interval. Thus, in programme year 2, the survived population is aged 1 and over, in programme year 3, it is 2 and over, and so on. Proportions married applied to the reproductive age groups yield the numbers of potential mothers over the projection period. In a 10-year period, the number of married women is unaffected by the births in the interval.

Step one also calculates "expected" births in the absence of acceptors over the projection period, that is, at natural fertility rates, except as modified by any initial users. Survival of each annual birth cohort by single year of age added to the five-year age group projections produces the total population of all age groups for each year of the projection interval.

TABLE 59. COUPLE-YEARS OF USE, POTENTIAL FERTILITY, AND BIRTHS AVERTED, PER ACCEPTOR AGED 25–29

Use interval (years from acceptance)		*Use*[a]				*Interval nine months following use*	
t_2	t_B	*Low method*	*Medium method*	*High method*	*Average all users*[b]	*Potential fertility*[c]	*Births averted*[d]
0.166	0.75	0.3258	0.4289	0.5530	0.4084	0.4559	0.1862
0.75	1.75	0.2448	0.5171	0.9247	0.4829	0.4346	0.2098
1.75	2.75	0.0831	0.3297	0.8974	0.3483	0.4133	0.1440
—	—	Etc.	Etc.	Etc.	Etc.	Etc.	Etc.
—	—						
Etc.	Etc.						

Note: Acceptance of low, medium and high continuation rate methods in the proportions of 50, 25 and 25 per cent, respectively.

[a] Use = $(a/r)[\exp(-rt_a)-\exp(-rt_b)]$. This formula is the definite integral of the C curve between t_a and t_b. For each method, the parameters a and r in the continuation schedule $C = a \exp(-rt)$ are assigned the following values:

Method	*a*	*r per annum*
Low	0.9	1.08
Medium	0.9	0.45
High	0.96	0.03

[b] (0.5 × low use) + (0.25 × medium use) + (0.25 × high use).

[c] Linear interpolation between rates at acceptance time and five and 10 years after acceptance shown in table 58 in section D.1 of this chapter.

[d] Average use × potential fertility.

Step two

Step two, independent of step one, converts acceptors into births averted by means of couple-years of use nine months earlier. The procedure is age-specific; but, in the births averted calculation, the method becomes a composite of the individual methods adopted by the age group. As illustrated in table 59, the technique for handling multiple methods is to derive use (area under the decay curve) independently for each method; and then by weighting the use per method by the proportion of the age group adopting that method, an average, composite amount of use per acceptor is obtained as though all acceptors of given age had taken one composite method.

In the illustration given above, three methods are accepted by age group 25–29, in the proportions 50 per cent for a low continuation method ($C_L = 0.9 \exp(-1.08t)$), 25 per cent for a medium method ($C_M = 0.9 \exp(-0.45t)$), and 25 per cent for a high method ($C_H = 0.96 \exp(-0.03t)$). *ZO*, the overlap between use and post-partum amenorrhoea, is taken as two months (0.166 years). With acceptance in mid-year, as shown in figure V, the use per method per acceptor (area under the C curves) in the intervals from t_2 to t_B will avert births in successive programme years after the acceptance year The weighted average use for all methods combined multiplied by the potential fertility of the acceptor in the births averted year yields the births averted per acceptor in age group 25–29 at acceptance time. That acceptors age with the passage of time is structured into a changing potential fertility schedule that becomes 0 at age 45.

Step three

In step three, demographic measures are computed as the residual between steps one and two. Step two has already established the births averted per acceptor of given age in each successive year after acceptance. Multiplication of this product by the corresponding number of acceptors in each age group each year, with summation over age groups for all acceptor cohorts averting births in any given programme year, yields the total births averted in each year of the projection period. That is, extrapolated first are total births averted per age group of a given cohort in successive programme years; summation over age groups gives total births averted per year by the given cohort; and lastly, summation over cohorts gives total births averted per year by all acceptor cohorts. In programme year 1, no births are averted; in year 2, only cohort 1 averts births; in year 3, cohorts 1 and 2 avert births; and in general, in programme year t, the cohorts from 1 to $t-1$ avert births.

With births produced under the programme being simply the difference between the number expected (step one) and the number averted, the population under age 1 is calculated annually as the survivors of each year's produced births, and the population aged 1 and over are simply the survivors of the previous year's total population. The crude birth rate may thus be obtained by dividing the produced births by the corresponding total population. Moreover, because the calculations are age-specific, age-specific fertility rates are also readily yielded, as are the age structure, total population size, crude death rate and other demographic measures.

2. *Disposition of "initial users"*

Among the input requirements for CONVERSE are the number, age and marital status of initial users. This information is important because the model equates potential fertility with natural fertility, modified by the prevalence of contraceptive use among fecund married women in each age group (see section C).

Initial users are incorporated into the model as though they had been acceptors in programme year 0, with account taken of the one-year age differential between year 0 and year 1. Two input variables are required: the number of initial users per method; and the proportion of married women per age group using all methods combined.

Having converted initial users into acceptors (step one described above), the models project their use in intervals set back nine months from programme years according to the same procedure applied to subsequent acceptors described under step two of the methodology. The computation of births averted described under step three includes the contraceptive use of year 0 along with later acceptors. These procedures are organized so that the births averted in year 1 by the year 0 "acceptors" exactly account for the difference between the reconstructed natural fertility rates for year 0 and the rates observed in year 1.

3. *Induced abortion*

Because macro-model population projections deal with births rather than pregnancies, it is inherently awkward to incorporate abortion into the CONVERSE model. To do so requires conversion of the aborted pregnancy into an estimate of the fraction of the birth averted by the abortion. That an aborted pregnancy is not the equivalent of one averted birth is immediately obvious because everyone recognizes the possibility of a foetal death. Not so obvious, however, is the fact that an abortion often delays rather than averts the next birth and that it hastens the next pregnancy. The reason for this situation is that the abortion shortens the gestation period by several months and eliminates the breast-feeding anovulatory period, and therefore returns the woman to the fecundable state considerably sooner than had the pregnancy terminated naturally. Thus, on average, an abortion averts almost one birth only if contraception is adopted immediately after the abortion and is practised successfully for one year or more – to compensate for six or seven months of the foreshortened gestation period and from five to six or more months for the eliminated breast-feeding period. Potter[12] found that an induced abortion in itself, assuming no contraception, averts about 0.45 of a birth, irrespective of the age of the woman.

The model accommodates abortion as just another method, with parameters in the continuation schedule $C = a e^{-rt}$ selected so that virtually all use occurs within a very short time period after acceptance, and with ZO, the overlap of use with post-partum amenorrhoea, set equal to zero. As with other methods, the model computes births averted as the product of use and potential fertility. Unlike other methods, however, for which the births averted are a computed output, the births averted equivalent of an abortion is postulated in advance. To meet these requirements and to yield Potter's finding of 0.45 birth averted per abortion, a value of 10 is suggested for r, with a taking on the value $4.5/F$ where F = potential fertility. Since total use, U, equals a/r, births averted $= U \times F = (a/r) \times F = (4.5/F)(1/10)(F) = 0.45$. It should be noted that with almost all abortion use concentrated around acceptance time, virtually no users are retained to diminish the supply of eligibles the year after abortion.

The price paid for these advantages is that aborters who adopt a contraceptive immediately following the abortion are counted twice, once as an aborter and once as a contraceptor, in the same year. Thus, if 100 acceptors include 20 aborters, the number of persons among the 100 acceptors can range from 80 to 100, the former if all aborters are also contraceptors, the latter if no aborters take a contraceptive immediately following the abortion. The CONVERSE user can readily eliminate the duplication in the count of acceptors by estimating the proportion of aborters who adopt a contraceptive method following the abortion. However, the count of individuals is external to the models.

In order not to credit abortion use over time to contraceptive use, the FORTRAN program specifically ignores the method identified by number as abortion in computing mid-year users and couple-years of use.

F. Interpretation and analysis

The component projection approach to evaluation of the impact of a family planning programme on fertility makes possible an assessment of the relationships among birth and growth rates and birth control acceptance and practice. Analytical items are illustrated in table 60, a run of the CONVERSE model for the population and family planning programme described above in section D. The 10-year programme with acceptors increasing from 3 per cent of the married women of reproductive ages in year 1 to 7.5 per cent in year 10, yielded a crude birth rate of 35.5 compared with 41.4 without the family planning programme. Total population size after 10 years was 2.6 per cent less than it would have been; the general fertility rate was 15 per cent lower. The effect on the total fertility rate was a reduction from the potential 5.82 to an actual 4.68; and there were 341 children (female) under age 5 per 1,000 women aged 15–44 compared with the potential 389. In achieving these results, couple-years of use grew from a trivial level at the beginning of the programme to 18 per cent of the married women of reproductive age in year 10, during which year, 9 per cent of the eligibles (non-users) were recruited, with the heaviest recruitment, 12.3 per cent, among those aged 25–29. Per point off the crude birth rate, 1 million acceptors were recruited over a 10-year period from a female population numbering 40 million at the beginning of the programme, of whom 12 million were married and of reproductive age.

The value of the model is not in an isolated run, useful as that might be to measure the demographic impact of a specific programme, but rather in the economical cost of performing the repeated runs necessary to plan programme strategy. The birth control methods offered, the rates at which these methods are continued and the age distribution of acceptors are to some extent under the

[12] Robert G. Potter, "Additional births averted when abortion is added to contraception", *Studies in Family Planning*, vol. 3, No. 4 (April 1972), p. 56.

control of programme administrators. Analyses that vary these factors one at a time can help assess the pay-offs of more youthful acceptors, more reliance on modern methods and longer duration of use.

TABLE 60. CONVERSE: DEMOGRAPHIC IMPACT OF A 10-YEAR FAMILY PLANNING PROGRAMME IN COUNTRY D

Item	*Natural fertility*	*Family planning programme impact*[a]
Year 11		
Crude birth rate[b] (output)	41.4	35.5
Crude death rate[c]	14.9	14.3
Crude rate of natural increase[d]	26.5	21.2
Cumulative acceptors (thousands)		
Number (input)	0	6 886
Per point off crude birth rate	–	1 007
Population in year 11		
Number (thousands of females)	51 134	49 805
Percentage reduced by programme	–	2.6
Total fertility rate in year 11	5.82	4.68
Age structure in year 11 (percentage)		
0–4	16.7	15.0
0–14	42.2	40.7
15–44	42.9	44.1
45 +	14.9	15.2
Female children under 5 years per 1,000 women aged 15–44: year 11	389	341
Cumulative acceptors/couple-years of use in year 10	–	1.75
Acceptors as percentage of eligibles in year 10		
15–44	0	9.0
15–19	0	5.4
20–24	0	11.0
25–29	0	12.3
30–34	0	10.0
35–39	0	7.8
40–44	0	3.3
Contraceptive use during year 10 as percentage of married women of reproductive age		
15–44	0	18.0
15–19	0	6.3
20–24	0	14.5
25–29	0	21.9
30–34	0	23.3
35–39	0	20.9
40–44	0	14.9
Percentage reduction in marital age-specific fertility rates, year 11/year 1		
15–44	0	15.0
15–19	0	3.7
20–24	0	9.6
25–29	0	19.1
30–34	0	23.2
35–39	0	23.7
40–44	0	23.6

[a] For programme characteristics and population to which programme is applied, see input data given in table 56.
[b] Number of live births during the year per 1 000 population at mid-year.
[c] Number of deaths during the year per 1 000 population at mid-year.
[d] Difference between the crude birth rate and the crude death rate.

With respect to birth or growth rate targets, these goals are usually set not by family planning administrators but by planning officials concerned with slowing population growth to facilitate economic and social development. The use of CONVERSE to project the population on the basis of recent family planning acceptance trends will show whether the target is reasonable within the prevailing programme budget and structure. Another approach predicated on CONVERSE is to postulate the most optimistic assumptions that appear reasonable with respect to acceptor quotas, ages and methods, and then to adopt the projected birth rate as the upper limit of the target.

The value of the component projection approach lies in the fact that at little financial cost, administrators can test the demographic consequences of various types of programmes. For the demographic scholar, it has the advantage of disclosing the dynamics in the relation between birth rates and birth control.

G. AUXILIARY FORTRAN PROGRAMS

The TABRAP methodology of which CONVERSE is the converse had a series of test runs in a United Nations project, the Multinational Study in Methodologies for Setting Family Planning Projections in the ESCAP Region.[13] In the course of this project, eight auxiliary programs were added to the two core programs to serve as input and analytical aids. These programs are described below.

1. *Input aid auxiliary computer programs*

ADJUST

The ADJUST model reconciles any discrepancy in the input data between the crude birth rate and age-specific fertility rates, empirical data often being inconsistent in that the age-specific rates applied to the reported age distribution do not produce a crude birth rate equivalent to the reported rate. ADJUST provides both the crude birth rate that corresponds to the age-specific fertility rates and an adjustment of the input age-specific rates to yield the reported crude birth rate. The user selects one of these two options.

MORT

Given the irreversible nature of sterilization, use of the MORT model is not subject to voluntary discontinuation as is the case with other methods. Therefore, to subtract women no longer at risk due to marital dissolution, principally by widowhood, MORT computes the annual age-specific risk of death of either spouse over a five or 10-year interval. Inputs to this model are both male and female $5^{L}-x$ values, the product of which determines the joint probability of survival of the couple.

CONTINUE

With method defined by the decay curve, $C = a$

[13] *Report of the Multinational Study in Methodologies for Setting Family Planning Targets in the ESCAP Region*, Asian Population Studies Series, No. 31 (Bangkok, 1976).

exp $(-rt)$, the parameters a and r are required input for CONTINUE. When the proportion of couples still using a method is available for two observation times from acceptance, CONTINUE computes these parameters. It should be noted that with only two observations, unrealistic values of "a", exceeding 1, may result.

CONTINU2

The CONTINU2 model performs the same function as CONTINUE, handling from 2 to 12 observations by the linear least-squares technique applied to the natural logarithm of the observations.

2. *Analytical aid auxiliary programs*

Analytical aid auxiliary programs require input from CONVERSE output tables. They could have been incorporated into the core model but their occasional use did not appear to warrant the increment of complexity that this step would have entailed.

TABLE 4

The auxiliary model TABLE 4 permits further analysis of the powers of each method to provide contraceptive protection. It gives couple-years of protection and births averted per acceptor of a particular method as a function of age at acceptance, of continuation of the method and of the time elapsed since acceptance.

COMPETE

Since CONVERSE consolidates methods, output tables on contraceptive use and births averted do not distinguish individual methods. COMPETE indicates how individual methods compete to attract acceptors, maintain users and contribute to births averted. COMPETE is limited to a 10-year projection without aborters or initial users.

RATIOS

RATIOS is a computer program designed to explore the consequences of changing the method composition of acceptance during a particular family planning programme year. Evaluation is by births averted per acceptor during each subsequent year of the residual target period. The output is obtained for each method and for all methods weighted together. In addition, the first method is chosen as the standard, and ratios of births averted by each of the other methods to those averted by the standard method are calculated. It should be noted that each run, or pass, of RATIOS deals with the consequences in subsequent years of acceptance during a particular family planning programme year.

MACHO

Since CONVERSE is a single-sex projection model, presumably female, vital rates relating to the one sex could be quite different from a realistic, two-sex population, especially in instances of anomalies in age structure or large sex differentials in life expectancy at birth. MACHO is a male projection based on total births from CONVERSE and an initial male age distribution and male mortality (by means of life tables), both with and without contraception. The outputs are vital rates for females, males and the two-sex population.

Chapter IV

COMPONENT PROJECTION APPROACH II: A MODEL FOR DESK CALCULATORS*

*United Nations Secretariat**

The primary purpose of this discussion of the component projection approach is to offer an alternative to application of the method through use of a sophisticated model requiring an electronic computer, such as that presented in the preceding chapter. A secondary, but important purpose relates to the nature of the method. Most applications of the component projection approach assess the potential effect of a family planning programme on fertility (and thus estimate future changes in fertility). But the discussion that follows deals with the impact of a programme from the past to the present rather than from the present to the future. The procedure described in this chapter is a free application of the methodology originally proposed by Lee and Isbister.[1]

This application of the component projection method is appropriate for use when it is desired to obtain results quickly and when suitable computer facilities or the skills needed to utilize them are lacking. Given the necessary data, the method proposed here can be applied with relative ease using a desk calculator, and the rationale is relatively simple and straightforward.

The various simplifying assumptions and the factors not taken into consideration in this procedure are likely to yield results affected by biases of magnitudes difficult to assess, but the procedure remains a helpful tool when an estimate of the approximate programme effects on fertility is required immediately by programme managers and policy-makers, and where the researcher is in a position to make only simple hand calculations.

A. Description of method

1. *Principle*

The method is designed to estimate the births averted in a given calendar year through the use of birth regulation methods provided by a family planning programme. The logic is that if t is the year for which births averted are estimated and since there is an interval of about nine months between conception and birth, it follows that births prevented in year t result from the practice of family planning that took place approximately between 1 April of the year $t-1$ and 1 April of year t. The number of births averted by couples or women in age group i is thus obtained as the product:

$$Q_{i,t} \cdot g_i$$

where $Q_{i,t}$ = number of women in the ith age group in year t who were practising totally effective contraception during the period from 1 April of year $t-1$ to 1 April of year t;[2]

g_i = potential fertility estimate of the number of women $Q_{i,t}$ in age group i;[3]

i = sucessive age groups of women of reproductive ages, 15–19, 20–24, 25–29 etc.[4]

There are therefore two major steps, i.e., the estimation of $Q_{i,t}$ and g_i. The estimation of $Q_{i,t}$ becomes a somewhat more lengthy task than in the method resorted to in connexion with the standardization approach. Indeed, in the present case, births averted are estimated by age group; thus, acceptors of age x at the time of acceptance will be $x+u$ years old by the time they enter the 12-month period during which contraception must be practised if births are to be prevented in year t. If data on users are not available directly from service statistics records or follow-up surveys, it becomes necessary to estimate the number of users in age group i at time t from the number of acceptors classified by age group at the time of acceptance.

2. *Assumptions*

As with other methods of evaluation discussed in this *Manual*, the procedure for applying the component projection method necessarily implies a number of assumptions, which are made owing to lack of certain essential data as well as to insufficiency of knowledge about the interplay of some factors.

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

[1] B. M. Lee and John Isbister, "The impact of birth control programs on fertility", in Bernard Berlson and others, eds., *Family Planning and Population Programs: A Review of World Development* (Chicago, University of Chicago Press, 1966), pp. 737–758. In their estimate of births averted as a result of an intra-uterine device programme, the authors assumed that, inasmuch as the acceptors formed a select group by virtue of their fertility performance and interest in family planning, it would be inappropriate to equate their potential fertility with that of the general population. As acceptors usually have a higher fertility than their non-accepting cohorts, the authors assumed that their fertility would have been 20 per cent higher than the marital fertility rate of other women of the same age.

[2] The reference is to female acceptors or wives of male acceptors.

[3] "Potential fertility" is defined as the fertility that family planners in the ith age group would have experienced had they not been using a family planning method.

[4] Any other appropriate age group can, of course, be utilized with these notations provided data are available.

The computation of $Q_{i,t}$ involves the following assumptions:

(*a*) Acceptance occurs at a constant rate throughout each year of the programme, so that acceptors who do not discontinue use will be in the programme for an average of six months during the year of acceptance;

(*b*) The number of users as of 1 October of year $t-1$, mid-point between 1 April of year $t-1$ and 1 April of year t, is assumed to represent the average number of users of that period;

(*c*) Because only acceptors up to 30 September of year $t-1$ are taken into account,[5] they are assumed to remain in the programme for an average of 4.5 months during year $t-1$;

(*d*) It is assumed that for the purpose of estimating users by age, the annual numbers of acceptors shown in service statistics records relate to 1 July of that year;

(*e*) Mortality of users between 1 April of year $t-1$ and 1 April of year t is considered negligible;

(*f*) Acceptors are distributed evenly among all ages within age groups.

If data for users as of 1 October of year $t-1$ are not readily available, $Q_{i,t}$ is computed in two steps. First, continuation rates by age group are applied to the number of acceptors classified by age group at the time of acceptance, on the assumption that continuation rates are constant within age groups. The result of this step yields the number of users as of 1 October of year $t-1$ classified by age group as of year of acceptance. The second step consists in translating this latter result into number of users classified by age group as of 1 October of year $t-1$. The rationale for calculating this second step is as follows.[6] Of all acceptors in an age group in year $t-2$, 75 per cent will remain in that age group as of 1 October of year $t-1$ and 25 per cent will pass on to the next age group. Of those having accepted in year $t-3$, 55 per cent will remain and 45 per cent will pass on. Of those having accepted in year $t-4$, 35 per cent will remain and 65 per cent will pass on, and so forth. In year $t-1$, users having accepted in the first nine months are observed to continue use for an average of 4.5 months, i.e., from 15 May, the mid-point of the first nine months of year $t-1$, to 1 October of year $t-1$. Thus, 92.5 per cent of acceptors in an age group will remain in that age group and 7.5 per cent will pass on to the next age group, as of 1 October of year $t-1$.

3. *Computation of* $Q_{i,t}$ and g_i

The total number of effective users as of 1 October of year $t-1$, who will also be the women in the ith age group in year t, is therefore obtained by:

$$\begin{aligned} Q_{i,t} = {} & 0.925\, q_{i,t-1} + 0.075\, q_{i-1,t-1} + 0.75\, q_{i,t-2}, \\ & + 0.25\, q_{i-1,t-2} + 0.55\, q_{i,t-3} + 0.45\, q_{i-1,t-3} \\ & + 0.35\, q_{i,t-4} + 0.65\, q_{i-1,t-4} + 0.15\, q_{i,t-5} \\ & + 0.85\, q_{i-1,t-5} + 0.95\, q_{i-1,t-6} + 0.05\, q_{i-2,t-6} \\ & + \ldots \end{aligned}$$

where $q_{i,t-n}$ $(n = 1, 2, \ldots, p)$ = number of effective users in the ith age group who accepted in year $t-n$ classified as of year of acceptance.[7]

For year $t-1$, only users who accepted in the first nine months of that year are included in the calculations, since to be a user as of 1 October, a woman would have become an acceptor prior to that date. If monthly data are available, the figures for the first nine months may be totalled; if annual data are available, it is sufficient to take three quarters of the annual figure or to multiply the first two terms of the formula of $Q_{i,t}$ by (0.75). The coefficients and the number of terms included in the formula will vary both with the date for which the estimated $Q_{i,t}$ is computed and with the number of programme years taken into account. In the illustration by Lee and Isbister,[8] a five-year programme is evaluated as of 1 July of year $t-1$; in another study,[9] a seven-year programme is evaluated as of 31 December of year $t-1$.

As concerns the estimation of g_i, the selection of appropriate potential age-specific fertility rates also raises a number of problems. In practice, at least two options are open: one may take either age-specific marital fertility rates of the population as a whole or the acceptors' own fertility during the period prior to entering the programme.[10] The decision as to the appropriate measure for estimating g_i rests on the opinion whether, in any age group, acceptors are more likely to have a higher potential fertility than do married women in general, since the chances are that the latter include some sterile and subfecund women, women whose husbands are temporarily absent etc. Indeed, although data often show higher fertility among acceptors, it has been argued that this finding results from biases due to the fact that acceptance of a method frequently occurs shortly after a birth, or among other things, to the chance factors affecting the occurrence of conception rather than to higher fecundability. It has been contended, furthermore, that higher fertility of acceptors might not have remained so, comparatively speaking, over the long run or even over the period for which programme impact is being evaluated. In other words, one type of indicator is somewhat more conservative than the other and, depending upon the choice, is likely to constitute a built-in concept that favours the outcome of either a stronger or a weaker effect of the programme on fertility.[11] Additional qualifications not discussed here are dealt with in sections B.1 and D of this chapter.

[5] In fact, to be a user as of 1 October, one has to be an acceptor prior to that date.

[6] In calculating this second step it is assumed that women are uniformly distributed within a five-year age group and that one fifth of these women pass on to the next five-year age group every 12 months.

[7] In year $t-1$, users in age group i are nine months younger than the conventional age group in that year.

[8] *Loc. cit.*, p. 743.

[9] Yalande Jemai and Hedi Jemai, "Application of methods of measuring the impact of family planning programmes on fertility: the case of Tunisia", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 66–106.

[10] Other options include the computation of fertility rate for acceptors directly from calendar-year simulation models or through matrices of birth probabilities. These options are not considered in this chapter.

[11] The major prerequisite to making this choice is that the needed data are available; otherwise, one is limited by the type of data at hand. In such a case one may use the fertility rate of the general population or of the

B. Use of method

1. *Significance*

An advantage of this application of the component projection method is that it yields the number of births averted in a particular calendar year or a series of calendar years following the initiation of the family planning programme.

Unlike the standardization method, for example, the change may be measured by age-specific fertility rates to achieve greater accuracy than would be allowed by a crude birth rate or a general fertility rate. In addition, a better perspective of the pattern of fertility changes as well as of the effect of programme strategy is afforded by an examination of the impact of the programme on women in each five-year age group. Needs for data are somewhat less demanding than for several other methods of evaluation, the essential requirements being data from population censuses, vital statistics, programme statistics on acceptors and survey data on continuation of use.

The cumulative number of births averted during the existence of the programme cannot normally be obtained by this application of the component projection method. However, this feature is not necessarily a short-coming because, for most purposes, a summation of the annual impact over time will suffice. This method of evaluation cannot be used to determine the effect of a particular method of birth control per segment of use. For this purpose, it is required to apply the reproductive process analysis method illustrated in chapter V.

The validity of the results obtained by this method of evaluation is made conditional, as is the case with other methods, by the nature of certain assumptions involved in the computation of $Q_{i,t}$. In the illustration, it is assumed that mortality and sterility among acceptors are negligible for the period from 1 April of year $t-1$ to 1 April of year t. It is further assumed that, during the same period, contraception is totally effective for $Q_{i,t}$ users, accidental pregnancies being taken into account in the concept of continuation of use. There is also an implied postulate in the omission of an assessment of the number of births occurring in year t due to postponement or to accidental pregancies which would not have occurred in that year had the mothers not previously entered the programme or resorted to non-programme contraception.[12]

The assumption regarding the potential fertility of acceptors, namely, whether they would have higher fertility than the average married women, greatly influences the validity of the estimated number of births averted. Because it cannot be known with certainty what this fertility might have been, the estimates of births averted are necessarily somewhat conjectural, even though, as already stated, records indicate that at the time of acceptance the fertility of acceptors is above that of their non-accepting cohorts. This problem arises in the selection of the indicators of potential fertility (g_i); conclusions based on results of the application of this method should thus be drawn with caution.

In the illustration that this chapter provides, potential fertility is indicated by the age-specific fertility rates of the acceptors prior to their affiliation with the programme.[13] If the researcher is willing to accept results within a margin and perhaps thereby to achieve added confidence in the evaluation, the procedure may be executed first with age-specific fertility rates for all married women and then with rates for the acceptors. The results achieved with the former procedure would represent a lower estimate of the effect and that with the latter the maximum effect, and the impact of the programme could be stated as a range in number of births averted.

In order to smooth out biases that may be due to chance effects and to post-partum acceptance, the researcher may utilize a fertility indicator averaged for a period of from three to five years prior to acceptance.

2. *Data problems*

Two categories of data are needed: those required to estimate $Q_{i,t}$; and those needed for g_i. Estimates of the first category require data on acceptors by family planning method, age group and year of acceptance. Translating the number of acceptors into number of users requires continuation rates by age group, type of family planning method and duration of use reflecting the length of the period of evaluation. Whenever data on users are available from statistical records or surveys and need not be derived from acceptance data, statistics on continuation are not required. In practice, it often happens that not all of the required data are available and that some estimates must be developed. A few such examples are included in the illustrated application of the method; the solutions adopted are by no means the only solutions for the number and types of data problems arising in programme evaluation varies, among other things, with the type of programme and the structure of the family planning service statistics system. Evaluators will find it necessary to find appropriate solutions as various problems arise. The two major sources of the data for the application used in the illustrations given below were the service statistics system and sample surveys of programme acceptors.[14] The data available from the service statistics system provide infor-

married population (as illustrated in chapter I of this *Manual*). In their pioneering work, Lee and Isbister, *loc. cit.*, used the marital fertility of the general population increased by 20 per cent to account for the acceptors' higher fertility. For a review of potential fertility conceptual problems, see "Methods of measuring the impact of family planning programmes on fertility: problems and issues", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility* (United Nations publication, Sales No. E.78.XIII.2), pp. 3–42.

[12] See for instance, C. Chandrasekaran and others, "Some problems in determining the number of acceptors needed in a family planning programme to achieve a specified reduction in the birth rate", *Population Studies* (London) vol. XXV, No. 2 (July 1971), pp. 303–308.

[13] However, some scholars argue that the rate for all married women should be used, as they represent the average and because the past fertility of the acceptors might have been a temporary pattern with a change occurring in any event.

[14] Reliable information on the period over which women continue to use a method (referred to in the text as "continuation") is obtainable only through sample surveys. The data on continuation shown in the illustrations given below were collected in sample surveys that were carried out in the country referred to as Country A.

mation about first-time method acceptors,[15] reacceptances such as intra-uterine device (IUD) reinsertions and visits to the programme for supplies (pill, condom etc.), and data on sterilizations and abortions. The statistics used in this text are considered to be generally of good quality and they have not been corrected for errors. Duplications are assumed to be negligible.[16] The data from the follow-up surveys are also considered to be reliable except that their representativeness was questioned because of a substantial number of persons in the sample who could not be found for interview. The data on continuation rates computed from the sample have been corrected on the basis of family planning clinic files; and the fertility rates of acceptors prior to acceptance, computed from the births histories of the interviewed acceptors, have been weighted on the basis of family size at acceptance, age group and year of acceptance.

Where the statistics that would serve as suitable basis for evaluation are in meagre supply, all available sources should be tapped and, in the absence of needed data, reasonable assumptions made. For instance, if there are no statistics on the age composition of acceptors from service statistics, the researcher may apply data from follow-up surveys, adjusted if necessary. If the age distribution of women who have accepted a given contraceptive method is completely lacking, one may, if it is deemed appropriate, borrow the information from another country, from another contraceptive method in the programme or from information on the same method but not for the same time period. However, this procedure can produce misleading results and should be applied with great care. Knowledge of the programme characteristics should shed some light on the magnitude of the possible bias involved. Thus, the researcher may borrow continuation rates from another country, but only if there is enough evidence of similarity of conditions; borrowing continuation rates of one contraceptive method to be applied to another may be even more hazardous as patterns of discontinuation often vary greatly from one family planning method to another. If data for a given year are not available, one may, depending upon the nature of the missing data, borrow from another calendar year if there is evidence that conditions were sufficiently stable with respect to the particular data. When sample data are used, adjustments may be needed to ensure representativeness, which must always be tested.

As concerns the potential fertility indicator, g_i, the fertility of married women or of the acceptors themselves can be used, depending upon the evaluator's decision; and data can be obtained from service statistics and sample surveys, as well as from vital statistics (for married women). Some of these cases are illustrated in the following section. In all cases, great care has to be taken concerning the quality of the data utilized, and appropriate corrections must be made. If too many approximations and assumptions become necessary, the data may be judged too poor to yield reliable results.

C. Application of method

1. *Estimating number of users: $Q_{i,t}$*

The method is applied to Country A, and the illustration estimates the hypothetical number of births averted in the year 1971 resulting from programme activities undertaken from 1966 to 1970.[17]

In applying this method of evaluation, the essential aim is to estimate separately the number of births averted to acceptors of each method offered by the family planning programme, with the acceptors being classified according to age group (i) and year (t). If allowance is made for the nine months of pregnancy, women who avert births in 1971 are those who were protected against the risk of pregnancy during the period from 1 April 1970 to 1 April 1971. On the assumption that users are uniformly distributed throughout a year, it is further postulated, in order to simplify computations, that users as of 1 October 1970 represent the average number of users for the period from 1 April 1970 to 1 April 1971.

Accepting these postulates, it is then possible to calculate in three steps the number of births averted by each method. The first step consists in estimating $Q_{i,t}$, the number of women in the ith age group in year t who were practising contraception between 1 April 1970 and 1 April 1971; these are the contraceptive users as of 1 October 1970. In the second step, the researcher determines the value of g_i, i.e., the appropriate potential fertility rates. The third step consists in computing the hypothetical number of births averted in 1971: $Q_{i,t} \cdot g_i$.

Since there is sufficient evidence that family planning practice was both limited and inefficient prior to acceptance,[18] it is assumed that no family planning programme acceptors recorded in the service statistics system would have been protected against pregnancy in the absence of the programme. In other words, it is assumed that no switching from non-programme to programme contraception took place and that, in the case of Country A, the small core of highly motivated pre-programme family planners continued to obtain contraceptives from private sources.

The family planning methods offered by the official family planning programme are: intra-uterine devices; oral contraceptives; condoms; jellies; sterilization; and interruption of pregnancy (abortion). The assumptions made specifically with respect to each method are stated in

[15] A first-time method acceptor is one who receives a programme method for the first time, whether he or she enters the programme for the first time or switches from one programme method to another. A first-time pill acceptor may thus be a former intra-uterine device (IUD) acceptor in the programme.

[16] In the present case, there is duplication when the same acceptor of one contraceptive method is counted twice as a first-time acceptor, which occurs by simple error or when the acceptor is transferred to another centre where a new file is made. When evidence of duplication is reliable and if there is sufficient information as to type of contraceptive method and the age group involved, appropriate corrections can be undertaken.

[17] In this particular case, Country A is the same as that which illustrates the standardization approach during the same span of time; and, consequently, results of the present exercise are comparable to those of chapter I.

[18] The evidence was derived from a survey of Knowledge, Attitude, Practice (KAP) of family planning undertaken in Country A prior to implementation of the programme.

the respective subsections dealing with these methods. Only direct programme effects are taken into consideration; effects on fertility resulting from acceptance of contraception by family planners who were motivated by programme activities but who resorted to the private sector for their contraceptive needs are not accounted for. This is an implicit assumption that all private sector contraception is motivated by non-programme factors. As indicated previously, statistics on acceptors and users for 1970 are for the first nine months, and only those acceptors who took a method prior to 1 October 1970 could be users as of this latter date. Because acceptance is assumed to occur uniformly during the calendar year, acceptors in 1970 remain in observation for an average of 4.5 months in the absence of discontinuation; and, to simplify computations, acceptance in 1970 is assumed to occur as of 15 May, the mid-point between 1 January and 1 October 1970.

Intra-uterine device

The statistics on the insertion of IUDs are from service statistics records and refer to first insertions only. The information on acceptance patterns according to age group was obtained from results of surveys with adjustments on the basis of clinic data for the whole country.

Where the number of acceptors by age and year of acceptance is unknown or is not known reliably, it is required to estimate them or to make adjustments to improve the quality.

Table 61 gives the results of such estimates. Part (a) shows age distributions of acceptors from returns of a sample survey, and part (b) shows the age distribution of acceptors determined by applying the distribution observed from the survey to total the number of acceptors recorded in the service statistics. This method was used because it was considered that the service statistics system yielded a more complete account of the total number of acceptors, though it did not record their ages. Women protected by IUDs are then estimated on the basis of continuation rates.

The importance of the reliability and accuracy of continuation rates should be borne in mind, despite the fact that biases associated with these rates are difficult to ascertain. The construction of the life tables needed to compute continuation rates is an important step of the procedure described here, and it is recommended that the excellent step-by-step descriptions of these techniques published in the family planning literature be thoroughly examined and followed.[19] In the present case, continuation rates for IUD acceptors were obtained from an acceptor follow-up sample survey and the data were corrected for non-response. It is assumed that rates were constant during programme years and within age groups.

[19] Robert G. Potter, "The multiple decrement life table as an approach to the measurement of use-effectiveness and demographic effectiveness of contraception", in *Contributed Papers. Sidney Conference, Australia, 21–25 August 1967* (International Union for the Scientific Study of Population, n.d.), pp. 869–883; *idem*, "Application of life table techniques to the measurement of contraceptive effectiveness", *Demography*, vol. 3, No. 2 (1966), pp. 297–304; Christopher Tietze and Sarah Lewit, "Recommended procedures for the statistical evaluation of intrauterine contraception", *Studies in Family Planning*, vol. 4, No. 2 (February 1973), pp. 35–42; J. A. Grinblat, "Analysis of the continuation of pill use from medical records" (POP/CONF.3/28), paper prepared for the African Population Conference, Accra, Ghana, 9–18 December 1971; C. Chandrasekaran and M. Karkal, "Continuation rates, use-effectiveness and their assessment for the diaphragm and jelly method", *Population Studies*, vol. XXVI, No. 3 (November 1972); pp. 487–494; Robert G. Potter and Roger C. Avery, "Use-effectiveness of contraception", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effects of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and

TABLE 61. INTRA-UTERINE DEVICE ACCEPTORS, BY AGE GROUP AND YEAR OF ACCEPTANCE, COUNTRY A, 1966–1970

Age group *i*	*Year of acceptance* 1966 (1)	1967 (2)	1968 (3)	1969 (4)	1970 (5)	*Total* (6)
(a) *Age distribution of first intra-uterine device acceptors in each acceptance year*[a]						
Under 25	9.64	9.57	15.03	16.30	17.63	
25–29	20.40	19.55	24.36	24.65	23.99	
30–34	29.66	29.44	28.46	28.02	27.54	
35–39	29.06	31.41	24.00	24.28	23.34	
40 and over	11.24	10.03	8.15	6.75	7.5	
TOTAL	100.0	100.0	100.0	100.0	100.0	
(b) *Number of women having accepted first intra-uterine device insertion*[b]						
Under 25	1 164	924	1 398	1 417	1 274	6 177
25–29	2 464	1 888	2 266	2 144	1 734	10 496
30–34	3 582	2 843	2 649	2 437	1 992	13 503
35–39	3 510	3 033	2 233	2 111	1 687	12 574
40 and over	1 357	969	758	587	542	4 213
TOTAL[c]	12 077	9 657	9 304	8 696	7 229	46 963

[a] From results of sample surveys on the characteristics of intra-uterine device acceptors. Data adjusted for the whole of Country A.

[b] Total number of acceptors according to family planning service statistics distributed by age according to the distributions given in (a).

[c] Totals from Family Planning Service Statistics publication of Country A. The total of 7,229 for 1970 represents three quarters of the annual number of recorded first insertions in that year.

The data used to compute these rates reflected the acceptors for the period 1969–1972 and it is assumed that these rates are valid for the 1966–1970 acceptors studied in this illustration.[20] All rates are for the first method accepted in the programme, whether first or subsequent insertion. It is assumed in the present case that taking reinsertions into account has only a negligible effect on the number of users estimated from these continuation rates. This is mainly because the time interval between expulsion or removal and reinsertion was usually very short. Women who were continuing use of a given method at the time of the interview are assumed not to be a self-selected group. The period of observation is from 1 July of year of acceptance to 1 October 1970 and continuation rates are thus interpolated to match the appropriate span of time.[21] Estimated continuation rates for IUD acceptors at the required reference points are presented in table 62.

The number of women protected by IUDs as of 1 October 1970 can now be computed for each age group. Between 1 July of the acceptance year and 1 October 1970, 1966 acceptors were under observation for 51 months, 1967 acceptors for 39 months, 1968 acceptors for 27 months, 1969 acceptors for 15 months and 1970 acceptors for 4.5 months. The appropriate continuation rates in table 62 are applied to the specified number of acceptors in each year and age group, and the results are presented in table 63.

Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 133–162; C. Paulet, L'evaluation d'un programme de planification de la famille en terms de continuation (Bucharest, Centre de demographie ONU Roumanie, 1977); Anrudh K. Jain and Irving Sivin, "Life-table analysis of IUDs: problems and recommendations", *Studies in Family Planning*, vol. 8, No. 2 (February 1977), pp. 25–47; Charles J. Mode and others, "Methodological issues underlying multiple decrement life table analysis, *Demography*, vol. 14, No. 1 (February 1977), pp. 87–96. Use of the exponential curve is described in W. Parker Mauldin, "Births averted by family planning programs", *Studies in Family Planning*, vol. 1, No. 33 (August 1968), p. 6.

[20] Such an assumption requires some supporting evidence, which appears satisfactory for the intra-uterine device, but not for oral contraceptives.

[21] It is for the evaluator to decide whether smooth graphic interpolation may be preferable to straight linear interpolation. This aspect is particularly important if some extrapolation is also needed. Extrapolation may be very hazardous and this operation should not be undertaken mechanically for periods longer than from 9 to 12 months. In

TABLE 62. CONTINUATION RATES FOR INTRA-UTERINE DEVICE INSERTIONS, FIRST METHOD BY AGE GROUP AND DURATION OF USE, COUNTRY A

Age group *i*	*Retention rates (per 100)* — *Number of months after acceptance* (1)	(2)	(3)	(4)	(5)
	(a) *Observed retention rates p months after acceptance*[a]				
	6 months	*12 months*	*24 months*	*36 months*	*48 months*
Under 25	79.7	63.0	45.3	31.7	(26.7)
25–29	82.2	71.3	57.3	43.0	(36.5)
30–34	90.2	82.3	66.5	56.4	43.7
35–39	87.0	78.8	60.6	47.6	(42.0)
40 and over	84.8	77.4	67.4	61.9	(51.9)
	(b) *Interpolated retention rates*[b]				
	4.5 months	*15 months*	*27 months*	*39 months*	*51 months*
Under 25	84.78	58.58	41.90	30.45	(25.45)
25–29	86.65	67.80	53.72	41.37	(34.87)
30–34	92.65	78.35	63.97	53.22	(40.52)
35–39	90.25	74.25	57.35	46.20	(40.60)
40 and over	88.60	74.90	66.02	59.40	(49.40)

[a] From results of follow-up sample survey; rates in parentheses are based on less than 20 observations. Rates were corrected for those lost to follow-up.

[b] Rates obtained by linear interpolation; extrapolation to 51 months is based on the 36–48 months trend.

TABLE 63. NUMBER OF WOMEN PROTECTED AGAINST PREGNANCY BY AN INTRA-UTERINE DEVICE AS OF 1 OCTOBER 1970, BY AGE GROUP IN YEAR OF ACCEPTANCE, COUNTRY A

Age group (i)	*Year of acceptance* 1966	1967	1968	1969	1970	*Total*
Under 25	296	281	586	830	1 080	3 073
25–29	859	781	1 217	1 454	1 503	5 814
30–34	1 451	1 513	1 695	1 909	1 846	8 414
35–39	1 425	1 401	1 281	1 567	1 523	7 197
40 and over	670	576	500	440	480	2 666
TOTAL	4 701	4 552	5 279	6 200	6 432	27 164

Note: Each figure is obtained as the product of number of acceptors in table 61, part (b) and corresponding continuation rates in table 62, part (b). For example, 296 = 1,164 × 0.2545 (or the rate of retention at 51 months applied to the number of women under age 25 who accepted an intra-uterine device insertion for the first time in 1966).

TABLE 64. NUMBER OF WOMEN PROTECTED AGAINST PREGNANCY BY AN INTRA-UTERINE DEVICE, BY AGE GROUP AS OF 1 OCTOBER 1970, COUNTRY A

	Women protected as of 1 October 1970 classified by year of acceptance					
Age group i	*1966* (1)	*1967* (2)	*1968* (3)	*1969* (4)	*1970* (5)	*Total* (6)
Under 25	44	98	322	623	999	2 086
25–29	381	456	933	1 299	1 471	4 540
30–34	948	1 038	1 480	1 796	1 821	7 083
35–39	1 447	1 473	1 468	1 652	1 547	7 587
40 and over	1 312	1 113	851	722	558	4 556
TOTAL	4 132	4 178	5 054	6 092	6 396	25 852

Note: Results are obtained from formula $Q_{i,t}$ as applied in the following statistical exercise; users having accepted an insertion in the same calendar year are summed up:

$$Q_{25,1971} = 0.925(1\,080)^{1970} + 0.75(830)^{1969} + 0.55(586)^{1968} + 0.35(281)^{1967} + 0.15(296)^{1966}$$
$$= 999 + 623 + 322 + 98 + 44 = 2\,086$$

$$Q_{25-29,1971} = 0.925(1\,503)^{1970} + 0.075(1\,080)^{1970} + 0.75(1\,454)^{1969} + 0.25(830)^{1969} + 0.55(1\,217)^{1968} + 0.45(586)^{1968} + 0.35(781)^{1967} + 0.65(281)^{1967} + 0.15(859)^{1966} + 0.85(296)^{1966}$$
$$= 1\,390 + 81 + 1\,091 + 208 + 669 + 264 + 273 + 183 + 129 + 252 = 4\,540$$

$$Q_{30-34,1971} = 0.925(1\,846)^{1970} + 0.075(1\,503)^{1970} + 0.75(1\,909)^{1969} + 0.25(1\,454)^{1969} + 0.55(1\,695)^{1968} + 0.45(1\,217)^{1968} + 0.35(1\,513)^{1967} + 0.65(781)^{1967} + 0.15(1\,451)^{1966} + 0.85(859)^{1966}$$
$$= 1\,708 + 113 + 1\,432 + 364 + 932 + 548 + 530 + 508 + 218 + 730 = 7\,083$$

$$Q_{35-39,1971} = 0.925(1\,523)^{1970} + 0.075(1\,846)^{1970} + 0.75(1\,567)^{1969} + 0.25(1\,909)^{1969} + 0.55(1\,281)^{1968} + 0.45(1\,695)^{1968} + 0.35(1\,401)^{1967} + 0.65(1\,513)^{1967} + 0.15(1\,425)^{1966} + 0.85(1\,451)^{1966}$$
$$= 1\,409 + 138 + 1\,175 + 477 + 705 + 763 + 490 + 983 + 214 + 1\,233 = 7\,587$$

$$Q_{40+,1971} = 0.925(480)^{1970} + 0.075(1\,523)^{1970} + 0.75(440)^{1969} + 0.25(1\,567)^{1969} + 0.55(500)^{1968} + 0.45(1\,281)^{1968} + 0.35(576)^{1967} + 0.65(1\,401)^{1967} + 0.15(670)^{1966} + 0.85(1\,425)^{1966}$$
$$= 444 + 114 + 330 + 392 + 275 + 576 + 202 + 911 + 101 + 1\,211 = 4\,556$$

Total: 25 852

The next exercise consists in estimating the number of women, $Q_{i,t}$, protected against pregnancy by an IUD classified by age group as of 1 October 1970 (who also are the women who prevent the occurrence of a live birth in 1971). The formula described in section A.3 can be applied if the following additional assumptions are made. Since, in this illustration, the first and the last age groups of acceptors are somewhat larger than a conventional five-year age group,[22] it is assumed that the group "under 25" includes the conventional 20–24 year-old acceptors and a very small percentage of acceptors aged 18–19 years;[23] a similar assumption is made regarding the "40 and over" age group, which is assumed to include at least 90 per cent of women aged 40–45. Results are given in table 64.

Oral contraceptives

Depending upon data availability, there are several approaches to estimating oral contraceptive users by age group. If reliable data on both the number of pill acceptors and the continuation rates of pill users are available, the same procedure as that resorted to for the intra-uterine device can be applied.

If monthly data on number of visits made for supplies are available, the number of users as of 1 October 1970 can be equated as the monthly average of acceptors of supplies recorded between 1 April 1970 and 31 March 1971.

The latter approach has been adopted here, with the following assumptions: all women received supplies to cover one menstrual cycle; all women utilized the supplies received;[24] and all women came for supplies only once a

these, as well as in other cases, the evaluator's experience of the programme is his major criterion of judgement. In the absence of appropriate data, continuation rates may sometimes be borrowed from other experiences, but this step can be undertaken only under the strictest conditions of similarity of experience. In certain cases, one can also resort to a decay curve of the form:

$$R = ae^{-rt}$$

where R = retention rate at time t;
a = a constant that allows for immediate termination;
e = natural logarithm base;
r = constant annual rate of decline;
t = time.

See W. P. Mauldin, *loc. cit*; R. G. Potter, chap. V of this *Manual*; and Dorothy L. Nortman, "Births averted by the post-partum program: a methodology and some estimates and projections", in G. I. Zatuchni, ed., *Post-Partum Family Planning: A Report on the International Program* (New York, McGraw Hill, 1970), pp. 133–166. See also P. M. Kulkarni and R. G. Potter, "Extrapolation of IUD continuation curves", *Population Studies* (London), vol. 30, No. 2 (July 1976), pp. 353–368 and chapter V of this *Manual*, especially section A.2 and section B, as regards the effect of marriage dissolution.

[22] Data on acceptors for the two younger and two older age groups were combined because of the small number of observations.

[23] The basis for the assumption is the fact that in country A, there is virtually no non-marital family planning, that legal age at marriage for girls is 17; and hence, that most acceptors below age 20 can be expected to be 18–19 years old. Although no data on acceptors by single year of age are available, there is some evidence from a survey that acceptors younger than 20 years of age do not account for more than 6–8 per cent of the "under 25" age group of acceptors.

[24] If there is evidence that part of the supplies are actually not utilized and if the non-use can be quantified, an adjustment can be made to correct the number of pill users.

month;[25] over-estimation and underestimation resulting from these assumptions more or less compensate each other. From 1 April 1970 to 31 March 1971, 79,815 visits were made by women who received oral contraceptives from official family planning centres,[26] thus showing an average of 6,651 pill users per month.[27]

Since the service statistics do not provide information on the age of the visitors coming for pill supplies, the next step consists in deriving the number of pill users by age group. This step can be done by various procedures. If data on pill acceptors by age group and year of acceptance are available from another source, such as a survey, the procedure would be the same as that applied above in respect of the intra-uterine device. If age distribution at time of acceptance is available, but not simultaneously by year of acceptance, assumptions can be made regarding the duration of continuation and hence of the year of acceptance.[28] Once the year of acceptance is derived, the procedure is also the same as that used in connexion with the IUD estimate.

Whereas the preceding approaches are more rigorous,[29] another procedure illustrated here has the advantage of simplifying computations substantially at the cost of another assumption, namely, that as far as oral contraceptives are concerned, continuation rates are so low[30] that a satisfactory approximation can be obtained if one assumes that age distribution at acceptance and age distribution as of 1 October 1970 are fairly similar. It is emphasized, however, that this approach is rather crude from the standpoint of potential fertility rates because to those who do use longer will still be attributed fertility rates applicable to their (younger) age at acceptance and not to their age at current use. Consequently, this procedure is recommended only if all required data are not available and if there is some evidence pointing to short duration of continuing use of the pill. Results of this estimate are shown in table 65.

TABLE 65. NUMBER OF WOMEN PROTECTED BY ORAL CONTRACEPTIVES AS OF 1 OCTOBER 1970, COUNTRY A

Age group i (1)	*Age distribution of pill acceptors (percentage) (2)*	*Number of pill users as of 1 October 1970[a] (3)*
Under 25	22.7	1 510
25–29	24.7	1 643
30–34	26.5	1 762
35–39	18.0	1 197
40 and over	8.1	539
TOTAL	100.0	6 651[b]

SOURCE: Age distribution taken from follow-up sample survey of acceptors of country A, corrected for non-respondents and ages unknown.

[a] Numbers obtained by prorating total according to percentage age distribution observed in the survey and shown in column (2).

[b] Average number of pill users for the 12-month period from 1 April 1970 to 31 March 1971. Data obtained from programme service statistics records of country A.

[25] Some women will visit the programme twice in a given month because there are 13 menstrual cycles over a 12-month period.

[26] Data from service statistics records of Country A.

[27] If a substantial number of family planning centres of Country A were to provide pill supplies for more than one month and if the needed data were available, the number of pill users, taking into account previously distributed supplies, could be estimated for any given month with the following formula:

$$U_m = \frac{\sum_n (K_n - V_n)}{c-1} + V_m = \sum_n V_n + V_m$$

where m = month for which the total number of pill users is estimated;
U_m = total number of pill users in month m;
V_m = number of visits in month m to receive a supply of pills;
c = constant number of pill cycles provided at each visit;
$n = 1, 2, \ldots, c-1$ is the successive number of months preceding month m to be taken into account for computing U_m;
V_n = number of visits in the nth month to receive pill supplies;
$K_n = (V_n) \times (c)$ the total number of cycles distributed in month n.

[28] This approach is used in Y. Jemai and H. Jemai, *loc. cit.*, where it is assumed that 50 per cent of pill users are one-year users; 40 per cent have been users for over two years and 10 per cent for over three years.

[29] Although it is difficult to assess the validity of assumptions regarding the year of acceptance of oral contraceptives if no data are available.

[30] Evidence from the follow-up survey already referred to show that by the end of 12 months after acceptance, about 60 per cent of the pill acceptors (more than 40 per cent after six months) have discontinued use of that contraceptive. In other words, after one year only about 40 per

Condoms and jellies

The total number of condom and jelly users are estimated along the same lines as the oral contraceptive users and estimates are based on similar assumptions. Users as of 1 October 1970 are represented by the monthly average of the number of users having received supplies between 1 April 1970 and 31 March 1971. As there are no data on the age distribution of jelly users and wives of condom users, it is assumed further, following the practice of Lee and Isbister,[31] that they are distributed by age in the same manner as IUD users. It can be seen that the validity of estimates obtained on the basis of such assumptions[32] cannot be ascertained, and hence they constitute even more than the preceding estimates gross approximations of reality. Estimates of average number of condom and jelly users as of 1 October 1970 are: condom, 2,317; jelly, 331.[33] The age distribution and number of jelly users and wives of condom users are shown in table 66.

TABLE 66. NUMBER OF WOMEN PROTECTED BY CONDOM AND JELLY, BY AGE GROUP AS OF 1 OCTOBER 1970, COUNTRY A

Age group i	*Age distribution of intra-uterine device users as of 1 October 1970[a] (1)*	*Number of wives protected by spouse's condom as of 1 October 1970[b] (2)*	*Number of women protected by jelly as of 1 October 1970[b] (3)*
Under 25	8.07	187	27
25–29	17.56	407	58
30–34	27.40	635	91
35–39	29.35	680	97
40 and over	17.62	408	58
TOTAL	100.0	2 317[c]	331[c]

[a] Computed from table 64, column (6).

[b] Distribution obtained by prorating total according to the distribution in column (1).

[c] Monthly average of number of users of condom and jelly between 1 April 1970 and 31 March 1971; data from service statistics records for Country A.

TABLE 67. NUMBER OF WOMEN STERILIZED, BY AGE GROUP AT TIME OF ACCEPTANCE, COUNTRY A, 1966–1970

Age group *i*	*Number of sterilized women in 1974*[a] *(1)*	*Number of sterilized women, 1974, corrected for unknown* *(2)*	*Age distribution of sterilized women in 1974 (per 100)* *(3)*	*Year of acceptance*[b] *1966* *(4)*	*1967* *(5)*	*1968* *(6)*	*1969* *(7)*	*1970* *(8)*	*Total* *(9)*
Under 25	108	114	1.53	12	11	25	38	29	115
25–29	701	741	9.98	76	74	162	251	190	753
30–34	1 931	2 042	27.47	210	204	447	690	523	2 074
35–39	2 733	2 890	38.86	298	289	632	977	740	2 936
40 and over	1 558	1 647	22.16	170	164	361	557	422	1 674
Unknown	403								
TOTAL	7 434	7 434	100.0	766[a]	742[a]	1 627[a]	2 513[a]	1 904[a c]	7 552

[a] Data taken from service statistics records of Country A.
[b] Distribution obtained by prorating totals according to age structure in column (3).
[c] The figure of 1,904 represents three quarters of the annual number of recorded tubal ligations for that year.

Female sterilizations

Data on sterilization are also obtained from service statistics records; however, although the records for Country A provided monthly data for successive programme years, information on age at acceptance was available only for 1974. In the absence of an age structure for sterilized women, it is assumed here that the age distribution at acceptance is constant over time. The number of women sterilized is shown in table 67.

The procedure of estimating number of sterilized women as of 1 October 1970 is as follows. The first step is to assess continuation, i.e., to determine within each age group of sterilized women how many will survive, cohabiting with spouse, who would not have become sterile in the absence of sterilization and who were still protected against pregnancy as of 1 October 1970. Assuming that women are uniformly distributed within each age group, but that average age at time of sterilization is 23 for women younger than 25 years and 42.5 for women aged 40 years and over, women still protected p months after sterilization are as follows:

Average age at time of sterilization	*Proportion of sterilized women still protected against pregnancy p months after sterilization (per 1 000)* *12 months*	*24 months*	*36 months*	*48 months*	*60 months*
23	977.0	954.0	924.0	894.0	864.0
27.5	963.0	926.0	892.0	865.0	839.0
32.5	966.0	931.0	893.0	848.0	804.0
37.5	944.0	889.0	821.0	742.0	661.0
42.5	880.0	758.0	628.0	486.0	349.0

SOURCE: Rates taken from "Births averted by tubal ligations in Tunisia", by L. Behar, in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 102–106. See also chapter I, section D.2 of this *Manual*.

These rates, taken here to illustrate the evaluation procedure, are assumed to reflect the experience of Country A. Sterilizations are assumed to be uniformly distributed over 12-month periods, average duration of protection in year of acceptance is six months and annual data are assumed to be the annual average as of 1 July, except for 1970, where the annual average is as of 15 May, mid-point between 1 January and 1 October. Further, sterilization rates are assumed to be constant within an age group. Appropriate interpolation of the rates shown above, assuming linearity of trend,[34] yields rates for periods from 1 July of the acceptance year to 1 October 1970:

Average age at time of sterilization	*Proportion of sterilized women still protected against pregnancy p months after sterilization (per 1 000)* *51 months*	*39 months*	*27 months*	*15 months*	*4.5 months*
23	886.50	916.50	946.50	971.25	991.37
27.5	858.50	885.25	917.50	953.75	986.12
32.5	837.0	881.75	921.50	957.25	987.25
37.5	721.75	801.25	872.0	930.25	979.0
42.5	451.75	592.50	725.50	849.50	955.0

The number of women protected by sterilization as of 1 October 1970 classified by age group as of year of acceptance is then obtained, for each age group, as the product of the number of sterilization acceptors in a given year and the corresponding proportions still protected p months later, shown above. From 1 July 1966 to 1 October 1970, there are 51 months of exposure; thus, e.g., $77 = 170 \times 0.45175$, or the number of women aged 40 years or over who accepted a method in 1966 and who were still protected as of 1 October 1970 (see table 68).

The number of women protected by sterilization as of 1 October 1970 classified according to their age group on 1 October 1970 can now be computed as $Q_{i,\,t}$. The assumptions regrading this second step are the same as for the estimation of IUD acceptors by age group on 1 October 1970. The results are shown in table 69. The age distribution is derived as shown in the note to table 69.

cent of the acceptors are still in the observation group and barely 50 per cent have been using the pill for at least six months.

[31] *Loc. cit.*

[32] With respect to condoms and jellies, the assumptions are extremely weak because this category of contraceptives is generally packaged in varying numbers and their use is dependent on the frequency of sexual intercourse. As a result, it is not possible to ascertain whether one visit to a clinic ensures one month of supplies or even whether all supplies are actually utilized. In the absence of quantitative evidence, no further assumptions are made to correct these short-comings. Where there is reliable evidence, corrections for non-use could be attempted.

[33] Monthly service statistics data for Country A.

[34] As with continuation rates, it is advantageous to resort to graphic interpolation in the presence of erratic trends.

TABLE 68. NUMBER OF WOMEN PROTECTED BY STERILIZATION AS OF 1 OCTOBER 1970, BY AGE GROUP AS OF YEAR OF ACCEPTANCE, COUNTRY A

Age group *i*	Year of acceptance 1966 (1)	1967 (2)	1968 (3)	1969 (4)	1970 (5)	Total (6)
Under 25	11	10	24	37	29	111
25–29	65	66	149	239	187	706
30–34	176	180	412	661	516	1 945
35–39	215	232	551	909	724	2 631
40 and over	77	97	262	473	403	1 312
TOTAL	544	585	1 398	2 319	1 859	6 705

SOURCE: Sterilization acceptors taken from table 67. Data on proportions of sterilized women still protected against pregnancy *p* months after sterilization are given above in the text.

TABLE 69. NUMBER OF WOMEN PROTECTED BY STERILIZATION AS OF 1 OCTOBER 1970, BY AGE GROUP AS OF 1 OCTOBER 1970, COUNTRY A

Age group *i*	Year of acceptance 1966 (1)	1967 (2)	1968 (3)	1969 (4)	1970 (5)	Total (6)
Under 25	2	4	13	28	27	74
25–29	19	30	93	188	175	505
30–34	81	106	294	556	491	1 528
35–39	182	198	488	847	709	2 424
40 and over	195	185	392	582	427	1 781
TOTAL	479	523	1 280	2 201	1 829	6 312

Note: Results are obtained from formula $Q_{i,t}$ as applied below:

$$Q_{25,1971} = 0.925(29)^{1970} + 0.75(37)^{1969} + 0.55(24)^{1968} + 0.35(10)^{1967} + 0.15(11)^{1966}$$
$$= 27 + 28 + 13 + 4 + 2 = 74$$

$$Q_{25-29,1971} = 0.925(187)^{1970} + 0.075(29)^{1970} + 0.75(239)^{1969} + 0.25(37)^{1969} + 0.55(149)^{1968} + 0.45(24)^{1968} + 0.35(66)^{1967} + 0.65(10)^{1967} + 0.15(65)^{1966} + 0.85(11)^{1966}$$
$$= 173 + 2 + 179 + 9 + 82 + 11 + 23 + 7 + 10 + 9 = 505$$

$$Q_{30-34,1971} = 0.925(516)^{1970} + 0.075(187)^{1970} + 0.75(661)^{1969} + 0.25(239)^{1969} + 0.55(412)^{1968} + 0.45(149)^{1968} + 0.35(180)^{1967} + 0.65(66)^{1967} + 0.15(176)^{1966} + 0.85(65)^{1966}$$
$$= 477 + 14 + 496 + 60 + 227 + 67 + 63 + 43 + 26 + 55 = 1\ 528$$

$$Q_{35-39,1971} = 0.925(724)^{1970} + 0.075(516)^{1970} + 0.75(909)^{1969} + 0.25(661)^{1969} + 0.55(551)^{1968} + 0.45(412)^{1968} + 0.35(232)^{1967} + 0.65(180)^{1967} + 0.15(215)^{1966} + 0.85(176)^{1966}$$
$$= 670 + 39 + 682 + 165 + 303 + 185 + 81 + 117 + 32 + 150 = 2\ 424$$

$$Q_{40+,1971} = 0.925(403)^{1970} + 0.075(724)^{1970} + 0.75(473)^{1969} + 0.25(909)^{1969} + 0.55(262)^{1968} + 0.45(551)^{1968} + 0.35(97)^{1967} + 0.65(232)^{1967} + 0.15(77)^{1966} + 0.85(215)^{1966}$$
$$= 373 + 54 + 355 + 227 + 144 + 248 + 34 + 151 + 12 + 183 = 1\ 781$$

Abortions

Estimating births averted by abortions is a complex matter. In the present case, data on abortions distributed by age group were not available and since the formulation of an assumption regarding the age structure of abortion acceptors was deemed too hazardous in the absence of some reliable information, it was decided to estimate only the total number of births averted instead of estimating births averted by age group. The procedure utilized here to estimate births averted by abortion is based on research by R. G. Potter and is exactly the same as that followed in chapter I (see section D.2), in which the number of abortions performed in Country A between 1 June 1970 and 31 May 1971 was estimated at 2,910. The total number of women protected by programme family planning methods as of 1 October 1970 is shown in table 70.

2. *Estimating potential fertility g_i*

In this illustration, potential fertility is computed as an average of the acceptors' own fertility prior to acceptance. The required statistics on fertility are from a follow-up survey of pill and IUD acceptors during the period 1964–1972. However, because no data are available on the fertility of sterilized women, wives of condom users and jelly acceptors, it is assumed arbitrarily that these family planners had a pre-programme fertility equivalent to the (arithmetic) mean fertility of the IUD and pill acceptors.[35] For the pill and IUD acceptors, estimated potential

[35] It would be preferable if some information were available on the fertility rates that would best reflect the experience of these acceptors. Lacking such data, the researcher must make an arbitrary, though reasonable assumption, such as that made here.

fertility is obtained, for each age group, as the arithmetic mean of the fertility experienced in the second, third, fourth and fifth year preceding acceptance. By taking a span of time prior to the programme, it is designed to average out random fluctuations; and, by eliminating the first year preceding acceptance, biases occurring when acceptance takes place shortly after a birth are partially eliminated.[36] In the present case, the data are assumed to be of satisfactory quality, but at all times great care has to be taken in assessing the data reliability, because both random and non-random errors may affect fertility data obtained from sample surveys.[37]

When pre-programme fertility of acceptors is taken as their potential fertility, another bias is introduced because of annual changes in the age composition of each age group. Indeed, at the time of acceptance, women in age group 20–24 had an average age of 22.5 years and a corresponding fertility. But this group, five years prior to acceptance, was the group aged 15–19 years with an average age of 17.5 years. If average fertility between the second and the fifth year prior to acceptance is taken as the potential fertility estimate for age group 20–24, this average fertility is actually that which might be expected of women at an average age of 19.5, not 22.5 years. Such distortions occur in each age group, although to a varying extent. The magnitude of these distortions, as well as their compensatory effects, do not appear to have been assessed so far.[38] Potential fertility estimates for IUD, pill, sterilization, condom and jelly acceptors are provided in table 71.

[36] It should be mentioned that it is sometimes difficult to distinguish between data errors, upward biases due to short birth intervals at the time of acceptance and genuine upward trends; compare columns (3) and (4) in table 71.

[37] In the present case, age-specific fertility rates were obtained from detailed pregnancy histories. For insight into the problem of non-random errors, see notably William Brass and Joseph E. Potter, "Methods of detecting errors in the World Fertility Survey data", *International Population Conference, Mexico 1977* (Liège, International Union for the Scientific Study of Population, 1977), pp. 87–120; and R. K. Som, *Recall Lapses in Demographic Inquiries* (Bombay, Asian Publication House, 1973); Lolagene C. Coombs, "Levels of reliability in fertility survey data", *Studies in Family Planning*, vol. 8, No. 9 (September 1977), pp. 218–232.

[38] It was not deemed satisfactory to undertake appropriate adjustments because data are not available on fertility by single year of age.

3. *Estimating number of births averted, $Q_{i,t} \cdot g_i$*

The number of births averted can now be estimated as the product of the number of users of a specified family planning method and the corresponding potential fertility rate for each appropriate age group. The hypothetical number of births averted in 1971 is shown in table 72.

To the 13,743 births averted (see table 72), the 1,891 births averted by the 2,910 abortions can be added.[39] The estimated total number of births averted by the family planning programme of Country A for 1971 amounts to 13,743 + 1,891 = 15,634.

D. Interpretation of results

The calculations carried out in the preceding section suggest that in 1971, about 15,600 births were averted by family planning programme acceptors who entered the programme from 1966 to 1970. The order of magnitude of this figure for births averted is consistent with the over-all estimate of births prevented in 1971 as computed through the standardization procedure described in chapter I of this *Manual*. That estimate suggested that in 1971, the total number of births averted in Country A was somewhat higher than 17,000 (see chapter I, section D.2), of which 15,600, estimated by the present method, would be credited to the family planning programme. The validity of this estimate remains, however, difficult to assess and depends upon the quality of the data used,[40] on the effect of the numerous assumptions made in the process of this application procedure and on the extent to which overestimates and underestimates resulting from both data and methodology compensate each other.

Among all causes of bias in estimates of births averted, the choice of the potential fertility indicator may well be the major source of over-estimation or underestimation. In the present illustration, it is assumed that in the absence

[39] The assumption is that each abortion prevents 0.65 birth, hence 2,910 × 0.65 = 1,891 births prevented. For rationale and description of this application, see chapter I, section D.2.

[40] No basis for assessing reliability of service statistics data was at hand; data from sample surveys are affected by sample variations and the effect of non-respondance, although minimized by corrections, may still affect results.

TABLE 70. NUMBER OF WOMEN PROTECTED BY SPECIFIED FAMILY PLANNING PROGRAMME METHODS, BY AGE GROUP AS OF 1 OCTOBER 1970, COUNTRY A

Age group *i*	*Women protected by:* Intra-uterine device[a] (1)	Contraceptive Oral[b] (2)	Condom[c] (3)	Jelly[c] (4)	Sterilization[d] (5)	Total (6)
Under 25	2 086	1 510	187	27	74	3 884
25–29	4 540	1 643	407	58	505	7 153
30–34	7 083	1 762	635	91	1 528	11 099
35–39	7 587	1 197	680	97	2 424	11 985
40 and over	4 556	539	408	58	1 781	7 342
TOTAL	25 852	6 651	2 317	331	6 312	41 463

SOURCES: For data on intra-uterine device, table 64; on oral contraceptives, table 65; on condoms and jellies, table 66; and on sterilization, table 69.

of the programme, acceptors would have continued to experience their pre-programme fertility. On this basis, the number of births prevented by the programme was estimated at about 15,600. If it were assumed that, in the absence of the programme, acceptors would have experienced the same fertility as all married women of similar ages,[41] the number of births prevented by the programme would have been about 13,700.[42] As emphasized previously, one cannot know with complete confidence what the potential fertility of the acceptors would have been. But it can be seen that, in the present case, the number of births averted estimated may be underestimated by 1,900 births or over-estimated by 1,900 births.[43]

The impact of the programme is also underestimated to the extent that a certain number of couples who actually become family planners as a result of programme activities tend to resort to private sources for their contraceptive needs. These contraceptors do not appear in the

[41] Assuming that non-marital family planning is negligible.

[42] This approximation is obtained by applying the general marital fertility rate of all married women 15–49 years old: 285.5 per 1,000 (computed from table 6 in chapter I) to the total number of contraceptive users as of 1 October 1970 (taken from table 70 in this chapter) and adding the number of births prevented by abortions: 41,463 × 0.2855 = 11,838 + 1,891 = 13,729 births averted.

[43] This approach to potential fertility is justified on the ground that the most probable course of fertility in the future, in the absence of the programme, is that which prevailed in the past. Because assumptions regarding potential fertility are subject to wider margins of error when they are formulated for the long term than for the short term, it is suggested that programme effect on fertility be evaluated only on a short-term basis. For longer periods of time, potential fertility assumptions should be revised in the light of changing socio-economic and cultural or political conditions. In certain circumstances, this latter course may also be indicated for short-term assessments.

TABLE 71. AGE-SPECIFIC FERTILITY RATES BEFORE ACCEPTANCE AND POTENTIAL FERTILITY OF ACCEPTORS BY FAMILY PLANNING METHOD AND BY AGE GROUP, COUNTRY A

Age group *i*	*Age-specific fertility rates before acceptance (per 1000)* Fifth year (1)	Fourth year (2)	Third year (3)	Second year (4)	*Estimated potential[a] fertility (per 1 000)* (5)
	(a) *Intra-uterine device acceptors*				
Under 25	452.0	498.0	438.0	563.0	487.75
25–29	383.0	425.0	380.0	389.0	394.25
30–34	309.0	326.0	365.0	381.0	345.25
35–39	342.0	243.0	305.0	332.0	305.50
40 and over	210.0	167.0	131.0	292.0	200.00
	(b) *Oral contraceptive acceptors*				
Under 25	445.0	524.0	380.0	552.0	475.25
25–29	326.0	394.0	371.0	434.0	381.25
30–34	369.0	342.0	419.0	370.0	375.00
35–39	307.0	244.0	270.0	303.0	281.00
40 and over	350.0	254.0	157.0	278.0	259.75
	(c) *Sterilization, condom and jelly acceptors*				
Under 25	...	...	...	...	481.50[b]
25–29	...	...	...	...	387.75[b]
30–34	...	...	...	...	360.10[b]
35–39	...	...	...	...	293.25[b]
40 and over	...	...	...	...	229.85[b]

SOURCE: Age-specific fertility rates taken from published results of follow-up sample surveys of pill acceptors, Country A.

[a] Arithmetic mean of the four fertility rates in each age group.

[b] Arithmetic mean of potential fertility of intra-uterine device and pill acceptors.

TABLE 72. NUMBER OF BIRTHS AVERTED IN 1971 BY PROGRAMME FAMILY PLANNERS, BY AGE GROUP AND TYPE OF FAMILY PLANNING METHOD, COUNTRY A

Age group (i)	*Births averted by[a]* Intra-uterine device (1)	*Oral contraceptive (2)*	*Condom (3)*	*Jelly (4)*	*Sterilization (5)*	*Total (6)*
Under 25	1 017	718	90	13	36	1 874
25–29	1 790	626	158	22	196	2 792
30–34	2 445	661	229	33	550	3 918
35–39	2 318	336	199	28	711	3 592
40 and over	911	140	94	13	409	1 567
TOTAL	8 481	2 481	770	109	1 902	13 743

[a] Application of the formula $Q_{i,t} \cdot g_i$ with data of table 70, which gives the $Q_{i,t}$ values, and table 71, which provides the g_i values.

service statistics records and are thus not taken into account in the computations of births averted. On the other hand, a certain number of couples who become programme acceptors would have become family planners even in the absence of the programme. For these acceptors, the programme did not contribute anything[44] and their inclusion may result in a certain amount of over-estimation. A slight over-estimation may also have resulted from the assumption made in the foregoing illustration that the acceptors practised contraception with complete use-effectiveness between 1 April 1970 and 31 March 1971. A certain number of births occurred in 1971 to programme acceptors, births which would not have occurred in that year had these accepting couples not entered the programme,[45] and inclusion of these acceptors may also have caused a slight over-estimation of births averted. Unfortunately, there is no standard or simple means of assessing the magnitude of such biases.

Taking average fertility of acceptors for the period from the second to the fifth year preceding acceptance may also affect the estimate of births averted since users in age group 25–29, $Q_{25-29,\ 1971}$, for instance, are attributed the fertility of women about 25 years old (24.5, to be precise). Post-partum and post-abortum amenorrhoea are not taken into consideration. The bias due to this omission concerns mainly 1970 post-partum acceptors, but it is difficult on the basis of available information to assess the magnitudes of the over-estimation.[46] Extrapolation of continuation rates is another source of upward or downward bias, and an over-estimation of unknown magnitude is also expected as a result of the assumptions that all characteristics affecting fertility (such as fecundity and foetal mortality) of couples practising family planning between 1 April 1970 and 31 March 1971 remain constant and that mortality of these women is neglected. The need to make assumptions and to adjust data may also have introduced other unidentifiable biases in the foregoing application of the component projection method.[47]

In conclusion, it may be said that these estimates are hypothetical to the extent that they rely on a large number of assumptions, but that they are sufficient to give a satisfactory assessment of the order of magnitude of the effect of a family planning programme on fertility. It appears that the factor having the strongest effect on the estimates of births averted is the indicator of potential fertility. Taking into consideration the age structure of acceptors and age-specific potential fertility yields more precise results and provides more detailed information on the type of family planning method and the age group of acceptors who contributed most to the births prevented by the programme. At the aggregate level, the improvement obtained by taking age composition into account depends upon the particular age and potential fertility structure of the acceptors studied. If a closer look at the programme were needed, this procedure could be repeated for any population subgroups.[48]

It should be clear from the foregoing discussion that the great advantages of this approach are counteracted by the difficulties that arise in interpreting the validity of the results. By and large, there appear to be reasonable bases to conclude that there is a much greater probability of over-estimating than underestimating the number of births averted by this model, especially when the acceptors' own former fertility is used as potential fertility. It is thus strongly recommended that results should be interpreted with caution and that other evaluation procedures also should be applied so as to permit assessment of validity by replication of results.

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[44] Assuming that non-programme contraception would have been available in the absence of the programme.

[45] Meaning that no births would have been postponed to 1971 or no accidental pregnancy would have brought about a birth in 1971, assuming in this case that non-programme birth control would not have been available in the absence of the programme.

[46] This factor is especially important when impact is estimated per segment of contraception. See, notably, Robert G. Potter, "Estimating births averted in a family planning program", in S. J. Behrman, Leslie Corsa, Jr. and Ronald Freedman, eds., *Fertility and Family Planning: A World View* (Ann Arbor, University of Michigan Press, 1969), pp. 413–434. See also chapter V of this *Manual*.

[47] These biases would include, for example, improper use of methods and non-use of supplies received etc., which influence the evaluation product in one way or another.

[48] The results of such a study can indeed undergo further analysis, notably to ascertain programme impact according to various characteristics of acceptors, such as age at first birth, number of children (or sons) at acceptance, duration of marriage, educational level and urban-rural residence. By distinguishing, for instance, between urban and rural areas, the evaluation method may show that the programme has its strongest impact in, say, urban areas. Such results would guide the evaluator as to where programme activities should be expanded, given prevailing conditions. This method can also be applied for more refined analyses, notably to observe programme impact according to family planning method adopted, duration of use, use of first adopted contraceptive method *versus* situations where switching from one method to another has occurred etc. This is material for evaluation research; and if the direction of needed studies is known, advance plans may be made for the collection of the necessary data.

Chapter V

ANALYSIS OF REPRODUCTIVE PROCESS

Robert G. Potter*

A. Background information

1. *Rationale*

Suppose that, on the basis of a life-table analysis,[1] something is known about the continuation with which a sample of couples is practising contraception and that one wishes to convert this protection time into an estimate of fractional births averted per user. Of value here are certain procedures comprising the reproductive process analysis (RPA) considered in this chapter. Four basic steps are involved. For each cohort of acceptors, practice of the contraceptive is first translated into a continuation function (i.e., proportions still using as a function of duration since acceptance); secondly, the continuation function is converted into fractional years of protection per acceptor during each succeeding year after acceptance; thirdly, the corresponding annual rates (lagged nine months to allow for pregnancy time) of potential fertility to be expected in the absence of the contraceptive are estimated; and, lastly, products of annual fractional protection and potential fertility are summed to yield births averted per acceptance. If averages are used at each step—for example, mean lengths of usage and of protection and a mean potential fertility rate—instead of annual coefficients, formulae are simplified, although with some loss of flexibility and information.

The approach is illustrated here primarily in terms of the intra-uterine device (IUD). Nevertheless, the basic logic is applicable in a straightforward fashion to any contraceptive (including sterilization) for which a continuation function may be derived. To encompass induced abortion, it is necessary to credit each abortion with a specified amount of protection time, in effect treating it as though it were a contraceptive.

The perspective taken is that a couple is either sterile or, if not sterile, that the female partner at any moment is in one of three states: pregnant; temporarily anovulatory after a pregnancy termination; or fecundable and at risk of a conception. In the absence of contraception and induced abortion, the non-sterile female partner passes through successive cycles of pregnancy, anovulation and fecundability, with some or all of her pregnancies leading to live births. For the non-sterile couples, the potential birth rate expected in the absence of the contraceptive under study tends downward with advancing age for several reasons. First of all, as one passes beyond the ages of highest marriage rates, the proportion of birth intervals that are from marriage to first birth, and therefore not including an episode of post-partum anovulation, decreases in relation to birth-to-birth intervals. Also, fecundity[2] tends to decline with advancing age, while the likelihood that some other means of fertility regulation, if not the contraceptive under study, would have been practised is usually rising.

Contraception reduces fertility indirectly by the mechanism of holding the woman in the fecundable state longer than would otherwise be the case, thereby interrupting for a time the childbearing cycle and causing a forfeiture of potential fertility during the period of interruption. Often a span of childbearing interruption is shorter than the corresponding segment of contraceptive usage. No potential fertility is being lost if the couple practising contraception is already sterile. Nor is childbearing interruption contributed by the segments of practice coinciding with post-partum anovulation. If *n* fecundable months of contraceptive practice end in accidental pregnancy, then less protection is being conferred than if the *n* fecundable months of practice did not so terminate; indeed, the former period of childbearing interruption may be interpreted as shorter than the latter by an amount equal to the expected number of fecundable months required for a conception in the absence of the contraceptive under evaluation. Thus, to convert mean length of usage into per acceptor childbearing interruption, it is necessary to impose a number of adjustments.

2. *Previous study*

Two schemes for carrying out the operations of reproductive process analysis were developed independently by the present author[3] and by Wolfers[4]. The principal

* Professor, Department of Sociology, Brown University, Providence, Rhode Island. Professor Potter's work on this chapter was financed in part by Ford Foundation grant No. 630-0361D, National Science Foundation grant No. SOC76-12342 and Population Council grant No. D74.44A.

[1] Christopher Tietze, "Intra-uterine contraception: recommended procedures for data analysis", *Studies in Family Planning*, vol. 1, No. 18, supplement (April 1967), pp. 1-6.

[2] By fecundity is meant the capacity (of a woman) to produce a live birth. A woman is fecundable if her condition at the time is such that she can conceive, i.e., she is neither pregnant, lactating, in a state of amenorrhoea or in another condition that would prevent conception in a normally fecund woman.

[3] Robert G. Potter, "Estimating births averted in a family planning program", in S. J. Behrman, Leslie Corsa, Jr. and Ronald Freedman,

formulae of the former scheme were:

$$B = \frac{I}{D}$$

and $$I = F(R - A - PW)$$

where B = births averted per segment of contraception;
I = average duration that childbearing is interrupted;
D = average duration per birth required in the absence of the contraceptive;
R = mean length of contraceptive segment;
F = proportion of couples non-sterile at time of acceptance;
A = allowance for contraceptive overlap with post-partum anovulation;
P = proportion of segments ending in an accidental pregnancy;
W = penalty per accidental pregnancy.

In computing R, the usual life-table analysis recognizing pregnancy, expulsion and removals as reasons for discontinuing the intra-uterine device were expanded to include the extra competing risks of marital dissolution by death of a spouse and onset of secondary sterility. The logic of the analysis required that the D-term refer to the fertility of non-sterile women only. There being no way to observe directly non-sterile women, their potential fertility was estimated indirectly as follows. The expected durations D per birth in the absence of an IUD were estimated by taking reciprocals of the birth rates observed among IUD acceptors during the three years before acceptance. Interpolation was used to adjust for the fact that the IUD acceptors were older while wearing the device than during the three years preceding acceptance. For each five-year age group three alternative estimates of potential fertility were derived, one being an estimate of "gross" potential fertility in the absence of any contraception and sterilization, taken from the experience of acceptors who reported no contraceptive practice during the three years before acceptance; a second being the "net" potential fertility expected if the level of contraceptive usage in the absence of an IUD would have remained at the level observed among all IUD acceptors during their three years before acceptance; and third and most conservative, the "net" potential fertility expected if usage of contraception in the absence of an IUD had risen to the level characterizing the subsample of IUD acceptors who reported ever using during the three years before acceptance. Actually, in the latter two estimates of net potential fertility, provision was also made for acceptance of sterilization at the age-specific rates observed among non-acceptors of IUDs in the same population (Country C).

Exhibiting quite different procedures, Wolfers'[5] scheme of analysis embodied the same basic logic, operationalizes the same list of factors and, like the other scheme, also estimates births averted for acceptor cohorts rather than for calendar years. A major procedural contrast was that, in his approach, the analysis proceeds month by month, with the various corrections being imposed on each successive ordinal month of IUD wearing-time and with the cumulations of childbearing interruption and births averted carried along. Another difference was that durations per potential birth were estimated by means of age-specific prospective birth intervals. By a mean prospective birth interval for age group x to $x+4$ is meant the average length of all closed birth intervals commencing while the mother was aged from x to $x+4$. Under this definition the more highly fecund women could be expected to contribute more birth intervals on average than the less fecund women.

3. *Criticism of reproductive process analysis approach*

The two schemes discussed above have been subjected to a variety of criticisms,[6] six of which are worth mentioning:

(*a*) Estimates of net potential fertility, involving as they do conjectures as to what amounts of contraception, abortion and sterilization the acceptors might have practised if they had not adopted the method they did, are necessarily speculative. On the other hand, even if estimating gross potential fertility is a less speculative enterprise than estimating net potential fertility, reckoning births on this standard is to answer a question in which the administrator is frequently not interested;

(*b*) Pre-acceptance birth rates are influenced by the arbitrary lengths of the base period chosen for their computation and, at younger ages, are likely to be biased upwards by chance factors, therefore leading to inflated predictions of future fertility.[7] Regarding prospective birth intervals, at progressively older ages, they are subject to an increasing truncation bias owing to the fact that shorter birth intervals have more chance of closure before onset of secondary sterility than do long birth intervals.

(*c*) The concept of averted births applies awkwardly to spacers employing contraception in order to delay rather than to prevent the next birth;

(*d*) Because neither of the published schemes relate averted births to calendar time, they are of little use for setting quotas of acceptors needed to achieve designated reductions of population birth or growth rates;

eds., *Fertility and Family Planning: A World View* (Ann Arbor, University of Michigan Press, 1969), pp. 413–434.

[4] David Wolfers, "The demographic effects of a family planning programme", *Population Studies*, vol. XXIII (March 1969), pp. 111–141.

[5] *Ibid.*

[6] J. C. Barrett and W. Brass, "Systematic and chance components in fertility measurement", *Population Studies*, vol. XXVIII (November 1974), pp. 473–493; Lee L. Bean and William Seltzer, "Couple years of protection and births prevented: a methodological examination", *Demography*, vol. 5, No. 2 (1968), pp. 947–959; C. Chandrasekaran, D. V. R. Murty and K. Srinivasan, "Some problems in determining the number of acceptors needed in a family planning programme to achieve a specified reduction in the birth rate", *Population Studies*, vol. XXV (July 1971), pp. 303–308; and W. Parker Mauldin, "Births averted by family planning programs", *Studies in Family Planning*, vol. 1, No. 33 (August 1968), pp. 1–7.

[7] For an illustration, see annexes I and II, "Fertility projection/trend analysis", in this *Manual*.

(*e*) Data demands are inordinately heavy;

(*f*) The procedural details of the two schemes are not only specialized to intra-uterine contraception, but each is tailored to a unique constellation of data that is not repeated elsewhere; and perhaps mainly for this reason, neither of the published schemes has ever seen replication.

In a valuable critique, Wolfers[8] has responded to some of these criticisms and presented a synthesis of the best elements of the two published versions of reproductive process analysis. In the present chapter, rather than offering still another exposition of the two methods with little hope of improving on Wolfers' most recent treatment, it is proposed to present and illustrate a relatively cruder but more pragmatic version of this approach. By sacrificing some of the conceptual niceties, data requirements have been greatly reduced. This new version is described in the next section. Strategems for coping with deficient data are next discussed, followed by a numerical illustration of procedures. A last section deals with interpretation of results and some possible extensions.

B. Description of method

1. *Distinguishing features*

Five features distinguish what is being called the pragmatic version of analysis of reproductive process from its more ambitious predecessors. First, it treats only gross births averted, not net births averted. Gross births averted per acceptance of a contraceptive is operationally defined as the difference between average *per capita* number of births to be expected of wives of a specified age (if during a marriage duration equal to the estimated average length of usage of the contraceptive, no contraception was being practised) and the number that actually occurred to wives of that age. Net births averted is the corresponding *per capita* number of births during the same marriage duration but with allowance made for the alternative contraception that the wives might have practised had they not accepted the contraceptive that they did. Gross births averted can be more objectively assessed than net births averted from the standpoint that an estimate of natural fertility (potential fertility in absence of contraception or abortion) is typically subject to a narrower range of indeterminacy than an estimate of potential fertility predicated on the alternative methods of contraception and abortion that the couples might have been practising had they not accepted the method they did. The distinction between gross and net births averted is more fully discussed in a recent study.[9]

A second distinguishing feature of the present approach is that potential fertility in the absence of contraception is estimated on the basis of age schedules of marital fertility, data that are much more likely to be available than either age-specific pre-acceptance birth rates or prospective birth intervals. Thirdly, respecting the life-table analysis of continuation, it is assumed that included among the coded reasons for discontinuation are separation and divorce as well as marital dissolution by death of a spouse. Fourthly, several tables are furnished, specifying conditions under which particular corrections are more or less important. These tables serve to narrow the range of uncertainty when only some of the data desired are available or else indicate the magnitudes of bias being risked if missing data force one to borrow or forgo an individualized correction factor. Fifthly, the effects of some couples being already sterile or becoming sterile during contraceptive practice is automatically registered in the adjusted marital birth rates employed as measures of potential fertility.

2. *Overview of method*

As with the more elaborate versions of analysis of reproductive process, in this version reliance is still placed on a life-table analysis in order to derive the uncorrected proportions of acceptors $R(v)$ continuing use of the method for v months. Because the observation period is often no longer than 12 or 18 months, a curve such as the modified negative exponential[10] must be fitted to the proportions $R(v)$ so that they may be extrapolated and an estimate of total wearing-time derived.

The estimates needed and their symbols are as follows:

1. Age schedule of potential fertility (marital fertility in absence of deliberate birth control): $m(x)$;

2. Adjustment of the schedule given above to yield the age schedule of gross potential fertility $m^*(x, x+5i, k)$ of women accepting at ages from x to $x+4$ and currently ages $x+5i$ to $x+4+5i$ whose mean open interval between previous birth and acceptance was k years;

3. Life-table estimates of retention $R(v)$;

4. A modified negative exponential function fitted to the life-table proportions $R(v)$ to yield parameters a and r from which to estimate mean retention time and its partitioning into annual subsegments;

5. Allowance (in months) for overlap A between contraceptive practice and post-partum amenorrhoea;

6. Penalty PW for accidental pregnancy, where P designates the expected proportion of contraceptive segments ending in accidental pregnancy and W signifies the mean fecundable period (months) per conception in the absence of contraception;

7. Childbearing interruption $I = R - \frac{A}{12} - \frac{PW}{12}$ and its partitioning into annual components $I(0,1)$, $I(1,2)$,

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[8] David Wolfers, "Births averted", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 163–214.

[9] Dorothy L. Nortman and others, *Birth Rates and Birth Control Practice: Relations Based on the Computer Models TABRAP and CONVERSE* (New York, The Population Council, 1978); see, in particular, chap. I.

[10] W. Parker Mauldin, Dorothy Nortman and Frederick F. Stephan, "Retention of IUD's: an international comparison", *Studies in Family Planning*, No. 18 (April 1967), pp. 1–12.

. . . , during the first, second and so on years following acceptance;

8. Linking childbearing interruption and potential fertility to derive B, gross births averted per acceptance.

If one is dealing with sterilization instead of IUD, then as a substitute for a life-table analysis and its extrapolation (steps three and four), one requires:

9. Estimated proportions $R^*(v)$ still usefully protected, having avoided marital dissolution by divorce, separation or death of a spouse.

These several steps are considered below in more detail.

3. *Steps of analysis*

Step one

The potential fertility rates $m(x)$, $x = 20, 25, \ldots, 45$ in the absence of contraception refer to age groups 20–24, 25–29, . . . , 45–49. Any alleged contraceptive use during ages 15–19 is added to that of age group 20–24. Typically, one does not have for the population from which the sample of acceptors come an empirical age schedule of fertility that may be interpreted as reflecting freedom from birth control. For purposes of improvising such a schedule, reliance is placed on a two-parameter model of marital fertility described elsewhere[11] wherein:

$$r(x) = Mn(x)e^{-mv(x)}$$

where $r(x)$ = age-specific marital fertility rate of the age group from x to $x+4$;

$n(x)$ = natural fertility rate of the age group from x to $x = 4$, with values of 0.450, 0.431, 0.395, 0.322, 0.167 and 0.024 for $x = 20, 25, \ldots, 45$;

$v(x)$ = fixed coefficients constraining the decline of marital fertility with advancing age, $v(x) = 0.000, -0.279, -0.677, -1.042, -1.414$ and -1.671, for $x = 20, 25, \ldots, 45$;

M = scale parameter;

m = parameter controlling the intensity of effect from the $v(x)$ coefficients and indexing the extent of birth regulation.

To represent natural fertility m is set equal to zero, which renders $e^{-mv(x)}$ equal to one, and the problem of estimation then is reduced to finding a suitable value of M. The mechanics of this derivation are deferred until the next section. For the present, it is assumed that the age schedule $m(x)$ is available.

Step two

The second step is to adjust $m(x)$ so as to reflect the fecundity differences between users and all wives of the same age group. Users are apt to be more fecund than wives of the same age drawn at random if only because those who have reason to believe themselves seriously subfecund or sterile are less likely to accept a contraceptive than those who have no cause to doubt their fecundity. Let ${}_5F_x$ denote fecund years lived by women during ages from x to $x+4$ out of 100,000 surviving women, taken from the fecundity decrement table of Pittenger.[12] The corresponding average proportion non-sterile during these ages is designated by ${}_5\bar{S}_x = {}_5F_x/500{,}000$. Values of ${}_5\bar{S}_x$ and its complement ${}_5S_x$ are given in columns 5–12 of table 73.

It is assumed that so long as they are non-sterile, users and wives of the same age drawn at random share the same potential fertility and also the same conditional probabilities of becoming secondarily sterile. However, by virtue of shorter open intervals since last birth, IUD acceptors have a lower proportion sterile than coeval women, i.e., women of the same age or age group, drawn at random. Indeed, among acceptors aged from x to $x+4$ whose open interval since last birth is k years, the proportion expected to be non-sterile is ${}_5\bar{S}_x/{}_5\bar{S}_{x-k}$; whereas for women aged from x to $x+4$ taken at random it is ${}_5\bar{S}_x$. Thus, the potential fertility of the acceptors may be estimated as the potential fertility of like aged wives taken at random divided by ${}_5\bar{S}_{x-k}$ for $x = 20, 25, \ldots, 45$ and $k = 0, 1, 2, 5$.

Steps three and four

Assume for steps three and four that the monthly proportions $R(v)$ continuing the device have been calculated from a life-table analysis. To estimate average wearing time R (in years), one employs the model proposed by Mauldin and his colleagues:[13]

$$R(v) = ae^{-vr/12}$$

where a is the proportion of acceptors not discontinuing right away and $r/12$ is the monthly risk (and r the annual risk) of discontinuing among those not discontinuing right away. Estimates of the two parameters, $\hat{a}$ and $\hat{r}$, may be derived either by passing to natural logarithms so that the model becomes $\log n\ R(v) = \ln a - vr/12$ and then using a least-squares argument or else utilizing a maximum likelihood procedure found in Kulkarni and Potter.[14] Mean retention is given by $R = \hat{a}/\hat{r}$. Wearing-time may also be partitioned into annual subsegments $R(k-1, k)$ during the kth ordinal year from insertion:

$$R(k-1, k) = \frac{\hat{a}}{\hat{r}}\left(e^{-\hat{r}(k-1)} - e^{-\hat{r}k}\right)$$

$k = 1, 2, \ldots.$

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[11] Ansley J. Coale, "Age patterns of marriage", *Population Studies*, vol. XXV (July 1971), pp. 193–214; Robert G. Potter, "Contraceptive impact over several generations", in T. N. E. Greville, ed., *Population Dynamics* (New York, Academic Press, 1972), p. 140; Ansley J. Coale and T. James Trussell, "Model fertility schedules: variations in the age structures of childbearing in human populations", *Population Index*, vol. 40, No. 2 (April 1974), pp. 185–203; Ansley J. Coale, "Erratum", *Population Index*, vol. 41, No. 4 (October 1975), p. 572.

[12] Donald B. Pittenger, "An exponential model of female sterility", *Demography*, vol. 10, No. 1 (February 1973), p. 119, table 3.

[13] W. P. Mauldin, D. Nortman and F. F. Stephan, *loc. cit.*

[14] P. M. Kulkarni and R. G. Potter, "Extrapolation of IUD continuation curves", *Population Studies*, vol. XXX (July 1976), pp. 353–368.

TABLE 73. COEFFICIENTS FOR CONVERTING THE AGE SCHEDULE OF NATURAL FERTILITY $m(x)$ INTO THE AGE SCHEDULE OF GROSS POTENTIAL FERTILITY $m^*(x, x, k)$

Age range[a] (from x to $x+4$)	Fecund years lived during interval from x to $x+1$ ${}_5F_x$[b]				Average proportion non-sterile ${}_5\overline{S}_x$[c]				Average proportion sterile ${}_5\overline{S}_x$[d]				Adjustment factor $1/{}_5\overline{S}_{x-k}$ for converting $m(x)$ schedule into $m^*(x, x, k)$ schedule			
	K = 0 (1)	K = 1 (2)	K = 2 (3)	K = 5 (4)	K = 0 (5)	K = 1 (6)	K = 2 (7)	K = 5 (8)	K = 0 (9)	K = 1 (10)	K = 2 (11)	K = 5 (12)	K = 0 (13)	K = 1 (14)	K = 2 (15)	K = 5 (16)
20–24	4.86071	4.87153	4.88022	4.89717	0.972	0.974	0.976	0.979	0.028	0.026	0.024	0.021	1.029	1.026	1.025	1.021
25–29	4.75061	4.78316	4.80932	4.86071	0.950	0.957	0.962	0.972	0.050	0.043	0.038	0.028	1.052	1.045	1.040	1.029
30–34	4.42802	4.52179	4.59815	4.75061	0.886	0.904	0.920	0.950	0.114	0.096	0.080	0.050	1.129	1.106	1.087	1.052
35–39	3.56799	3.80526	4.00609	4.42802	0.714	0.761	0.801	0.886	0.286	0.239	0.199	0.114	1.401	1.314	1.248	1.129
40–44	1.83776	2.23941	2.62279	3.56799	0.368	0.448	0.525	0.714	0.632	0.552	0.475	0.285	2.717	2.233	1.906	1.401
45–49	0.24478	0.44470	0.71784	1.83776	0.049	0.089	0.144	0.368	0.951	0.911	0.856	0.632	20.408	11.244	6.965	2.717

SOURCE: Donald B. Pittenger, "An exponential model of female sterility", *Demography*, vol. 10, No. 1 (February 1973), p. 119, table 3.

[a] Ages from x to $x+4$ at last birthday which in his fecundity decrement table (table 3) Pittenger construes as exact ages $x+0.5$ to $x+4.5$.

[b] Values for ${}_5F_x$ computed from Pittenger's fecundity decrement table (table 3).

[c] Values for ${}_5S_x$ computed from the Fx values of Pittenger's fecundity decrement table (table 3) using ${}_5S_x = (F_{x+0.5} + F_{x+1.5} + \dots + F_{x+4.5})/500{,}000$.

[d] ${}_5S_x = 1 - {}_5S_x$.

Step five

The extent of overlap between contraceptive practice and post-partum anovulation depends upon the interaction of a number of factors: lengths of post-partum anovulation; lengths of open interval from last pregnancy termination to acceptance; the continuation with which the contraceptive is practised; and the proportion of pregnancies ending in a live birth (since overlap will be small after a stillbirth or abortion). Two additional qualifying factors are, first, that users tend to be selected for longer than average anovulation than non-users; and secondly, that the proportion of contraceptive segments associated with non-zero overlap is affected by the intensity of competition between pregnancy and initiation of contraception whenever contraception is deferred until after end of post-partum amenorrhoea.

One can hardly be intuitive about so complex a process. Direct data on overlap are virtually never available. Table 74, which furnishes estimates of overlap following a birth expressed as proportions of total retention time, may assist in deciding how important in particular cases the allowance for overlap is. Table 75 expresses overlap in absolute numbers of months A. (For algebraic details, see section F.1.) In the two tables, it is assumed that, among women selected at random, post-partum anovulation varies according to a Pascal distribution with parameters $(2, 2/h)$, where h denotes mean length of anovulation; that the conditional monthly probability of initiating contraception after a birth Pi (if not already pregnant) is π; and thus, but for the competition of pregnancy, the open interval from birth to acceptance would follow a geometrical distribution with a mean of $1/\pi$; that contraception of effectiveness 1 is subject to a monthly risk of discontinuation $r/12$ (among those not discontinuing right away) and therefore has an expected retention span of $12/r$ months; and that fecundability f following anovulation equals 0.20. One enters the tables with a choice of h, $r/12$ and π. To allow for a proportion a of pregnancies ending in abortion or stillbirth and a fraction of acceptors $1 - a$ discontinuing right away, multiply the results of tables 74 and 75 by the factor $(1 - a)a$.

TABLE 74. PROPORTION OF RETENTION TIME OVERLAPPING WITH ANOVULATION AS A FUNCTION OF EXPECTED LENGTH OF ANOVULATION, MONTHLY DISCONTINUATION RATE AND MONTHLY PROBABILITY OF INITIATING CONTRACEPTION[a]

Mean length of anovulation	*Monthly discontinuation rate*[a]	*Conditional monthly probability of initiating contraception*			
		1.0	*0.5*	*0.2*	*0.1*
Three months	0.05612	0.16	0.11	0.06	0.03
	0.02846	0.08	0.06	0.03	0.02
	0.01191	0.04	0.03	0.01	0.01
Eight months	0.05612	0.35	0.31	0.23	0.17
	0.02846	0.20	0.18	0.13	0.10
	0.01191	0.09	0.08	0.06	0.04
Twelve months	0.05612	0.46	0.42	0.35	0.28
	0.02846	0.28	0.26	0.21	0.17
	0.01191	0.13	0.12	0.10	0.08

SOURCE: Table values are based on formula given in section F.1 of this chapter.
[a] Rates correspond to 25, 50 and 75 per cent continuing two years or longer.

TABLE 75. MONTHS OF OVERLAP BETWEEN ANOVULATION AND CONTRACEPTION AS A FUNCTION OF EXPECTED LENGTH OF ANOVULATION, MONTHLY DISCONTINUATION RATE AND MONTHLY PROBABILITY OF INITIATING CONTRACEPTION

Mean length of anovulation	*Monthly discontinuation rate*[a]	*Conditional monthly probability of initiating contraception*			
		1.0	*0.5*	*0.2*	*0.1*
Three months	0.05612	3	2	1	1
	0.02846	3	2	1	1
	0.01191	3	2	1	1
Eight months	0.05612	6	6	4	3
	0.02846	7	6	5	3
	0.01191	8	7	5	4
Twelve months	0.05612	8	8	6	5
	0.02846	10	9	7	6
	0.01191	11	10	8	7

SOURCE: Table values are based on formula given in section F.1 of this chapter.
[a] Rates correspond to 25, 50 and 75 per cent continuing two years or longer.

Step six

With regard to the penalty for accidental pregnancy, it is argued elsewhere[15] that if a contraceptive is 98 per cent effective, say, meaning that it is reducing a woman's fecundability to 2 per cent of natural value, then an appropriate penalty for accidental pregnancy is 2 per cent of total average retention time. Stated more abstractly, if a contraceptive has an effectiveness e, $0 \leq e \leq 1$, then the penalty for accidental pregnancy as a proportion of retention time should be $1-e$. In ordinary circumstances the value of $1-e$ for IUD, oral contraception or sterilization is well below 0.05 and the correction may be ignored without major distortion.

Another approach leading to an individualized adjustment, PW, becomes possible when the results are available from a multiple-decrement life-table analysis of continuation in which coded reasons for discontinuation include accidental pregnancy. This approach is discussed in the next section.

It remains to consider how the estimates in the steps from one to six may be combined into measures of corrected protection time and gross births averted.

Step seven

For a given group of acceptors aged from x to $x+4$, corresponding protection time (in years) is given by $I - R - \frac{A}{12} - \frac{PW}{12}$, $\left(R - \frac{A}{12}\right)\left(1-e\right)$, or simply $R - \frac{A}{12}$ depending upon the way in which the penalty for accidental pregnancy is handled. If the penalty is ignored, then woman-years of protection during the first and subsequent years after acceptance are given by:

$$I(0, 1) = \frac{a}{r}\left(1 - e^{-r}\right) - \frac{A}{12}$$

$$I(i-1, i) = \frac{ae^{-r(i-1)}}{r}\left(1 - e^{-r}\right) \qquad i = 2, 3, \ldots.$$

If PW is non-zero, then one must adjust r downward to represent the penalty for accidental pregnancy as it affects each annual segment, which is readily done. One wants to change parameter r to r^*, such that:

$$1/r^* = 1/r - PW/12, \text{ or } r^* = \frac{r}{1 - rPW/12}$$

Then $I(0, 1) = \frac{a}{r^*}\left(1 - e^{-r^*}\right) - A/12$

$$I(i-1, i) = \frac{ae^{-r^*(i-1)}}{r^*}\left(1 - e^{-r^*}\right) \qquad i = 2, 3, \ldots.$$

Step eight

The simplest measures of gross births averted among acceptors aged from x to $x+4$ is corrected protection time I times potential fertility taken at the mean age during protection, in symbols:

$$B = I \cdot m^*(x, x + 0.75 + 0.5a/r^*, k)$$

Such a crude measure is defensible only when the ages of acceptors are below 35 years and r^* is high enough to give $a/r^* < 5$. Under these conditions, potential fertility is not changing markedly during the retention time of most acceptors. For older acceptors subject to rapid changes of potential fertility, or when continuation is long owing to a low r^*-value, a more refined measure is needed. Women aged from x to $x+4$ at acceptance average from $x+i+0.5$ to $x+4+i+0.5$ years during ordinal year $(i, i+1)$ after acceptance. Moreover, the effect of contraception upon fertility is delayed nine months by pregnancy. Hence, one may put:

$$B = \sum_{i=0}^{q} I(i, i+1)m^*(x, x+i+1.25, k),$$

where the summation is extended until at $i = g$, the $I(\,)m^*(\,)$ term falls below some predesignated criterion value such as 0.01. Respecting $m^*(x, x+i+1.25, k)$, if x_1 and x_2 are the two multiples of 5 which bracket $x+i+1.25 = j$, then by linear interpolation:

$$m^*(x, x+j, k) = \frac{5-(x+j-x_1)}{5} m^*(x, x_1, k) + \frac{5-(x_2-x-j)}{5} \cdot m^*(x, x_2, k)$$

Step nine

Before turning to data problems and strategems to cope with them, it is worth assessing the attrition on protection time resultant from marital dissolution by death of a spouse. Other than protection by sterilization, mortality and divorce are the two major attritions. The assumptions underlying tables 76 and 77 are that mortality conforms to the Coale-Demeny[16] West model life tables, that husbands and wives have independent risks, that husbands are a constant D years older than wives and that continuation of contraception varies according to the negative exponential function with parameter r. In the case of sterilization, r may be taken as zero. Accidental pregnancies and overlap with anovulation are ignored. Algebraic details are given in section F.2 of this chapter. Table 76 presents proportionate reductions of retention time as the result of spouse mortality; table 77 shows the corresponding proportionate reductions in gross births averted. The latter reductions are appreciably smaller than the former because mortality is highest at the ages when potential fertility is low. The two tables are entered with a stipulated life expectancy for females, an age of wife at the beginning of contraception, monthly discontinuation rate and seniority of husband. The implications of tables 76 and 77, as well as of the preceding tables, are addressed in the next section.

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[15] R. G. Potter, "Contraceptive impact over several generations", *loc. cit.*

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

TABLE 76. PROPORTION OF RETENTION TIME LOST DUE TO DEATH OF EITHER SPOUSE AS A FUNCTION OF LIFE EXPECTANCY OF WIFE, SENIORITY OF HUSBAND, WIFE'S AGE AT BEGINNING OF CONTRACEPTION AND MONTHLY DISCONTINUATION RATE

Life expectancy of females at birth (years)	Seniority of husband (years)	Wife aged 25 at beginning of contraception: Discontinuation rate 0.05612	0.02846	0.00000	Wife aged 35 at beginning of contraception: Discontinuation rate 0.05612	0.02846	0.00000
70	0	0.006	0.018	0.201	0.009	0.026	0.118
	5	0.007	0.020	0.233	0.012	0.033	0.147
	10	0.008	0.024	0.282	0.015	0.044	0.191
60	0	0.014	0.039	0.340	0.019	0.050	0.203
	5	0.015	0.042	0.369	0.022	0.058	0.234
	10	0.017	0.048	0.408	0.026	0.070	0.276
50	0	0.023	0.062	0.450	0.030	0.076	0.284
	5	0.025	0.067	0.474	0.034	0.084	0.314
	10	0.027	0.073	0.503	0.039	0.096	0.351

SOURCE: Table values are based on formula given in section F.2 of this chapter.

TABLE 77. PROPORTIONAL REDUCTION IN GROSS BIRTHS AVERTED RESULTING FROM DEATH OF EITHER SPOUSE AS A FUNCTION OF LIFE EXPECTANCY OF WIFE, SENIORITY OF HUSBAND, WIFE'S AGE AT BEGINNING OF CONTRACEPTION AND MONTHLY DISCONTINUATION RATE

Life expectancy of females at birth (years)	Seniority of husband (years)	Wife aged 25 at beginning of contraception: Discontinuation rate 0.05612	0.02846	0.00000	Wife aged 35 at beginning of contraception: Discontinuation rate 0.05612	0.02846	0.00000
70	0	0.006	0.015	0.088	0.008	0.014	0.039
	5	0.006	0.017	0.101	0.009	0.018	0.049
	10	0.008	0.020	0.124	0.012	0.024	0.064
60	0	0.013	0.034	0.172	0.016	0.029	0.074
	5	0.014	0.036	0.188	0.018	0.034	0.086
	10	0.016	0.041	0.212	0.022	0.041	0.103
50	0	0.022	0.054	0.253	0.025	0.046	0.112
	5	0.024	0.058	0.270	0.028	0.052	0.124
	10	0.026	0.064	0.294	0.032	0.059	0.142

SOURCE: Table values are based on formula given in section F.2 of this chapter.

C. USE OF METHOD

This section covers some procedural details omitted in the previous section but mainly considers stratagems for dealing with deficient data.

1. *Procedural details and problems of deficient data*

Age schedule of natural fertility

Ideally, one has at hand an empirical age schedule of marital fertility that can be interpreted as reflecting the absence of birth control. If ratios $(n(20+5i)-m(20+5i))/n(20+5i)$, $i = 0, 1, \ldots, 5$, are computed – as shown below in column (3) of table 79 – and they show a rapid and marked decline with advancing age, then the presumption of widely diffused birth control is plain. If the decline is gradual enough to create uncertainty, then a more formal test is to fit the two-parameter model of marital fertility[17] and examine whether the derived m-value is close to zero. The listing of a computer program designed to conduct this test is furnished in section F.3. Application of the computer program to an extensive collection of marital fertility schedules[18] produced 13 m-values in the range of from -0.20 to 0.29, 9 of them from 0.30 to 0.89, and 30 exceeding 0.90. Any m less than 0.30 implies that marital fertility is being only secondarily affected by deliberate birth control.

If little spacing effort may be assumed, then one can accept the observed marital birth rate $m(20)$ for ages 20–24 as approximating natural fertility for those ages even if older ages are affected by efforts to limit family size. Then one may set $\hat{M} = m(20)/n(20)$ and calculate $m(20+5i)$ as $\hat{M}n(20+5i)$ for $i = 1, 2, \ldots, 5$, with the $n(20+5i)$ coming from Coale's model described earlier.

If the observed age schedule of marital fertility is affected by birth control at all ages, one can contrive an estimate of $m(20)$ as follows. Assume that the average proportion non-sterile during ages 20–24 is ${}_5\bar{S}_{20} = 0.972$, calculated on the basis of data from Pittenger.[19] Postulate

[17] A. J. Coale and T. J. Trussell, *loc. cit.*

[18] *Demographic Yearbook 1965* (United Nations publication, Sales No.66.XIII.1), "Natality statistics", pp. 568–573.

[19] *Loc. cit.*, p. 119.

the mean natural birth interval b to be expected of non-sterile couples aged 20–24 guided by whatever fragmentary information is available about lactation practices, nutrition levels and rates of spontaneous foetal wastage. The three standards found in table 78 are no more than suggestive. The "optimistic" (i.e., optimistically high fertility) standard of 20 months presupposes no breast-feeding, good nutrition and rates of spontaneous abortion and stillbirth of 0.18 and 0.02; the intermediate standard of 27 months assumes the same conditions except that breast-feeding replaces bottle-feeding. The conservative estimate of 34 months is predicated on lactation, malnutrition and rates of abortion and stillbirth of 0.20 and 0.05. Further details about table 78 are given in section F.3. Given an estimate of b (in months), then $m(20) = 0.972(12.000)/b$; $\hat{M} = m(20)/0.460$; and with $m = 0$, $m(20+5i) = \hat{M}n(20+5i)$.

TABLE 78. DECOMPOSITION OF THREE STANDARD BIRTH INTERVALS RELEVANT TO AGES 20–24 YEARS UNDER CONDITIONS OF NATURAL FERTILITY[a]

	Potential fertility		
Component (months)	*High*	*Intermediate*	*Low*
Pregnancy leading to live birth . . .	9	9	9
Post-partum anovulation	3	8	11
Menstruating interval.	6	8	10
Months added by foetal deaths. . .	2	2	4
Birth interval	20	27	34

[a] For details, see section F.3 of this chapter.

Adjustment of age schedule of natural fertility

Two extremes are always available in adjusting the age schedule of natural fertility. To posit no difference in potential fertility between acceptors and coeval women selected at random is to be ultra-conservative and to bias downward to a degree that increases with advancing age the estimate of acceptors' gross potential fertility. At the other extreme, one may postulate that all acceptors are non-sterile at acceptance, implying a zero open interval (compare column (13) of table 73).

Given information about open intervals from last birth to acceptance, one can establish an intermediate adjustment factor either by referring to the latter columns of table 73 or by using the formula:

$$m^*(x, x, k) = m(x)/\bar{S}(x+2.5-k)$$

where $\bar{S}(x+2.5-k)$ is derived by linear interpolating between the relevant values of ${}_5\bar{S}_x$ in columns (5)–(8) of table 73.

Analysis of continuation

It matters which causes of termination are included in the life-table analysis of continuation. Ideally, the coded causes include divorce and death of either spouse. Otherwise, protection time is being over-estimated, though the bias is often small, as tables 76 and 77 have indicated with respect to mortality. The inclusion of menopause as a reason for discontinuation leads to a problem of double-counting because these self-diagnosed onsets of sterility are being allowed to depress both the measures of continuation and of potential fertility.

Extrapolation of continuation curve

If the period of observation is short, say under two years, and if the monthly conditional probabilities of discontinuation show a steep decline, it is likely to mean that the sample of women is highly heterogenous with respect to their risks of discontinuation. Under these conditions, use of the modified negative exponential function to extrapolate the continuation curve will often lead to an underestimate of average retention time. Other, more elaborate curves exist that by taking heterogeneity explicitly into account lead to less biased estimates.[20]

Calculation of overlap

From tables 74 and 75 it is evident that the proportionate overlap between retention and amenorrhoea is enhanced by longer anovulation, shorter open intervals and higher discontinuation not to mention lower rates of foetal loss. Other factors constant, the absolute magnitude of overlap A is increased by higher continuation. As already conceded, direct data on overlap are virtually never available. However, given an estimate of the monthly discontinuation rate, then with reference to table 75 even fragmentary information about the distribution of open intervals and amenorrhoea lengths should serve to narrow the range of uncertainty about the proper allowance A for overlap.

Penalty for pregnancy

Usually, the penalty for accidental pregnancy can be ignored with little distortion when the method is IUD, oral contraception or sterilization. It becomes important chiefly with respect to non-medical contraceptives characterized by an effectiveness well below 1.0. An individualized estimate of P, the proportion of contraceptive segments ending in accidental pregnancy, becomes possible when the life-table analysis of continuation includes accidental pregnancy as a reason for discontinuation. Suppose that for a given body of data, the longest duration for which a reliable life-table rate may be calculated is y months and that for this duration cumulative failures have a ratio p to total terminations. Crudely equating $P = p$ produces over-estimates or underestimates depending upon circumstances. If the span of y months is short and the contraceptive overlap extensive, then p may seriously underestimate P. Contrariwise, if the acceptors are in their late thirties or older, then p is likely to over-estimate P, perhaps grossly.

Knowledge of P is not enough; it is also necessary to postulate a mean number of months W required per conception in the absence of contraception. Lacking any direct information about W, one may attempt to derive it

[20] For additional details about this refinement, see P. M. Kulkarni and R. G. Potter, *loc. cit.*

as a residual in a birth interval calculation provided an estimate of mean post-partum anovulation is available. Alternatively, one might set W equal to 6, 7, 8, 9, 10 and 11 months, respectively, for ages 20–24, 25–29, . . . , 45–49; or more conservatively to values of 8, 9, 10, 12, 15 and 20. Comparative studies of natural fertility have indicated that, except in special circumstances such as rife venereal disease, the W component of birth intervals is not highly variable from one population to another, at least for ages below 35 years.

D. Application of method

Basic procedures are now numerically illustrated for age group 25–29 years. In the following section, results from four age groups are compared.

1. *Data available*

Suppose that one is dealing with a predominantly rural, developing country (Country C) which boasts a rising level of living and an expanding scope of birth control. Since its national family planning programme has emphasized IUDs, the goal is to estimate gross births averted per segment of IUD. It is preferred that estimates are on the conservative rather than the optimistic side.

The data situation is mixed. The earliest reliable age schedule of marital fertility, pertaining to 1962, implies that there is little practice of birth control at ages 20–24, but that the incidence is progressively greater at succeeding ages. Any direct estimates of mean menstruating intervals W or mean lengths of post-partum anovulation are lacking. However, ancillary information suggests that breast-feeding for a year or more is still the predominant infant-feeding pattern, that nutrition is not grossly deficient and that there is no cause to suspect abnormally high levels of spontaneous foetal wastage. Available from a large-scale follow-up study of IUD acceptors are life-table proportions continuing for durations up to 24 months. Coded causes of discontinuation encompass pregnancy, expulsions and removals, the latter including removals for such reasons as marital dissolution. Information collected at time of insertion indicates a median open interval from last birth to acceptance of slightly over one year.

2. *Steps of analysis*

Step A

The derivation of age schedule $m(x)$ is summarized in table 79. The observed 1962 rates, expressed as annual births per married woman, are given in column (1). Their ratios to the standard ratios from Coale's model (column (3)) hint at the presence of regulatory practices for ages over 25 years. Interpreting the rate of 0.452 as approximating natural fertility for age group 20–24 leads to the estimate: $\hat{M} = 0.452/0.460 = 0.983$, which, multiplied by the standard rates of column (2), yields the $m(x)$ values enumerated in column (4).

Had the observed rate for age group 20–24 implied fertility regulation, it would have been appropriate to borrow from table 78, $b = 27$, as this expected birth interval is at least broadly compatible with the suppositions stated above about infant feeding, nutrition and foetal wastage. Succeeding calculations would have been $m(20) = (0.972)(12/b)$; and $\hat{M} = m(20)/0.460$; and $m(20+5i) = \hat{M}n(20+5i)$.

Step B

To convert $m(x)$ into $m^*(x, x, k)$, the conservative value of $k = 2$ (in years) is adopted which yields from table 73 the adjustment factor 1.040. The resultant estimates of gross potential fertility $m^*(25, 25+5i, 2)$ for acceptors aged 25–29 are given in column (5) of table 79.

Steps C and D

Applying a life-table analysis to women aged 25–29 who report limiting family size as their motive for accepting an IUD yields a set of proportions $R(v)$ retaining the device for $v = 1, 2, \ldots, 24$ months or longer, found in column (1) of table 80. By passing to natural logarithms, the relationship $R(v) = ae^{-rv/12}$ is converted into the linear equation $\log n\, R(v) = \log n\, a - rv/12$. A least-squares argument (see table 80) yields $\hat{a} = 0.9133$ and $\hat{r}/12 = 0.0340$. Exactly the same derivation of a and r is found in the auxiliary computer program CONTINUE, mentioned in chapter III of this *Manual*. Predicted proportions retaining of $\hat{R}(v)$, namely, $0.9133e^{0.0340v}$, are shown in column (3) of table 81. Incidentally, the fact that the conditional monthly probabilities $q(v)$ of discontinuation (column (2) of table 81) decline so rapidly during the initial months of retention means the possibility of appreciable heterogeneity of termination risk among acceptors and the attendant underestimation of mean protection time when continuation is extrapolated by means of the modified negative exponential curve.

Step E

To approximate A, preferably with an upward rather than downward bias by reference to table 75, it is posited that the conditional monthly probability of initiating contraception after childbirth is $\pi = 0.1$ and that mean post-partum amenorrhoea averages 10 months. This combined with a monthly discontinuation rate already estimated as 0.0340 suggests a value of A nearer four than seven months when the last pregnancy before the insertion ends in a live birth. Allowance for other pregnancy outcomes and for immediate discontinuations entails a deflation factor of $(1-a)a = 0.8(0.9) = 0.72$. Hence, A may be put at four months, or more conservatively, at five months.

Step F

The next step is to estimate P, the proportion of IUD segments ending in accidental pregnancy, and W, mean menstruating interval per conception. From a more detailed life-table analysis of acceptors aged 25–29 it is learned that at the end of 12 months, 0.067 have terminated for reason of accidental pregnancy *versus* 0.463 for all reasons, allowing the estimate $P = 0.067/0.463 = 0.145$. To check for bias, it is noted from a multiple-decrement life-table analysis of the entire sample that the conditional probabilities of terminating for reason of accidental pregnancy within six months if still wearing the device up to the beginning of the interval are 0.023, 0.028, 0.031 and 0.029 for months 1–6, 7–12, 13–18 and 19–24. Plainly there is enough overlap with amenorrhoea during the initial 12 months so that $P = 0.145$ is more likely an under-estimation than an over-estimation.

As concerns W, from $m(20) = 0.972(12/b) = 0.452$, obtained above, $b = 25.8$, close to the intermediate expected birth interval of table 78, one of the components of which was $W = 8$. But whether $W = 6$ or $W = 10$, PW remains under two months, a minor adjustment, i.e., $PW = 2/12 = 0.1667$.

TABLE 79. DERIVATION OF AGE SCHEDULES OF MARITAL FERTILITY $m(x)$ AND GROSS POTENTIAL FERTILITY m^* (25, 25 + 5i, 2)

Age group from x to $x+4$	Age index i[a]	Observed 1962 marital fertility (annual births per married woman) (1)	Coale's model fertility $n(25+5i)$ (2)	$\hat{M}$ $\frac{(1)}{(2)}$ (2a)	Deviations $\frac{(2)-(1)}{(2)}$ (3)	Estimated marital fertility $m(x)$ $m(25+5i)$[b] (2) X 0.983 (4)	Gross potential fertility for acceptors aged 25–29 $m^*(25, 25+5i, 2)$[c] (5)
20–24	−1	0.452	0.460	0.983	0.017	0.452	–
25–29	0	0.372	0.431	0.863	0.137	0.424	0.441
30–34	1	0.210	0.395	0.532	0.468	0.388	0.404
35–39	2	0.107	0.322	0.332	0.668	0.317	0.330
40–44	3	0.053	0.167	0.317	0.683	0.164	0.171
45–49	4	0.009	0.024	0.375	0.625	0.024	0.025

[a] $x = 25 + 5i$, or $i = (x - 25)/5$.

[b] $m(25+5i) = \hat{M}n(25+5i)$, with $\hat{M} = 0.452/0.460 = 0.983$.

[c] $m^*(25, 25+5i, 2) = 1.04m(x+5i)$.

TABLE 80. THE MODIFIED NEGATIVE EXPONENTIAL FUNCTION OF MAULDIN AND COLLEAGUES, WITH PARAMETERS $\hat{a}$ AND $\hat{r}$, FITTED TO LIFE-TABLE PROPORTIONS RETAINING THEIR FIRST INTRA-UTERINE DEVICE

Duration v (months)	Life-table proportions retaining $R(v)$ (1)	log n $R(v)$ (2)	log n $R(v)v$ (3)	v^2 (4)
1	0.923	−0.080	−0.080	1
2	0.873	−0.136	−0.272	4
3	0.832	−0.184	−0.552	9
4	0.792	−0.233	−0.933	16
5	0.763	−0.270	−1.352	25
6	0.733	−0.311	−1.864	36
7	0.714	−0.337	−2.358	49
8	0.690	−0.371	−2.969	64
9	0.667	−0.405	−3.645	81
10	0.644	−0.440	−4.401	100
11	0.619	−0.480	−5.276	121
12	0.599	−0.512	−6.150	144
13	0.579	−0.546	−7.104	169
14	0.564	−0.573	−8.018	196
15	0.544	−0.609	−9.132	225
16	0.524	−0.646	−10.340	256
17	0.510	−0.673	−11.447	289
18	0.498	−0.697	−12.549	324
19	0.480	−0.734	−13.945	361
20	0.464	−0.768	−15.357	400
21	0.452	−0.794	−16.676	441
22	0.438	−0.826	−18.162	484
23	0.422	−0.863	−19.843	529
24	0.408	−0.896	−21.516	576
TOTAL 300	14.732	−12.384	−193.941	4 900

$$\frac{\hat{r}}{12} = \frac{\Sigma \log n\, R(v)v - \dfrac{\Sigma v(\log n\, R(v))}{24}}{\Sigma v^2 - \dfrac{(\Sigma v)^2}{24}};\ \hat{r} = -0.4084$$

$$\log n\, \hat{a} = \frac{\Sigma \log n\, R(v)}{24} - \frac{\hat{r}}{12}\frac{\Sigma v}{24};\ \hat{a} = e \log n\, \hat{a} = 0.9133$$

SOURCE: W. Parker Mauldin, Dorothy Nortman and Frederick F. Stephan, "Retention of IUD's: an international comparison", *Studies in Family Planning*, No. 18 (April 1967), pp. 1–12.

TABLE 81. LIFE-TABLE PROPORTIONS RETAINING, CONDITIONAL PROBABILITIES OF DISCONTINUING AND PREDICTED PROPORTIONS RETAINING

Duration v (months)	Life-table proportions retaining $R(v)$[a] (1)	Conditional monthly probability of discontinuing $q(v)$[b] (2)	Predicted proportions retaining $\hat{R}(v)$[c] (3)	Derivations $R(v)-\hat{R}(v)$ (4)
1	0.923	0.077	0.885	0.038
2	0.873	0.054	0.853	0.020
3	0.832	0.047	0.825	0.007
4	0.792	0.048	0.797	−0.005
5	0.763	0.037	0.771	−0.008
6	0.733	0.039	0.745	−0.012
7	0.714	0.026	0.720	−0.006
8	0.690	0.034	0.696	−0.006
9	0.667	0.033	0.673	−0.006
10	0.644	0.034	0.650	−0.006
11	0.619	0.039	0.628	−0.009
12	0.599	0.032	0.607	−0.008
13	0.579	0.033	0.587	−0.008
14	0.564	0.026	0.567	−0.003
15	0.544	0.035	0.548	−0.004
16	0.524	0.037	0.530	−0.006
17	0.510	0.027	0.512	−0.002
18	0.498	0.024	0.495	0.003
19	0.480	0.036	0.479	0.001
20	0.464	0.033	0.463	0.001
21	0.452	0.026	0.447	0.005
22	0.438	0.031	0.432	0.006
23	0.422	0.037	0.418	0.004
24	0.408	0.033	0.404	0.004

[a] Values taken from column (1) of table 80.
[b] $q(v) = (R(v-1)-R(v))/R(v-1)$.
[c] $\hat{R}(v) = \hat{a}e^{-\hat{v}r/12}$, $\hat{a} = 0.9133$ and $\hat{r}/12 = 0.0340$ derived from table 80.

Step G

All necessary quantities having been estimated, the rest is straightforward algebra. Uncorrected mean retention time (in years) is $R = \hat{a}/\hat{r} = 0.9133/0.4080 = 2.2385$. With adjustments imposed, effective protection is:

$$I = R - A/12 - PW/12 = 2.2385 - 0.4167 - 0.1667 = 1.6551$$

For purposes of partitioning this protection time into annual segments, one needs

$$r^* = \frac{\hat{r}}{1-\hat{r}PW/12} = \frac{0.408}{0.932} = 0.4378$$

The more precise of the two formulae for births averted B per segment of IUD use is $\sum_{i=0}^{z} m^*(25, 25+i+1.25, 2)\, I(i, i+1)$, where z is that smallest integer giving $I(i, i+1)$ or $m^*(25, 25+i+1.25, 2) < 0.01$. The set $I(i, i+1)$ forms a geometrical series with

$$I(0, 1) = \frac{\hat{a}}{r^*}\left(1-e^{-r^*}\right) - \frac{A}{12} = 0.3228$$

$$I(1, 2) = \frac{\hat{a}}{r^*}e^{-r^*}\left(1-e^{-r^*}\right) = 0.4774$$

and succeeding terms computed recursively by

$$I(i, i+1) = I(i-1, i)e^{-r^*} = I(i-1, i)0.6455$$

until reaching $I(10, 11) = 0.0093$, less than the criterion 0.01.

The $m^*(25, 25+i+1.25, 2)$ terms, $i = 0, 1, \ldots, 10$, are derived by linear interpolation based on the values $m^*(25, 25+5i, 2)$ found in column (4) of table 79. For example:

$$m^*(25, 25+7+1.25, 2) = m^*(25, 33.5, 2) = w_1 m^*(25, 30, 2) + w_2 m^*(25, 35, 2)$$

with $w_1 = \dfrac{5-(33.5-30.0)}{5}$ and $w_2 = 1 - w_1$

to give a value of $0.35(0.404) + 0.65(0.330) = 0.3550$. The calculation of B is detailed in table 82. Note that despite the truncation of $I(i, i+1)$ terms at $i = 10$, their sum 1.6535 is close to the value of $I = 1.6551$.

The value of 0.6831 births averted, derived in table 82, may be compared with the short-cut calculation:

$$\begin{aligned} B &= I\cdot m^*(25, 25+0.75+0.50a/r^*, 2) \\ &= (1.6551)m^*(25, 26.79, 2) \\ &= (1.6551)m^*(25, 26.75, 2) \\ &= 0.7090 \end{aligned}$$

with $m^*(25, 26.75, 2) = 0.65(0.441) + 0.35(0.404) = 0.4284$. Owing mainly to the non-linearity of $m^*(25, 25+j, 2)$ over ages $25+j$, this second estimate of B carries a small upward bias.

TABLE 82. COMPUTATION OF GROSS BIRTHS AVERTED PER SEGMENT OF INTRA-UTERINE DEVICE

Duration i	Fractional years protected $I(i, i+1)$[a] (1)	Age j[b] (2)	Weighting coefficient w_1[c] (3)	Duration-specific potential fertility $m^*(25, j, 2)$[d] (4)	Duration-specific births averted (1).(4) (5)
0	0.3228	26.25	0.75	0.4320	0.1394
1	0.4774	27.25	0.55	0.4248	0.2028
2	0.3082	28.25	0.35	0.4176	0.1287
3	0.1989	29.25	0.15	0.4104	0.0816
4	0.1284	30.25	0.95	0.4012	0.0515
5	0.0829	31.25	0.75	0.3858	0.0322
6	0.0535	32.25	0.55	0.3704	0.0198
7	0.0354	33.25	0.35	0.3550	0.0122
8	0.0223	34.25	0.15	0.3396	0.0076
9	0.0144	35.25	0.95	0.3202	0.0046
10	0.0093	36.25	0.75	0.2888	0.0027
TOTAL	1.6535				0.6831

[a] For $i = 2, 3, \ldots, I(i,i+1) = I(i-1,i)e^{-r^*} = 0.6455I(i-1,i)$.
[b] $j = 25 + i + 1.25$.
[c] $w_1 = \frac{5-(j-25-5k)}{5}$, with $25+5k$ being the largest multiple of five not exceeding j.
[d] $m^*(25,j,2) = w_1 m^*(25, 25+5k, 2) + (1-w_1)m^*(25, 25+[k+1]5, 2)$.

E. INTERPRETATION AND EXTENSIONS

1. *Interpretation*

Few if any populations reproduce at the natural fertility level. In most societies, observed fertility is well below natural levels owing to use of a variety of contraceptives, perhaps backed by induced abortion and, in some cases, by sterilization. The procedures described above serve to translate average spans of contraceptive practice into subtractions from natural fertility.

The technique is most powerful when applied concurrently to several subsamples. As an example, consider the comparison of four age cohorts of women accepting a first IUD to limit births. (More details of the analysis are given in section F.4 of this chapter.) It is apparent from table 83 that the uncorrected mean retention span, $R = a/r$, increases with ascending age—a common finding with reference to IUDs. The ratios I/R, in column (3), show that corrections for amenorrhoea overlap A and accidental pregnancy PW, non-trivial for all ages, are proportionately more important for the two younger age groups with their shorter retention spans. Because potential fertility declined with rising age, the maximum in gross births averted according to the sum of products estimate of B—column (4)—occurs for age group 30–34, not the age group with highest continuation. Owing to the convexity of the gross potential fertility curve, the mid-duration estimate of B, column (5), is upwardly biased, that bias as shown by column (6) becoming progressively more serious at the older ages.

As regards reduced data requirements, a special advantage of using Coale's model of marital fertility as a basis for estimating potential fertility is worth mentioning. If it is desired to estimate absolute numbers of births averted, then it is necessary (in step one) to stipulate a value for the parameter M. However, if one's interest is the relative number of gross births averted per IUD among age groups, then the parameter M need not be specified. In effect, step one of the analysis is trivialized to setting parameter m equal to zero while leaving the second parameter M unspecified.

TABLE 83. MEAN PROTECTION TIME AND GROSS BIRTHS AVERTED AMONG FOUR AGE GROUPS OF LIMITERS ACCEPTING AN INTRA-UTERINE DEVICE

Age at insertion of first intra-uterine device $x, x+4$	Uncorrected retention time R[a] (1)	Mean protection time I[b] (2)	Ratio I/R (3)	Gross births averted, B: Sum of products estimate[c] (4)	Mid-duration estimate[d] (5)	Percentage deviation[e] (6)
20–24	1.68	1.18	0.70	0.52	0.54	2.2
25–29	2.24	1.65	0.74	0.68	0.71	3.8
30–34	3.43	2.85	0.83	0.94	1.09	15.9
35–39	5.02	4.43	0.88	0.83	1.20	44.3

[a] $R = a/r$.
[b] $I = R - A/12 - PW/12$.
[c] $B = \Sigma I(i, i+1)m^*(x, x+i+1.25, 2)$.
[d] $B = I \cdot m^*(x, x+0.75+0.50a/r^*, 2)$.
[e] $100((5)-(4))/(4)$.

2. *Extensions*

The corrected estimate of mean retention I, derived in step D, is not equivalent to the operational concept of childbearing interruption as defined in the original two reproductive process analysis schemes published in 1969.[21] As is illustrated in those studies, in order to establish its meaning as an estimate of prolongation of stay in the fecundable state, it is necessary to incorporate into the life-table analysis of step C the additional competing risk of onset of secondary sterility and, if deemed necessary, also that of divorce.

By a small change of procedure, gross births averted may be allocated to calendar time. If this procedure is then incorporated into a suitably designed component projection scheme, the study of relationships among contraceptive acceptance, continuation and crude birth and growth rates becomes possible. Required are assumptions about the distribution of acceptances in each year as well as the time-lag between contraceptive protection and births averted. In a recent study,[22] an example is given in which it is assumed that annual acceptances all occur at mid-year combined with a nine-month lag in contraceptive effect. As an alternative to step D, woman-months of protection are partitioned into 12-month segments displaced nine months backwards in time from the calendar years of interest.

The procedures given in this chapter may be extended to any contraceptive other than IUD for which it is possible to postulate a continuation schedule. Plainly this task is more easily accomplished for a permanent or semi-permanent method and more difficult for a supply-based method, or a coitus-related contraceptive subject to irregular usage for which the adjustment for accidental pregnancy becomes so crucial. Nevertheless, Chandrasekaran and Karkal[23] were able to assess the continuation rates of a sample of diaphragm and jelly users. Perhaps the most thorough treatment of protection time estimates for a variety of contraceptives is found in Gorosh and Wolfers.[24] Lastly, to extend the present procedures to induced abortion, it is necessary to translate each abortion into an amount of protection time.[25]

To estimate net births averted per segment of a contraceptive, it is only necessary to substitute a potential fertility curve that takes account of the birth control practices the acceptors might have used had they not accepted the method they did. Unfortunately, the technique of reproductive process analysis *per se* does not contain any special insights as to how such a set of potential fertility rates might be derived.

F. Solving special problems in the analysis

1. *Overlap with anovulation*

This subsection, which deals with the formulae underlying tables 74 and 75, begins by reviewing the notations that are used:

d': monthly risk of discontinuation during anovulation;

$d' = (1-p)d'$: monthly risk of discontinuation for a reason other than accidental pregnancy during a fecundable month;

f: natural fecundability;

$p = (1-e)f$: residual fecundability;

$Pr(\alpha_j)$: probability that anovulation lasts exactly j months.

The definitions of d and p presuppose that acceptance of contraception is near the beginning of the month, conception in the middle and discontinuation near the end. The probability of continuing contraception to the end of a fecundable month (i.e., avoiding both accidental pregnancy and discontinuation for any other reason) is $1-d-p$.

If contraception is initiated during the fecundable period, expected length of retention (including the month of discontinuation or accidental pregnancy) is $1/(d+p)$. By definition there is no overlap with anovulation.

Alternatively, suppose that contraception is begun immediately after a birth and that anovulation lasts j months. Then contraception may be discontinued at the end of month $1, 2, \ldots, j$; or with a probability of $(1-d')^j$ it may be retained into the fecundable period. Accordingly, expected months of overlap (i.e., retention coinciding with anovulation) are:

$$\phi_j = d' + 2(1-d')d' + 3(1-d')^2 d' + \ldots + j(1-d')^{j-1}d' + j(1-d')^j$$
$$= \frac{1-(1-d')^j}{d'}$$

Length of anovulation α_j is assumed to follow a truncated Pascal distribution with parameters 2, $2/h$ and m. As auxiliary values, define:

$$f(\alpha_0) = f(\alpha_1) = 0$$
$$f(\alpha_j) = (j-1)\left(1-\frac{2}{h}\right)^{j-2}\left(\frac{2}{h}\right)^2 \qquad j = 2, 3, \ldots, m$$

where m is the smallest positive integer satisfying

$$0.999 \leq \sum_{j=2}^{m} f(\alpha_j) < 1.000.$$

Then $Pr(\alpha_j) = f(\alpha_j) \qquad j = 0, 1, \ldots, m$

and $Pr(\alpha_{m+1}) = 1 - \sum_{j=2}^{m} f(\alpha_j)$.

Taken across all lengths of anovulation, expected

[21] R. G. Potter, "Estimating births averted in a family planning program", *loc. cit.*; and D. Wolfers, "The demographic effects of a family planning program", *loc. cit.*

[22] D. L. Nortman and others, *op. cit.*

[23] C. Chandrasekaran and M. Karkal, "Continuation rate, use-effectiveness and their assessment for the diaphragm and jelly method", *Population Studies*, vol. XXVI (November 1972), pp. 487–494.

[24] Martin Gorosh and David Wolfers, *Standard Couple-Years of Protection: A Methodology for Program Assessment, Manuals for Evaluation of Family Planning and Population Programs*, No. 10 (New York, Columbia University, Center for Population and Family Health, 1977).

[25] A somewhat crude convention for doing this procedure is found in D. L. Nortman and others, *op. cit.* For a second option, see M. Gorosh and D. Wolfers, *op. cit.*

length of anovulatory overlap is:

$$E(\phi) = \sum_{j=1}^{m+1} Pr(\alpha_j)\left(\frac{1-(1-d')^j}{d'}\right).$$

Of the $(1-d')^j$ women whose anovulation lasts j months and who continue contraception into the fecundable period, their expected retention per woman during fecundable months is $1/(d+p)$. Averaged over all anovulatory lengths, expected number of fecundable months of practice is:

$$F = \sum_{j=1}^{m+1} Pr(\alpha_j)(1-d')^j\left(\frac{1}{d+p}\right).$$

The ratio $\phi/(\phi+F)$ subject to the simplifying assumption that contraception is perfectly effective (i.e., $e = 1$) yields the values found in the column headed $\Pi = 1.0$ of table 74.

As a more general case, one may assume that the conditional monthly probability of initiating contraception if not already pregnant is Π, $0 < \Pi \leq 1$. As before, one assumes that contraception is always initiated at the beginning of the month. During anovulation there is no risk of conception. Overlap with anovulation given that it lasts j months is:

$$\sum_{i=1}^{j} \Pi(1-\Pi)^{i-1}\left(\frac{1-(1-d')^{j-i+1}}{d'}\right).$$

Averaged across all anovulatory lengths,

$$\phi = \sum_{j=1}^{m+1} Pr(\alpha_j)\left[\sum_{i=1}^{j} \Pi(1-\Pi)^{i-1}\left(\frac{1-(1-d')^{j-i-1}}{d'}\right)\right].$$

Given an anovulatory length of j months, a proportion $(1-\Pi)^j$ of the women at end of anovulation have not yet commenced contraception. They face a competition between pregnancy and initiating contraception. A fraction $\frac{\Pi}{f+\Pi}$ will begin contraception before conceiving. Among the latter group, expected retention is $(p+d)^{-1}$. Averaged across anovulatory lengths, their total retention during fecundable months is:

$$F_1 = \sum_{j=1}^{m+1} Pr(\alpha_j)\left[(1-\Pi)^j\left(\frac{\Pi}{f+\Pi}\right)(p+d)^{-1}\right].$$

There remain those who begin contraception during anovulation and continue into the fecundable period with an average of $(p+d)^{-1}$ fecundable months of practice ensuing. Their total practice during fecundable months is:

$$F_2 = \sum_{j=1}^{m+1} Pr(\alpha_j)\left[\sum_{i=1}^{j} \Pi(1-\Pi)^{i-1}(1-d')^{j-i+1}(p+d)^{-1}\right].$$

Actually, the condition $e = 1$ enormously simplifies the algebra. Given no accidental pregnancies, the expected span of contraception once initiated is $1/d'$ independent of anovulatory length or month of initiation of contraception. Mean use per acceptor is therefore $1/d'$. All women having non-zero overlap between contraception and anovulation are necessarily acceptors. Therefore, the fraction of practice overlapping with anovulation is simply $\phi\frac{1}{d'}$, the simple formula providing the values found in the remaining columns of table 74. The corresponding values, ϕ, are reported in table 75.

2. *Marital dissolution by death of spouse*

Two ratios must be evaluated, the first of which measures IUD retention subject to mortality risks as a proportion of IUD retention free of spouse mortality. Under the assumptions enumerated in the text, the ratio is

$$R_1 = \int_0^{50-x} ae^{-rt}\frac{\ell(x+t)}{\ell(x)}\frac{\ell^*(x+D+t)}{\ell^*(x+D)}dt \Big/ \int_0^{50-x} ae^{-rt}dt$$

with all variables being measured in years; x denotes age at acceptance. If one assumes that the force of mortality is constant within five-year age groups:

$$e^{-5\mu_1} = \frac{\ell(x+5)}{\ell(x)}\frac{\ell^*(x+D+5)}{\ell^*(x+D)}$$

$$\text{or } \mu_1 = -\log n\left(\frac{\ell(x+5)}{\ell(x)}\frac{\ell^*(x+D+5)}{\ell^*(x+D)}\right)\Big/5$$

and more generally

$$\mu_j = -\log n\left(\frac{\ell(x+5j)}{\ell(x)}\frac{\ell^*(x+D+5j)}{\ell^*(x+D)}\right)\Big/5.$$

Proportions surviving, $\ell(x)$ and $\ell^*(x)$, are taken from the West family of Coale-Demeny model life tables. The ratio given above can now be simplified to:

$$R_1 = \frac{\sum_{i=1}^{5}\int_{i-1}^{i} ae^{-(r+\mu_1)t}dt + \sum_{i=6}^{10}\int_{i-1}^{i} ae^{-(r+\mu_2)t}dt + \ldots + \sum_{i=46-x}^{50-x}\int_{i-1}^{i} ae^{-(r+\mu_k)t}dt}{\int_0^{50-x} ae^{-rt}dt}$$

where $k = \frac{50-x}{5}$. Numerical evaluation is simplified if D is kept a multiple of five.

Simplifying further,

$$R_1 = \frac{\sum_{j=1}^{k}\sum_{i=5j-4}^{5j}\int_{i-1}^{i} e^{-(r+\mu_j)t}dt}{\frac{1}{r}(1-e^{-(50-x)r})}$$

with the a-terms cancelling.

The second ratio measures gross births averted subject to risks of spouse mortality in relation to gross births averted in the absence of such mortality. The formula is:

$$R_2 = \frac{\int_0^{50-x} ae^{-rt}\left(\frac{\ell(x+t)}{\ell(x)}\frac{\ell^*(x+D+t)}{\ell^*(x+D)}\right)m(x+t+0.75)dt}{\int_0^{50-x} = ae^{-rt}m(x+t+0.75)dt}$$

Fertility $m(x+t+0.75)$ is changing slowly enough to treat it as constant within single years of age. Accordingly, one may equate $m(x+i+0.75)$ with $Mn(x+i)$. In the formula for R_2, the M term cancels out. Values of $n(x+i)$ are taken from Coale and Trussell.[26] See table 84.

TABLE 84. VALUES OF $n(x)$ CENTRED ON THE MID-POINT OF EACH YEAR OF AGE

Mid-point (age in years)	*Natural fertility rate n(x)*	*Mid-point (age in years)*	*Natural fertility rate n(x)*
12.5	0.175	31.5	0.410
13.0	0.225	32.0	0.400
14.0	0.275	33.0	0.389
15.0	0.325	34.0	0.375
16.0	0.375	35.0	0.360
17.0	0.421	36.0	0.343
18.0	0.460	37.0	0.325
19.0	0.475	38.0	0.305
20.0	0.477	39.0	0.280
21.0	0.475	40.0	0.247
22.0	0.470	41.0	0.207
23.0	0.465	42.0	0.167
24.0	0.460	43.0	0.126
25.0	0.455	44.0	0.087
26.0	0.449	45.0	0.055
27.0	0.442	46.0	0.035
28.0	0.435	47.0	0.021
29.0	0.428	48.0	0.011
30.0	0.420	49.0	0.003

The numerator and denominator are evaluated as sums of annual terms:

$$\hat{R}_2 = \frac{\sum_{i=1}^{50-x} H(i)m(x+i+0.75)}{\sum_{i=1}^{50-x} G(i)m(x+i+0.75)}$$

where $G(i) = \int_{i-1}^{i} ae^{-rt}dt = \frac{ae^{-r(i-1)}}{r}(1-e^{-r})$;

$$H(i) = \int_{i-1}^{i} ae^{-(r+\mu_j)}dt = \frac{ae^{-(r+\mu_j)(i-1)}}{r+\mu_j}(1-e^{-(r+\mu_j)}).$$

3. *Potential fertility*

Derivation of M

The parameter M may be estimated as a function of the expected birth interval b (in months) by the following equation:

$$\hat{M} = \frac{{}_5\bar{S}_{20}}{n(20)}\frac{12}{b} = \frac{0.972}{0.460}\frac{12}{b} = \frac{25.36}{b} \quad (1)$$

If the estimate of b is derived from empirical birth interval data, there may be the problem of separating and setting aside intervals from marriage to first birth that do not include a period of post-partum anovulation. Given late marriage, this problem being smaller among women aged 25–29 than among those aged 20–24, it becomes preferable to use an alternative equation:

$$\hat{M} = \frac{{}_5\bar{S}_{25}}{n(25)}\frac{12}{b} = \frac{0.950}{0.431}\frac{12}{b} = \frac{26.45}{b} \quad (2)$$

Implied values of M, based on equations (1) and (2), taken over a range of b from 19 to 36 are given in table 85.

TABLE 85. ESTIMATES OF THE PARAMETER M AS A FUNCTION OF EXPECTED BIRTH INTERVAL b

Expected birth interval b	$M = \frac{26.45}{b}$	$M = \frac{25.36}{b}$
19	1.392	1.335
20	1.327	1.268
21	1.260	1.208
22	1.202	1.153
23	1.150	1.103
24	1.102	1.057
25	1.058	1.014
26	1.017	0.975
27	0.980	0.939
28	0.945	0.906
29	0.912	0.874
30	0.882	0.845
31	0.853	0.818
32	0.827	0.792
33	0.802	0.768
34	0.778	0.746
35	0.756	0.725
36	0.735	0.704

Included among the components composing the expected birth interval is that for months added by foetal deaths. Estimates of this component from table 78 were 2, 2 and 4 months pertaining to the high, medium and low values of b, respectively. Their derivation is as follows. Let θ_2 and θ_3 signify the probabilities of pregnancy ending in abortion and stillbirth, and W denote the mean menstruating interval. Assume that three months of pregnancy and anovulation associate with an abortion on average and 11 months with a stillbirth. These considerations lead to the following calculation:

W	θ_2	θ_3	$\theta_2(W+3)+\theta_3(W+11)$
6	0.18	0.02	1.62 + 0.34 = 1.96
8	0.18	0.02	1.98 + 0.38 = 2.36
10	0.20	0.05	2.60 + 1.05 = 3.65

Upon rounding, this calculation gives 2, 2 and 4.

Listing of computer program to estimate m

The computer program used to estimate m is given below in table 86.

[26] *Loc. cit.*, appendix A.

TABLE 86. COMPUTER PROGRAM TO ESTIMATE *m*

```
FORTRAN IV G   LEVEL   21        MAIN        DATE = 78229        12/17/03        PAGE 0001

      C  PROGRAM COALE
      C  APRIL 7, 1977
      C
         REAL N(6),MCAP,MSMALL
         DIMENSION V(6),R(6),JJ(6),DATE(30),NAME(50),Y(6),X(6)
      C
      C  ASSIGN VALUES TO N(J) -- NATURAL BIRTH RATES -- AND
      C                        V(J)--EXPONENTIAL COEFFICIENTS, J = 20, 25, . . . , 45,
                               AND JJ(J)--AGE
            DATA N/.460,.431,.395,.322,.167,.024/
            DATA V/.000,-0.279,-0.677,-1.042,-1.414,-1.671/
            DATA JJ/20,25,30,35,40,45/
      C
      C  DEVICE NUMBERS
      C     NRD--INPUT, CARD READER
      C     NPR--OUTPUT, LINE PRINTER
      C  INSERT DEVICE NUMBERS APPROPRIATE TO INSTALLATION
          NRD=5
          NPR=6
      C
      C  READ INPUT
      C    NJOBS, NUMBER OF JOBS TO BE RUN
            READ(NRD,1) NJOBS
      C    DATE(J), DATE OF RUN
            READ (NRD,11)(DATE(J),J=1,30)
            DO 2 I=1,NJOBS
      C  THE FOLLOWING TWO VARIABLE CARDS ARE REPEATED NJOBS TIMES
      C    NAME(J), NAME OF COUNTRY
            READ(NRD,30)(NAME(J),J=1,50)
      C    R(J), OBSERVED BIRTH RATES, J = 20, 25, . . . , 45
            READ(NRD,3)(R(J),J = 1,6)
      C
      C  DERIVE Y(J) AND X(J)
            DO 70 J=1,6
            Y(J) = ALOG(R(J)/N(J))
         70 CONTINUE
            DO 71 J=1,6
            X(J) = V(J)
         71 CONTINUE
      C
      C  COMPUTE YBAR, MSMALL, AND MCAP
            XN=6.0
            SUM = 0.0
            DO 72 J=1,6
            SUM = SUM+Y(J)
         72 CONTINUE
            YBAR = SUM/XN
            SUM1 = 0.0
            SUM2 = 0.0
            SUM3 = 0.0
            DO 73 J=1,6
            SUM1 = SUM1+X(J)
            SUM2 = SUM2+X(J)*Y(J)
            SUM3 = SUM3+X(J)**2
         73 CONTINUE
            MSMALL = (SUM2-((SUM1*SUM)/XN))/(SUM3-(SUM1**2/XN))
            MCAP = EXP(YBAR)
      C  WRITE PROGRAM RESULTS
            WRITE(NPR,15)
            IF(I.EQ.1) WRITE (NPR,16) (DATE(J),J=1,30)
            WRITE(NPR,31)(NAME(J),J=1,50)
            WRITE(NPR,17)
            DO 18 J=1,6
            WRITE(NPR,19)JJ(J),R(J)
         18 CONTINUE
            WRITE(NPR,20)
            WRITE(NPR,35)(JJ(J),J=1,6)
            WRITE(NPR,26)(X(J),J=1,6)
            WRITE(NPR,27)(Y(J),J=1,6)
            WRITE(NPR,21) YBAR
            WRITE(NPR,22)MSMALL
            WRITE(NPR,25)MCAP
          2 CONTINUE
          1 FORMAT(I2)
          3 FORMAT(6F5.4)
         11 FORMAT(30A1)
         15 FORMAT(1H1)
         16 FORMAT(59X,'COALE'///1X,'DATE OF RUN: ',30A1///)
         17 FORMAT(1X,'ECHO CHECK OF INPUT'//11X,'AGE',10X,'OBSERVED BIRTH RATE
           1ES'/12X,'J',19X,'R(J)'/)
         19 FORMAT(12X,I2,17X,F5.4)
         20 FORMAT(/////1X,'PROGRAM RESULTS')
         21 FORMAT(/5X,'YBAR = ',F7.4)
         22 FORMAT(///5X,'MSMALL = ',F7.4)
         25 FORMAT(/5X,'MCAP = ',F7.4)
         26 FORMAT(/5X,'X(J) = ',6F10.4)
         27 FORMAT(/5X,'Y(J) = ',6F10.4)
         30 FORMAT(50A1)
         31 FORMAT(1X,50A1//)
         35 FORMAT(//10X,6I10)
            STOP
            END
```

COALE

DATE OF RUN: JUNE 15, 1977

ALGERIA, 1955

ECHO CHECK OF INPUT

AGE J	OBSERVED BIRTH RATES R(J)
20	.3096
25	.2139
30	.1197
35	.0731
40	.0211
45	.0021

PROGRAM RESULTS

	20	25	30	35	40	45
X(J) =	0.0	−0.2790	−0.6770	−1.0420	−1.4140	−1.6710
Y(J) =	−0.3959	−0.7006	−1.1939	−1.4827	−2.0687	−2.4361
YBAR =	−1.3797					

MSMALL =	1.2014
MCAP =	0.2517

DAHOMEY, 1961

ECHO CHECK OF INPUT

AGE J	OBSERVED BIRTH RATES R(J)
20	.3424
25	.3009
30	.2545
35	.1681
40	.0944
45	.0319

PROGRAM RESULTS

	20	25	30	35	40	45
X(J) =	0.0	−0.2790	−0.6770	−1.0420	−1.4140	−1.6710
Y(J) =	−0.2952	−0.3593	−0.4396	−0.6500	−0.5705	0.2846
YBAR =	−0.3383					

MSMALL =	−0.1488
MCAP =	0.7130

4. *Age comparison*

Further particulars respecting the age comparison, summarized in table 83, are given in table 87. The parameters a and r are derived by the methods depicted in table 80. The P values are considered underestimates; the W values medium estimates. To avoid optimism, the calculated PW values are raised to an integral number of months as indicated.

Concerning amenorrhoea overlap, no information exists to differentiate by age the mean or median open interval from last birth to acceptance. One knows that as age increases, continuation improves and presumably post-partum anovulation lengthens—both factors operating to increase overlap. Higher abortion rates and what may be presumed to be longer open intervals operate in the opposite direction. With the assumption that opposing forces cancel each other, the allowance for overlap A is kept at a conservative five months. The ${}_5\bar{S}_{x-2}$ adjustment factor comes from table 73. The e^{-r^*} term has special significance since $I(i,i+1) = e^{-r^*} I(i-1,i)$ for $i = 2, 3, \ldots$. Recall that $r^* = r/(1 - rPW/12)$.

The last column of table 79 contains the gross potential fertility rates $m^*(25, 25+5i, 2), i = 0, 1, \ldots$, for acceptors 25–29 years old. The corresponding rates for acceptors aged 20–24, 30–34 and 35–39 are enumerated in table 88.

Details about protection time and births averted given in table 82 for acceptors aged 25–29 are provided by tables 89–91 for the other three acceptor cohorts.

TABLE 87. ADDITIONAL PARTICULARS CONCERNING FOUR AGE COHORTS OF INTRA-UTERINE DEVICE ACCEPTORS

Age at insertion $x, x+4$	*Parameter* a[a]	$r/12$	*Parameter* r[a]	*Expected proportion ending in accidental pregnancy* P	*Mean fecundable period without contraception* W *(months)*	*Calculated penalty* PW *(months)*	*Adjusted penalty* PW *(months)*	*Amenorrhoeic overlap* A *(years)*
20–24	0.8844	0.0439	0.5265	0.098	6	0.558	1	5/12
25–29	0.9133	0.0340	0.4083	0.145	7	1.015	2	5/12
30–34	0.9334	0.0227	0.2722	0.180	8	1.440	2	5/12
35–39	0.9222	0.0153	0.1838	0.147	9	1.323	2	5/12

Age at insertion $x, x+4$	${}_5S_{x-2}{}^{-1}$[b]	$r^*/12$	r^*[c]	a/r^*	e^{-r^*}	$1-e^{-r^*}$
20–24	1.025	0.0459	0.5508	1.6057	0.5765	0.4235
25–29	1.040	0.0365	0.4378	2.0861	0.6455	0.3545
30–34	1.087	0.0238	0.2856	3.2682	0.7516	0.2484
35–39	1.248	0.0158	0.1896	4.8639	0.8273	0.1727

[a] Values of a and r derived by the method described in table 80.

[b] ${}_5S_{x-2}{}^{-1}$ values from table 73, column (5).

[c] $r^* = r/(1 - rPW/12)$.

TABLE 88. DERIVATION OF GROSS POTENTIAL FERTILITY RATES FOR AGE GROUPS 20–24, 25–29 AND 35–39 YEARS

Age groups from x to x + 4	$m(x)$	$m^*(20, x, 2)$[a]	$m^*(30, x, 2)$[b]	$m^*(35, x, 2)$[c]
20–24	0.452	0.4633	–	–
25–29	0.424	0.4346	–	–
30–34	0.389	0.3987	0.4228	–
35–39	0.315	0.3229	0.3424	0.3931
40–44	0.164	0.1681	0.1783	0.2047
45–49	0.024	0.0246	0.0261	0.0300

[a] $m^*(20, x, 2) = 1.025m(x)$, $x = 20, 25, \ldots, 45$.

[b] $m^*(30, x, 2) = 1.087m(x)$, $x = 30, 35, 40, 45$.

[c] $m^*(35, x, 2) = 1.248m(x)$, $x = 35, 40, 45$.

TABLE 89. GROSS BIRTHS AVERTED PER SEGMENT OF INTRA-UTERINE DEVICE, AMONG ACCEPTORS AGED 20–24 YEARS

Duration i	Fractional years protected $I(i, i+1)$[a] (1)	Index age $j = 20+i+1.25$[b] (2)	Weighting coefficient w_1[c] (3)	Duration-specific potential fertility $m^*(20, j, 2)$[d] (4)	Duration-specific births averted (1).(4) (5)
0	0.2633	21.25	0.75	0.4561	0.1201
1	0.3920	22.25	0.55	0.4504	0.1766
2	0.2260	23.25	0.35	0.4446	0.1005
3	0.1303	24.25	0.15	0.4389	0.0572
4	0.0751	25.25	0.95	0.4328	0.0325
5	0.0433	26.25	0.75	0.4256	0.0184
6	0.0250	27.25	0.55	0.4186	0.0105
7	0.0144	28.25	0.35	0.4113	0.0059
8	0.0083	29.25	0.15	0.4041	0.0034
TOTAL	1.1777				0.5250

[a] $I(i, i+1) = 0.5765 I(i-1, i)$ for $i = 2, 3, \ldots$.

[b] $j = 20+i+1.25$.

[c] $w_1 = \frac{5-(j-20-5k)}{5}$, with $20+5k$ being the largest multiple of 5 not exceeding j.

[d] $m^*(20, j, 2) = w_1 m^*(20, 20+5k, 2) + (1-w_1) m^*(20, 20+5[k+1], 2)$.

TABLE 90. GROSS BIRTHS AVERTED PER SEGMENT OF INTRA-UTERINE DEVICE, AMONG ACCEPTORS AGED 30–34 YEARS

Duration i	Fractional years protected $I(i, i+1)$[a] (1)	Index age $j = 30+i+1.25$[b] (2)	Weighting coefficient w_1[c] (3)	Duration-specific potential fertility $m^*(30, j, 2)$[d] (4)	Duration-specific births averted (1).(4) (5)
0	0.3951	31.25	0.75	0.4027	0.1591
1	0.6102	32.25	0.55	0.3866	0.2359
2	0.4586	33.25	0.35	0.3705	0.1699
3	0.3447	34.25	0.15	0.3545	0.1222
4	0.2591	35.25	0.95	0.3342	0.0866
5	0.1947	36.25	0.75	0.3014	0.0587
6	0.1463	37.25	0.55	0.2686	0.0393
7	0.1100	38.25	0.35	0.2357	0.0259
8	0.0827	39.25	0.15	0.2029	0.0168
9	0.0621	40.25	0.95	0.1707	0.0106
10	0.0467	41.25	0.75	0.1402	0.0065
11	0.0351	42.25	0.55	0.1098	0.0038
12	0.0264	43.25	0.35	0.0794	0.0021
13	0.0198	44.25	0.15	0.0489	0.0010
14	0.0149	45.25	0.95	0.0248	0.0004
15	0.0112	46.25	0.75	0.0196	0.0002
16	0.0084	47.25	0.55	0.0143	0.0001
TOTAL	2.8260				0.9391

[a] $I(i, i+1) = 0.7516 I(i-1, i)$ for $i = 2, 3, \ldots$

[b] $j = 30+i+1.25$.

[c] $w_1 = \frac{5-(j-30-5k)}{5}$, with $30+5k$ being the largest multiple of 5 not exceeding j.

[d] $m^*(30, j, 2) = w_1 m^*(30, 30+5k, 2) + (1-w_1) m^*(30, 30+5[k+1], 2)$.

TABLE 91. GROSS BIRTHS AVERTED PER SEGMENT OF INTRA-UTERINE DEVICE, AMONG ACCEPTORS AGED 35–39 YEARS

Duration i	Fractional years protected $I(i, i+1)$[a] (1)	Index age $j = 35 + i + 1.25$[b] (2)	Weighting coefficient w_1[c] (3)	Duration-specific potential fertility $m^*(35, j, 2)$[d] (4)	Duration-specific births averted (1).(4) (5)
0	0.4233	36.25	0.75	0.3460	0.1465
1	0.6949	37.25	0.55	0.3083	0.2142
2	0.5749	38.25	0.35	0.2706	0.1556
3	0.4756	39.25	0.15	0.2330	0.1108
4	0.3935	40.25	0.95	0.1960	0.0771
5	0.3255	41.25	0.75	0.1610	0.0524
6	0.2693	42.25	0.55	0.2161	0.0340
7	0.2228	43.25	0.35	0.0911	0.0203
8	0.1843	44.25	0.15	0.0562	0.0104
9	0.1525	45.25	0.95	0.0285	0.0043
10	0.1262	46.25	0.75	0.0225	0.0028
11	0.1044	47.25	0.55	0.0165	0.0017
12	0.0863	48.25	0.35	0.0105	0.0009
13	0.0714	49.25	0.15	0.0045	0.0003
14	0.0591	50.25	0.95	0.0000	0.0000
TOTAL	4.1640				0.8313

[a] $(I, i, i+1) = 0.8273I(i-1, i)$ for $i = 2, 3, \ldots$.

[b] $j = 35 + i + 1.25$.

[c] $w_1 = \frac{5-(j-35-5k)}{5}$, with $35+5k$ being the largest multiple of 5 not exceeding j.

[d] $m^*(35, j, 2) = w_1 m^*(35, 35+5k, 2) + (1-w_1) m^*(35, 35+5[k+1], 2)$.

Chapter VI

MULTIVARIATE AREAL ANALYSIS

*Albert I. Hermalin**

The strategy of family planning programmes is that increasing the knowledge, acceptance and availability of family limitation methods will lead through increased use to the reduction of aggregate fertility levels. At the same time, many of the countries that have introduced programmes have also been undergoing socio-economic change which raises the question of partitioning the credit for any decreases in fertility between the programme and modernizing factors, such as increasing levels of education and decreasing child mortality. One way of testing for a programme effect is to determine whether among the geographical areas within a country there is a relationship between levels of fertility and programme factors, after taking into account socio-economic and demographic factors also thought to influence fertility. This approach to the study of family planning programme effects on fertility may be termed "areal multivariate analysis" and has been employed in several countries, often as an adjunct to other methods of evaluation. The purpose of this chapter is to review the rationale of this approach, to point up its advantages and limitations and to provide a detailed example of its application.

A. Structure of multivariate areal analysis

The following features of an areal multivariate analysis as applied to the study of family planning programme effects on fertility have been identified:

"(i) for all or some subset of local areas within a country or other territorial unit, one has a series of characteristics whose influence on fertility is to be determined (these are the independent variables);

"(ii) one or more of these measures reflects inputs into the program, either in terms of manpower, supplies, money, or some intermediate effect of such inputs such as acceptances;

"(iii) a measure of fertility (or some characteristics assumed to bear directly on fertility) as dependent variable, which reflects the effects of the program and other factors; and

"(iv) a method of analysis which enables one to appraise the relative impact of the independent variables on the dependent variable."[1]

Attention to these features highlights some of the strengths and weaknesses of this approach.

1. *Advantages of method*

Contrasted with such procedures as standardization or trend analysis, this approach produces a direct estimate of the effect of the programme rather than inferring its impact as a residual. At the same time, it explicitly takes account of the effects of a range of other explanatory factors and does not require, as does analysis of births averted, that those factors be converted into measures of the substitution of private methods by programme methods or the potential fertility of acceptors, which have been troublesome to estimate. Further, it can be applied to both macro and micro data although, in evaluation studies, macro applications are more common. The method is suited for use with time-series data as well as with indicators for different moments in time, and it can be made to take account of time-lags.

In areal multivariate analysis, geographical areas are the units of analysis and the focus is on observed aggregate levels of fertility and, in so far as programmes are intended to reduce aggregate levels of fertility, using areas as the unit of analysis may be viewed as the preferred method of testing for programme effects and not simply a second-best alternative when individual correlations are not available. In addition to the general objective of determining whether a family planning programme has had a significant impact on fertility, while taking acccount of other factors, areal analysis has various other uses. Policy decisions can be aided by studying the returns obtained from different types of

* Director, Population Studies Center, University of Michigan, Ann Arbor, Michigan. Professor Hermalin's research for this chapter was supported in part by a grant from the National Institute for Child Health and Human Development. He wishes to express appreciation for the assistance of J. Michael Coble, Susan Etter and Dorothy Strand in computer programming, data processing and manuscript preparation.

[1] Albert I. Hermalin, "Regression analysis of areal data", in C. Chandrasekaran and Albert I Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), p. 247. This earlier work, which is to be treated as a companion piece for the present chapter, takes up some aspects of areal multivariate analysis not covered here, treats a number of others in more detail, provides a more complete description of previous applications and presents some alternative models. The focus in this chapter is on providing a detailed example of the mechanics of the technique; and for this reason, the chapter is less comprehensive in some other respects.

inputs; the differential success of the programme in areas with differing characteristics may suggest a reallocation of effort.

2. *Disadvantages of method*

One of the short-comings of this method is that results obtained for an areal level cannot be presumed to hold among individuals without further testing, as is shown in a discussion of the ecological fallacy.[2] The statistical interrelations between correlations on the individual and aggregate levels have been treated by various authors.[3]

Because a theory of fertility behaviour that is fruitful for explaining variations among individuals may not satisfactorily account for areal variation, it is necessary for the investigator to develop a model considered adequate at the areal level. Many of the conceptual schemes now current, be they of a sociological, psychological or economic nature,[4] focus on individual differences and few explicate fully how a family planning programme affects the fertility process. As with other approaches to evaluation, the absence of an accepted paradigm of aggregate fertility represents a weakness of the multivariate areal approach, in that findings on the effect of the programme are likely to vary with the model employed and there are no criteria for choosing one set of results over another.

Areal multivariate analysis is also limited by the types of data likely to be available. The investigator is largely limited to data from official sources—census, vital registration and service statistics reports—and these data may not contain operational measures of key concepts required by the model. Data for certain classes of variables, such as the biological factors which impinge on fertility (length of post-partum amenorrhoea, level of fecundity and the like), are rarely available on an aggregate basis and hence must usually be omitted even if called for by the conceptual model. As illustrated below, however, fertility and Knowledge, Attitude, Practice (KAP) surveys can sometimes be utilized to develop aggregate measures of variables not otherwise available, thus permitting the testing of a wider range of theories.

Some of the data desired for analysis may only be available infrequently from the usual sources, as in the case of the decennial census, and this factor constrains the timing of family planning evaluations.

Although reliance on official statistics of the type mentioned above may limit the range of available variables, from another standpoint it may present many choices for operationalizing other variables. For example, the educational level may be operationalized by literacy level, by years of school attained by males and/or females in certain age groups or by proportion of children enrolled in secondary school. If the theory is sufficiently detailed to indicate precisely how education affects fertility, it may point to one measure as most appropriate, but often this is not the case and the investigator has to make a decision on other grounds. To the extent that the various operational measures of a concept are not perfectly intercorrelated, the results are likely to vary somewhat with the particular measure employed, introducing a further note of ambiguity in the inferences drawn.

Using areas as the units of analysis limits the number of observations so that this approach is vulnerable to the problems that beset small sample size. Some of the sources of variation mentioned above are more troublesome because of the limited number of observations. Errors in data are also likely to be a problem with this approach because a large error in a few observations can have a sizable effect on the correlation and regression coefficients. Steps that can be taken to reduce errors in data are discussed in section B.

Options may also exist with regard to the statistical method of analysis used to obtain estimates of the effect of the independent variables. The use of ordinary least squares contains a series of assumptions about the distribution of the error term, the absence of reciprocal influence, independence of the error term and explanatory variables etc. Where these conditions are not met, a technique such as two-stage least squares may be called for.

In summary, areal multivariate analysis is congruent in many ways with the problem of determining the effect of family planning programmes on fertility. As such, it represents a useful approach to evaluation. At the same time, note has been taken of a number of limitations: the results obtained will vary with the conceptual model employed; for a given model the results will vary with the operational definitions of the concepts; and for a given model and set of definitions, variation can arise from the statistical method of estimation used. In addition, the nature and frequency of the available data may limit the analysis. These impediments are not unique, of course, to the evaluation of family planning programmes nor to the areal multivariate analysis method, but are common to many attempts to analyse social behaviour. Also, the level of sensitivity which has been stressed in this section must be compared with that of other evaluation approaches. It may be that other techniques of evaluation appear more robust because they have not yet been subject to the same type of sensitivity analysis as has the multivariate areal approach.

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[2] W. S. Robinson, "Ecological correlations and the behaviour of individuals", *American Sociological Review*, vol. 15 (June 1950), pp. 351–357.

[3] Otis Dudley Duncan, Ray P. Cuzzort and Beverly Duncan, *Statistical Geography: Problems in Analyzing Areal Data* (Glencoe, Ill., The Free Press of Glencoe, 1961), pp. 65–67; Michael T. Hannan, *Aggregation and Disaggregation in Sociology* (Lexington, Mass., Lexington Books, 1971), pp. 38–49; Howard R. Alker, Jr., "A typology of ecological fallacies", in Mattei Dogan and Stein Rokkan, eds., *Quantitative Ecological Analysis in the Social Sciences* (Cambridge, Mass., Massachusetts Institute of Technology Press, 1969), pp. 69–86; and Henri Theil, *Linear Aggregation of Economic Relations* (Amsterdam, North-Holland Publishing Company, 1954).

[4] See, for example, Ronald Freedman, "Applications of the behavioral sciences to family planning programs", *Studies in Family Planning*, No. 23 (October 1967), pp. 5–9; James T. Fawcett, *Psychology and Population: Behavioral Research Issues in Fertility and Family Planning* (New York, The Population Council, 1970); Bom Mo Chung and others, *Psychological Perspectives: Family Planning in Korea* (Seoul, Republic of Korea, Korean Institute for Research in the Behavioral Sciences/Hollym Corporation, 1972); Theodore W. Schultz, ed., "New economic approaches to fertility" (Proceedings of a conference, 8–9 June 1972), *Journal of Political Economy*, vol. 81, No. 2, part 2 (March–April 1973).

B. Initial steps in the analysis

The logical starting-point of an areal multivariate analysis would be a conceptual model that identifies the factors that determine aggregate fertility levels and their interrelationships. It is the operationalization of these concepts that points to the data desired, governs the assumptions and determines the mathematical model most appropriate for estimating the effect of the factors.

As a practical matter, however, it may be wise to begin with a preliminary investigation of the data base, since it is known that certain kinds of information on an areal basis will be required. Initial interest should centre on identifying the areal units of interest. Often the area of a country will be subdivided into a relatively small number of primary geographical divisions, such as regions, states or provinces, with these divisions further subdivided into secondary and tertiary subdivisions, such as countries, townships and districts. (The number of subdivisions and their titles will, of course, vary from country to country.) The number of units at each level and the types of data available for each will, as a practical matter, determine the level of aggregation to be used.[5]

Because the multivariate analysis will involve the simultaneous treatment of a number of variables, it is advisable to avoid the largest level of aggregation, such as the states of India, as these divisions may provide too few cases for reliable estimation of the effects.[6] Sometimes the structure of the family planning programme may suggest the level of aggregation. For example, where decisions about personnel or budgets are made on the basis of factors at a particular areal level, if other needed data are available, that level may be the most appropriate for analysis. As a first step, then, one determines whether relevant data are available for a sufficient number of areal units at an appropriate level of aggregation. If such data can be obtained only for primary subdivisions and these units number fewer than 20, the analysis is likely to be severely limited.

A secondary consideration might be the frequency and timeliness of the data. Ideally, one would like to repeat the analysis at several points in time both to study the trends in effects and because the reasonableness of the patterns over time will increase confidence in the results. In addition, data over time are necessary if first-difference models (discussed below) are to be developed.

1. *Types and sources of data needed*

Types of data

Assuming that these initial steps are encouraging, a closer look may be taken at the specific types of data needed and their likely sources. In the previous section, it was stated that in an areal multivariate analysis data of a demographic, socio-economic and family planning programme nature will usually be required. Always keeping in mind that the data to be sought are dictated by the conceptual model, the following list of specific variables[7] indicates those which may be available by area and relevant to a wide number of models:

(a) *Demographic and ecological variables*:

- (i) Fertility: crude birth rates; general fertility rates; age-specific fertility rates; total fertility rates; child-women ratios;
- (ii) Nuptiality: marital status by sex and age or proportion married by age; marriages, number and/or rates; marriages by age;
- (iii) Migration and mobility rates, migration streams;
- (iv) Mortality: crude death rates; infant mortality rates; other age-specific mortality rates;
- (v) Population: total number; sex and/or age distribution; sex ratio;
- (vi) Density: Population potential; distances to urban centres; level of urbanization; land-use measures (agricultural population per unit of arable land).

(b) *Socio-economic and related variables*:

- (i) Economic activity status (labour force)—by sex and age; occupational distribution (detailed or agricultural *versus* non-agricultural); other job characteristics;
- (ii) Adult educational level (percentage literate; detailed educational attainment—by sex and age);
- (iii) Ethnic group, religious characteristics, tribe;
- (iv) School attendance measures—primary, secondary;
- (v) Income measures—*per capita*, family or household;
- (vi) Housing characteristics, ownership of specified objects;
- (vii) Commercial activity, manufacturing and agricultural production; number of establishments, tax revenues;
- (viii) Communication and transportation measures (postal service volume, number of telephones etc.);
- (ix) Health and welfare measures: number of physicians, hospitals, clinics etc.; health budgets; health services—maternal and child care (proportion of births in hospital, with doctor in

[5] There is also a theoretical question here centring on whether an analysis conducted at one level of aggregation will coincide with that of another: for example, whether one will obtain the same results from primary subdivisions as from secondary or tertiary subdivisions. Generally speaking, this will not be the case. For the relation between the correlations at two different levels of aggregation, see O. D. Duncan, R. P. Cuzzort and B. Duncan, *op. cit.*, p. 110; and for further discussion of this issue, A. I. Hermalin, *loc. cit.*, pp. 275–276.

[6] However, note should be taken of three examples of studying variation in acceptances in an areal multivariate framework using the states of India as units of analysis: S. N. Agarwala, "A study of factors explaining variability in family planning performance in different states of India"; and O. P. Vig, "An application of path analysis to study variation in acceptance of the family planning programme in India, 1966–71", both papers presented at the All India Seminar on Family Planning Problems in India, Bombay, International Institute for Population Studies 1972 (mimeographed); and S. K. Srikantan, *The Family Planning Program in the Socioeconomic Context* (New York, The Population Council, 1977).

[7] A. I. Hermalin, *loc. cit.*, pp. 262–263.

attendance); number of examinations for specific diseases, incidence and prevalence rates; social service budgets; public work expenditures;

(x) Civic measures, such as proportion of adults voting;

(c) *Family planning programme characteristics*:

(i) Programme inputs: number of field-workers and other personnel; number of clinics and other facilities; physicians and other medical personnel employed or under contract; man-hours of efforts; number of contacts; expenditures; promotional efforts (number of posters, screenings etc.);

(ii) Number and characteristics of acceptors of contraceptive service, type of contraception accepted, first contacts *versus* subsequent contacts.

The foregoing list is not exhaustive nor does it typify the situation in any one country. Few countries will have data on all these characteristics by areal subdivision. Since fertility is typically the key dependent variable, the availability of a suitable measure is a pre-condition for undertaking the analysis. Among the possible fertility measures, the crude birth rate with its dependence on the age structure is, quite obviously, a less satisfactory measure than some of the others mentioned; but given age and sex population data, standardized measures can be developed. It should be noted, however, that a set of areal indirectly standardized rates does not strictly control for age-sex compositional differences.[8]

Sources of data

It will be necessary for the investigator to consult a number of statistical sources for the country of interest in order to obtain the required data. Census, vital statistics and/or household registration system publications should yield information on some of the characteristics listed under categories (a) and (b) given above. Information on the characteristics listed under (c) are generally derived from the service statistics reports of the agency responsible for the family planning programme. Beyond these more obvious sources, one may have reference to general statistical compendia of the country or to the reports of specific departments and ministries, such as those for transportation, health and education, in searching for data on the socio-economic characteristics in category (b). Occasionally data for each areal subdivision will not have been compiled centrally but may exist in the reports of the local governing units.

In assembling the information, care should be taken to assure that the variables of interest relate to the same geographical classification. Although many countries have a well-established system of classification of geographical areas, one may still find special areal definitions, such as health districts or school districts, for which the boundaries differ from those applicable to the other variables. In compiling a time series of the relevant variables, one should be alert to changes in the system of geographical classification as well as to changes in the boundaries of individual areas.

Most of the data used will be published statistics from primary or secondary sources so that typically the investigator will not have any control over the procedures involved in collecting, tabulating or preparing the information. In these circumstances, there is sometimes a tendency to accept the data as given and not be concerned with measurement error. Because measurement error can bias the results of the analysis, it is important that the investigator minimize it to the extent possible.[9] For the type of information typically employed in an areal analysis, the following steps to keep the bias to a minimum might be undertaken:

(*a*) Review any published information on the completeness and reliability of the data utilized. Many countries conduct evaluations of their censuses in accordance with United Nations recommendations. The *Demographic Yearbook* published annually by the United Nations offers a broad appraisal of the vital statistics system in each country;

(*b*) The investigator may employ analytical tests of data adequacy using various demographic techniques designed for that purpose;

(*c*) Familiarization with the procedures used to collect and process the information may provide guidelines as to likely sources of error as well as afford further understanding of the meaning of the data. Knowing the definitions of the events, the degree of local autonomy in collecting information and whether the data are tabulated locally or centrally is helpful in making proper use of the data;

(*d*) Where data are available for each area on a regular basis, consistency checks can be made to help detect such things as typographical errors and transpositions of data between areas. In one simple procedure, the annual percentage change in an item is computed for each area and an examination made of the instances of large deviations from the national average, taking into account the nature of the item and the size of the area. (An area with a small population, for example, might show large percentage changes in the crude birth rate.) Where both the detail and total are shown for a characteristic, it is simple to check on the addition, rates and other measures can be recomputed when the appropriate "raw" data are given. The errors thus found can often be corrected from internal evidence; in other instances, it may be necessary to inquire of the responsible agency. The experience of the present author is that "even data of generally high quality may contain a large number of such errors and that many of them can be detected by these simple procedures".[10]

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[8] Evelyn Kitagawa, "Standardized comparisons in population research", *Demography*, vol. 1, No. 1 (1964), pp. 296–315.

[9] In a simple regression, random measurement error in the independent variable will lead to an underestimation of the regression coefficient which is a function of the measurement-error variance in relation to the true-value variance; see J. Johnston, *Econometric Methods* (New York, McGraw Hill, 1963), pp. 148–150.

[10] A. I. Hermalin, *loc. cit.*, p. 267.

2. *Conceptual model*

Having considered the types, sources and quality of data, one can return to the question of the conceptual model to be employed. Due to the absence of a well-developed theory of the determinants of aggregate fertility, most applications of areal multivariate analysis have adopted a general framework that views fertility as a function of other demographic characteristics, the level of development or modernization and inputs from the programme. This broad approach[11] characterizes the analyses of Simmons[12] for India; of Riew[13] for the Republic of Korea; of Jones[14] for Barbados; of Taucher and Bocaz[15] for Chile; and of Hermalin.[16] There have also been recent studies[17] in which countries were units of areal analysis and in which the hypothesis was that fertility is interrelated with other demographic characteristics, the level of development and programme inputs. The precise indicators of development used in these analyses vary widely but centre around educational measures, labour force characteristics (proportion in non-agricultural occupations and/or proportion of women economically active), child mortality, the proportion in urban areas and *per capita* income. For measures of family planning programme input, these investigators have utilized the number of clinics, the number of workers or doctors, or hours of effort by field personnel. Some of the demographic characteristics, such as density, proportion urban or child mortality, are taken as indicators of development; others are used to control the dependent variable for non-fertility factors. For example, if the total fertility rate or an age-specific fertility rate is the dependent variable, a measure of age at marriage or the proportion married in a key age group should be included with the independent variables to control for the effect of nuptiality on those fertility measures. The particular fertility measure used as dependent variable will of course determine whether any demographic variables are needed as controls, and if so, which ones to select.

In contrast to these generalized development models, Schultz[18] employs a more detailed model of fertility determination based on the environmental constraints and opportunities that influence the number of surviving children parents want, the level of child mortality and the family planning activities viewed as assisting the avoidance of unwanted births. For example, the level of adult education is taken as indicative of the demand for higher quality children as well as of the ability to avoid unwanted births, and the level of secondary school enrolment reflects the cost of child-rearing. Although areal variables are used, the model is individualistic in formulation and the results are often interpreted on that level, which raises questions as to the appropriateness of areal data for testing and estimating this model.

The explication of a conceptual model will often lead to a number of equations. That is, the model will not only specify the determinants of fertility but may indicate independent-dependent relationships among other characteristics. In this case, it is important that the full system be developed, because the appropriate technique for estimating any equation that is part of a system must take into account the nature of the assumptions about the correlation of error terms across equations.[19]

It is assumed that, at this point, the potential user of areal multivariate analysis has determined that appropriate data exist and has some conceptual models in mind. Section C provides a detailed example of this approach which will allow introduction of a number of additional issues as well as illustrations of those discussed earlier.

C. Application of method

1. *General development model*

The detailed example of areal multivariate analysis presented in this section is applied to a general development model of fertility. Table 92 provides the data set to be used. It lists for 56 areas of a country in East Asia (Country C) 25 variables of a demographic, socio-economic and family planning nature. The 56 areas are a subsample of a larger number of areas for which such data are available. In this first model, concern is with the first 18 variables. The variables are taken from the sources described in the previous section and are defined in table 93. Note that, for convenience, decimal points have been omitted from table 92, and the definitions are in accord with the form in which the data are shown.[20]

Figure VII displays the model to be estimated. The diagram uses the conventions of path analysis, a multivariate technique useful in explicating linear causal mo-

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[11] Within this broad approach there are still differences among the investigations. Some were begun with a more explicit model; others took a more heuristic approach.

[12] George B. Simmons, *The Indian Investment in Family Planning* (New York, The Population Council, 1971);

[13] John Riew, "The family planning programs in Korea—an analysis of achievement and cost", University Park, Pennsylvania State University, 1971 (mimeographed).

[14] Huw W. Jones, "Fertility decline in Barbados: some spatial considerations", *Studies in Family Planning*, vol. 8, No. 6 (June 1977), pp. 157–163.

[15] Erica Taucher and Albino Bocaz, "Application of methods of measuring the impact of family planning programmes on fertility: the case of Chile", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII.2), pp. 107–135.

[16] *loc. cit.*

[17] S. K. Srikantan, *op. cit.*; Ronald Freedman and Bernard Berelson, "The record of family planning programs", *Studies in Family Planning*, vol. 7, No. 1 (January 1976), pp. 1–40; and W. Parker Mauldin and Bernard Berelson, "Cross-cultural review of the effectiveness of family planning programs", in *International Population Conference, Mexico 1977* (Liège, International Union for the Scientific Study of Population, 1977), vol. 3, pp. 163–186.

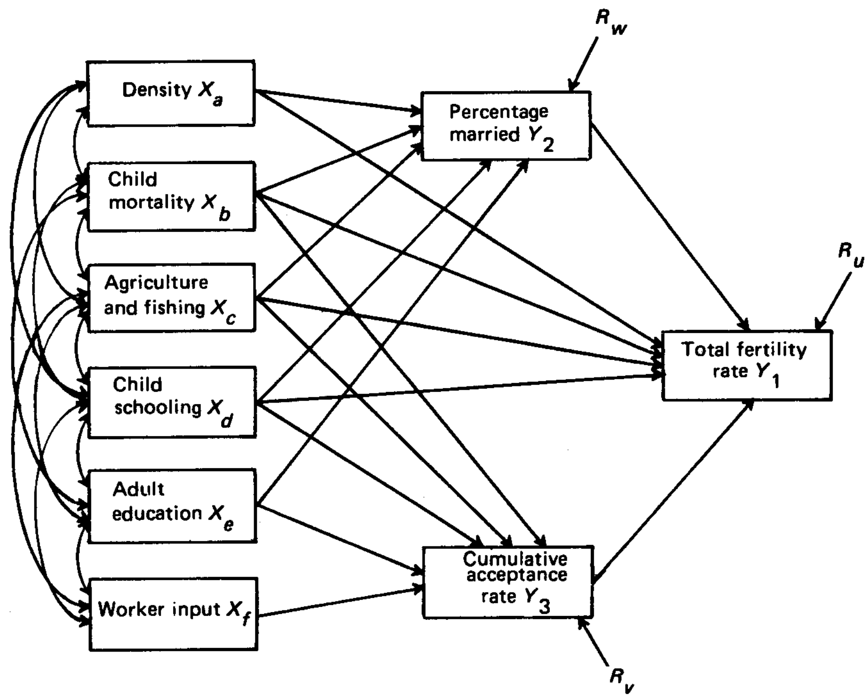
[18] T. Paul Schultz, *The Effectiveness of Population Policies: Alternative Methods of Statistical Inference*, report P-4663 (Santa Monica, Cal., Rand Corporation, 1971).

[19] J. Johnston, *op. cit.*, p. 231.

[20] Most of the variables are rates or proportions and require no further elaboration. Note should be taken of variables 15 and 16, the child-schooling index. This index has as its numerator all those in school above age 12 or 15 (depending upon the year in question) and in the denominator the population of just one age group (12–19 or 15–19). Hence, this index can go above 1,000, which happens in two areas. It might be noted also that Country C has a fairly late age at marriage, so that the proportion married at ages 20–24 well captures differentials in age at marriage across areas. In another study it was found that this variable correlates −0.90 with the singulate mean age at marriage.

dels. Path analysis bears close affinities to multiple regression analysis but helps make explicit the underlying assumptions and interrelationships.[21] The variables in figure VII are arranged in a temporal and/or presumed causal sequence. Each variable occurs earlier in time than those appearing to the right of it and later than those to the left of it, and can be affected by all the variables that precede it. The direct or net influences from one variable to another are represented by the one-way straight arrows and the curved, bi-directional arrows represent the correlations between the exogenous variables which are unanalysed in the model. It will be noted that, in the interest of clarity, not all of the possible curved arrows are shown in figure VII.

Figure VII. Path diagram of factors affecting total fertility rate



Note: The signs and magnitudes associated with the straight arrows are path coefficients (see text for definition and table 96 for values). The path coefficients from the residuals R_u, R_v and R_w are calculated as $\sqrt{1-R^2}$, where R^2 is the coefficient of determination for the respective endogenous variables, as given in table 96.

The model displayed in figure VII posits that the total fertility rate of an area is affected, among other things, by: (*a*) the percentage married at ages 20–24; and (*b*) the cumulative acceptance rate lagged nine months (since acceptances beyond March of the given year cannot affect that year's fertility). The proportion married serves as a control for nuptiality differences among areas which affect age-specific rates and hence total fertility. In addition, the total fertility rate is viewed as being affected by four of the exogenous variables—density, child mortality, the proportion of the labour force in agriculture and fishing, and the index of secondary-school enrolment. Note that it is assumed that the level of adult education influences fertility only indirectly, through its effect on the percentage married;[22] similarly, it is assumed that the amount of worker input influences fertility only through its effect on the level of acceptances.

Although the omission of the direct path to fertility from worker input might be postulated on theoretical grounds, it should be stressed that the omission here of the direct path from adult education is based on prior testing of this model for a series of years and a larger number of areas, which showed that the direct influence was negligible. This point illustrates one approach to theory development which Heise[23] calls "theory trimming": one begins by postulating all the possible direct influences and

[21] For detailed expositions of this technique, see Otis Dudley Duncan, "Path analysis: sociological examples", *American Journal of Sociology*, vol. 72, No. 1 (July 1966), pp. 1–16; and Kenneth C. Land, "Principles of path analysis", in Edgar F. Borgatta, ed., *Sociological Methodology* (San Francisco, Cal., Jossey-Bass Inc., 1969), pp. 3–37. The presentation in this chapter draws heavily on the work of Duncan.

[22] Figure VII also indicates that adult education would have an indirect effect on fertility through its influence on the cumulative acceptance rate.

[23] David R. Heise, "Problems in path analysis and causal inference", in Edgar F. Borgatta, ed., *Sociological Methodology* (San Francisco, Cal., Jossey-Bass Inc., 1969), pp. 38–73.

then deletes those which are negligible in order to achieve the most parsimonious model.

The exogenous (or predetermined) variables shown on the left side of figure VII, which the theory does not seek to explain, are demographic and socio-economic measures which reflect the level of urbanization and development in an area. However, this statement does not apply to the worker-input measure which is included to test for the relation of programme input to programme output, i.e., acceptances. This approach is in keeping with the general development approach discussed earlier. Though other socio-economic measures are available, they were excluded from the model to avoid the problem of multicollinearity, which makes it difficult to estimate reliably the individual effects of highly intercorrelated variables;[24] and the problem of redundancy, arising from the tendency of a cluster of intercorrelated variables to divide their joint effect and thereby reduce the apparent influence of any one characteristic.[25] The socio-economic measures used in figure VII have been lagged two to three years behind the date of the fertility variable on the presumption that there is a delay before developmental changes affect fertility.

The relationships shown in figure VII may be set forth in a series of equations, in accord with the conventions of path analysis:

$$Y_1 = p_{12} Y_2 + p_{13} Y_3 + p_{1a} X_a + p_{1b} X_b + p_{1c} X_c + p_{1d} X_d + p_{1u} R_u \quad (1)$$

$$Y_2 = p_{2a} X_a + p_{2b} X_b + p_{2c} X_c + p_{2d} X_d + p_{2e} X_e + p_{2w} R_w \quad (2)$$

$$Y_3 = p_{3b} X_b + p_{3c} X_c + p_{3d} X_d + p_{3e} X_e + p_{3f} X_f + p_{3v} R_v \quad (3)$$

In the equations, each variable is in standard form; the Y_i variables are considered endogenous, those which the model seeks to account for; the X_i are the exogenous variables, which the theory does not attempt to explain; and the R_i are the residual effects of unmeasured variables, which are uncorrelated with the other determining variables in each equation. In this system, each dependent variable is treated as completely determined by some set of variables in the model, including where necessary the unmeasured residuals. The p_{ij} in the equations are the path coefficients which represent the direct effect on variable i from variable j.

The model in figure VII does not postulate any reciprocal causation or feedback between variables. This point is also established by the equations of the system in that there is no instance where both p_{ij} and p_{ji} appear. Such a system is termed "recursive" and under the assumption that the residual effects are uncorrelated with each other and with the exogenous factors in the model, the system of equations can be solved equation by equation by ordinary least squares.[26] In this case the path coefficients will be equal to the partial regression coefficients in standard form, or the beta coefficients, of the multiple regression equation. For example, for equation (2) given above, $p_{2a} = \beta_{2a \cdot bcde}$; $p_{2b} = \beta_{2b \cdot acde}$; $p_{2c} = \beta_{2c \cdot abde}$; $p_{2d} = \beta_{2d \cdot abce}$; $p_{2e} = \beta_{2e \cdot abcd}$, obtained from the regression of Y_2 on X_a, X_b, X_c, X_d and X_e.

One may also solve for the unknown path coefficients by making use of the "basic theorem of path analysis", which may be written generally as

$$r_{ij} = \sum_q p_{iq} r_{jq}$$

where i and j are two variables and q runs over all the variables which have paths leading directly to variable i.[27] Application of this relationship leads to a set of simultaneous equations which can be solved for the path coefficients by using the observed correlations contained in the equations.[28] The following example illustrates a multiple regression, the standard partial coefficients of which are identical to the path coefficients in the formula given above.

An illustrative example

The model set forth in figure VII and equations (1), (2) and (3) is applied below to the data in table 92 for two points in time: 1966, shortly after the programme began; and 1972, when the programme was well under way. For 1972, two versions of the model are estimated: the first maintains the exogenous development indicators at their pre-programme levels; the second advances those indicators in time to maintain the same lag established for the 1966 model. Table 95 defines the variables entering each of these models in terms of the variable numbers and specifications identified in tables 92 and 93. The first approach to the 1972 model is labelled "fixed" in table 95 and the second "moving". The point of two regressions is to allow examination of the effect of slightly different specifications on the estimates obtained, in keeping with the earlier discussion of the sources of sensitivity in areal multivariate analysis.

Table 94 presents the correlation (2) matrix of the 18 variables entering these models as well as the mean and standard deviation of each variable. The correlation matrix forms a useful intermediate step between the data and the regression results. From table 94 it can be seen, for example, that there is a high positive correlation between the total fertility rates in 1966 and 1972 (variables 1 and 2),

[24] J. Johnston, *op. cit.*, pp. 201–207.

[25] Robert A. Gordon, "Issues in multiple regression", *American Journal of Sociology*, vol. 73, No. 5 (1968), pp. 592–616.

[26] More precisely the model given by equations (1)–(3) is not fully recursive because no influence is posited from Y_2 to Y_3 or vice versa. Hence, certain of the residuals may be correlated, namely, R_w and R_v. Knowledge that the assumption of independence among residuals is unwarranted may come from information on the nature of these unmeasured factors and their presumed influences or by tests on the correlations of estimated residuals. In addition, if a model posits reciprocal influences between two or more endogenous variables, it can be shown that the conditions for using ordinary least squares are not met. If for any of these reasons the assumption of independence of residuals is not maintained, then a technique such as two-stage least squares or another alternative is called for. For further discussion of these points, see A. I. Hermalin, *loc. cit.*, pp. 284–286; and for a description of alternative techniques, see J. Johnston, *op. cit.*, chap. 9.

[27] O. T. Duncan, *loc. cit.*, pp. 5–6.

[28] An example of developing these simultaneous equations is presented in A. I. Hermalin, *loc. cit.*, p. 282. This source also illustrates how the implied correlations from the model can be derived by use of the basic theorem for comparison with the observed correlations and how to explicate the indirect effects inherent in the model.

TABLE 92. DATA FOR 25 DEMOGRAPHIC, SOCIO-ECONOMIC AND FAMILY PLANNING VARIABLES FOR 56 AREAS

Area	Variable 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	4 645	3 680	54	49	62	400	901	958	13	122	58	62	783	330	517	533	10	85	49	256	0	128	656	10	8
2	4 035	3 385	50	46	153	744	802	849	20	172	63	67	765	425	696	752	28	130	132	179	45	119	666	13	24
3	5 215	4 330	54	45	90	572	703	723	26	232	52	58	989	536	491	326	0	196	85	74	37	86	1 002	28	0
4	4 820	3 395	60	51	111	694	729	767	13	106	54	61	1 359	450	614	610	26	163	86	143	57	130	957	5	19
5	5 440	3 445	70	54	84	668	664	731	36	185	50	58	1 402	450	423	511	12	152	71	173	19	138	1 254	6	11
6	4 100	3 105	48	40	193	749	769	819	25	277	47	56	1 173	635	531	467	32	162	153	150	75	150	887	38	28
7	5 365	4 100	71	55	165	649	573	584	72	579	27	36	1 568	773	411	305	61	255	145	225	150	157	1 422	33	53
8	5 280	3 670	76	54	91	638	655	687	44	320	47	57	1 171	626	532	638	9	151	77	83	0	135	714	42	9
9	5 565	4 035	60	47	136	691	614	629	84	726	36	49	717	508	601	368	42	219	99	267	53	140	557	53	36
10	5 160	3 925	54	46	56	402	626	638	69	462	34	45	1 683	835	351	246	17	164	39	132	0	151	889	71	11
11	4 080	3 210	50	39	180	648	723	753	26	162	62	67	829	587	824	767	35	169	161	239	43	132	859	46	33
12	5 245	4 015	50	45	104	577	592	601	76	648	33	41	1 196	805	444	250	45	226	85	45	45	158	846	30	38
13	4 440	3 580	50	40	208	830	555	563	76	690	45	55	1 096	361	553	386	102	228	178	146	63	137	883	30	94
14	4 500	3 120	53	45	182	648	607	622	56	571	54	62	1 136	564	423	423	16	124	156	182	45	130	854	28	16
15	4 455	3 390	52	38	77	518	672	686	57	476	54	52	1 383	408	432	380	9	163	70	279	23	151	1 014	9	9
16	4 730	3 720	47	36	76	533	680	697	57	447	43	49	1 662	468	504	423	11	155	67	75	9	169	935	2	10
17	4 870	3 530	58	49	157	648	676	696	64	521	47	58	1 395	561	407	332	43	259	138	132	57	142	1 013	17	33
18	5 045	3 790	62	54	222	788	577	591	79	804	49	52	1 163	489	510	293	91	316	198	133	144	127	819	24	79
19	4 840	3 795	54	44	90	481	659	665	83	669	42	49	1 944	674	390	191	14	231	83	77	0	180	1 350	10	14
20	4 105	3 645	56	45	117	484	657	662	90	812	23	33	1 150	427	325	246	15	171	85	132	13	173	894	44	12
21	4 340	2 990	55	46	142	725	627	615	51	480	45	53	949	465	520	404	21	156	118	179	71	142	744	50	18
22	4 505	3 225	61	49	118	490	531	545	64	545	38	49	1 290	556	502	384	36	172	102	160	32	158	971	55	32
23	4 695	3 435	52	46	170	618	520	522	74	633	46	46	1 130	576	462	309	39	241	113	175	53	150	809	54	32
24	4 615	3 385	67	60	129	558	594	574	57	475	60	49	1 239	716	352	387	52	229	109	130	111	142	904	58	43
25	4 505	3 165	58	42	139	605	713	722	39	374	43	49	1 424	508	564	453	65	265	125	140	100	166	1 059	63	56

26	5 395	3 585	77	61	118	669	583	599	82	798	18	23	1 787	655	357	194	4	153	99	128	115	175	1 013	66	4
27	4 030	2 850	53	38	128	506	810	830	13	123	50	57	939	487	648	656	25	123	110	330	71	129	755	59	17
28	5 060	3 085	67	51	138	604	594	604	80	790	25	35	1 382	912	306	237	73	271	116	17	51	175	1 223	51	64
29	4 820	3 060	75	60	178	618	551	561	84	744	33	43	1 208	913	429	290	70	221	141	78	94	157	966	56	62
30	4 220	2 800	57	44	74	478	627	630	71	674	31	41	1 147	648	584	419	5	124	64	220	20	154	965	46	5
31	4 345	2 980	64	53	110	590	784	828	18	109	46	54	844	461	634	664	26	124	101	276	86	141	633	15	25
32	5 845	4 475	59	59	66	579	702	739	68	371	19	28	1 399	652	406	244	49	231	60	117	25	155	975	27	47
33	5 730	4 145	62	55	69	262	525	527	91	808	24	30	583	273	298	187	87	195	63	0	0	152	620	21	87
34	4 455	3 950	47	46	110	555	682	690	55	389	25	34	1 151	645	431	311	69	318	72	182	23	154	783	15	56
35	5 040	4 025	54	46	15	514	737	753	56	512	21	32	1 437	863	279	175	8	198	12	140	18	161	1 257	16	5
36	3 975	2 605	57	41	136	484	764	784	19	151	48	56	851	441	757	714	17	108	122	50	109	136	772	18	15
37	4 690	3 415	63	55	160	619	651	664	68	685	28	36	811	433	445	334	44	166	136	118	108	152	784	25	38
38	4 910	2 940	57	44	94	558	643	655	70	609	52	58	1 176	432	424	447	107	335	87	176	59	135	952	29	93
39	4 300	3 370	55	46	133	669	663	670	58	520	40	46	818	613	593	476	105	373	114	229	0	170	892	30	87
40	6 585	4 820	72	64	62	440	434	451	81	710	31	40	1 778	691	384	228	81	319	39	75	19	163	1 421	95	59
41	4 745	3 260	56	46	96	457	646	752	26	220	52	59	1 417	644	393	555	6	130	86	174	72	131	903	96	4
42	6 670	3 975	81	71	52	550	486	508	74	728	60	61	2 083	1 209	281	152	65	307	45	91	109	140	1 855	122	53
43	5 425	3 680	71	57	85	623	467	480	80	752	42	49	1 396	1 020	298	262	55	269	73	261	87	99	1 244	100	44
44	3 375	2 510	44	31	71	386	959	1 002	4	30	75	77	483	383	1 065	1 514	24	105	58	392	52	107	356	0	20
45	4 515	3 330	57	46	82	542	977	1 014	8	29	56	66	832	344	451	642	23	116	72	304	51	131	653	0	19
46	3 370	2 685	42	31	66	494	1 085	1 081	2	7	65	70	652	216	760	797	23	150	52	273	45	114	640	0	17
47	3 795	3 035	45	36	91	498	1 042	1 053	6	22	61	65	706	336	688	680	26	133	61	333	39	126	548	0	20
48	5 000	3 590	66	51	118	555	840	857	3	42	43	50	1 499	636	696	530	32	143	100	235	59	122	982	0	26
49	4 830	3 710	65	48	147	612	772	803	7	73	43	52	1 493	586	578	543	72	213	132	179	107	116	1 058	0	67
50	4 350	3 075	62	41	131	556	792	820	4	46	46	55	928	350	886	814	39	188	105	433	33	114	843	0	32
51	4 165	3 035	56	38	190	601	878	901	11	94	58	63	1 065	486	605	713	44	176	174	178	22	119	751	0	37
52	3 655	2 700	50	39	172	520	911	939	10	100	61	68	901	453	961	1 042	39	150	145	317	111	138	565	0	31
53	3 845	2 620	52	39	132	650	796	846	13	82	53	61	850	389	928	840	15	103	117	340	21	124	721	0	10
54	4 100	2 955	55	44	151	565	872	897	5	53	52	56	795	391	733	688	21	132	117	391	43	134	564	0	15
55	3 090	2 520	33	30	117	545	1 057	1 067	2	23	65	70	649	356	916	866	24	140	102	500	16	116	451	0	19
56	4 355	3 205	60	50	65	437	850	875	17	187	46	55	790	487	668	522	33	141	50	170	19	141	618	0	25

a common finding when studying variations in fertility over time among areas. Fertility at each point in time is highly correlated positively with the proportions married, as expected (variable 1 *versus* 3; and variable 2 *versus* 4). There is a modest negative correlation between acceptances and fertility at the earlier time point (variable 1 *versus* 5) but almost no relation at the later date (variable 2 *versus* 6). At each point in time, fertility is negatively related to density, the level of education and the child-schooling index and is positively related to the proportion of the labour force in agriculture and the level of child mortality. All of these relations are in accordance with expectations about the influence of urbanization and modernization on fertility. Table 94 also shows that many of the socio-economic indicators are highly intercorrelated. For example, the correlation between density (1963) and the agricultural labour force (1964) is −0.86 (variable 7 *versus* 9); between agricultural labour force (1964) and adult education (1964), it is −0.67 (variable 9 *versus* 11); and between adult education (1970) and the child-schooling index for (1970), it is +0.76 (variable 12 *versus* 16). Lastly, note should be taken that the correlation of the same indicator at two points in time is very high: it is 0.99 for density (variable 7 *versus* 8); 0.98 for agricultural labour force (variable 9 *versus* 10); 0.96 for adult education (variable 11 *versus* 12). Only for child mortality, among the five socio-economic indicators, where the correlation is 0.68 (variable 13 *versus* 14), does the intercorrelation fall below 0.90.

Table 96 presents the results of carrying out the multivariate areal analysis displayed in figure VII and equations (1), (2) and (3). The top panel shows the direct effect of the various factors on the total fertility rate. The numbers shown are the standardized partial regression coefficients, or beta weights, which in this case are the same as the path coefficients defined in equation (1). They were obtained by linear multiple regression, in which the total fertility rate was regressed against the variables given in equation (1), omitting of course the residual. These are the variables with direct paths to fertility in figure VII.

The standardized partial regression coefficients can be interpreted as the amount of change in the dependent variable in standard deviation units, associated with a one standard deviation change in the independent variable, while controlling for the other variables.[29] For example, in the results for the total fertility rate in 1966, one finds that an increase of one standard deviation in the percentage married would be associated with a 0.371 standard deviation increase in the total fertility rate, while a rise of one standard deviation in the cumulative acceptance rate would be associated with a 0.232 standard deviation decrease in the total fertility rate.

Associated with each regression coefficient is its standard error, and the ratio of the coefficient to its standard error has a *t*-distribution. Coefficients shown with an asterisk in table 96 are two or more times their standard error, indicating a 5 per cent or less probability of obtaining a coefficient of this magnitude, if the coefficient of the parent population were zero. Table 96 also presents the coefficient of determination (R^2) for each equation, which indicates the proportion of variance in the dependent variable accounted for by the independent variables.

Focusing on the total fertility rate for 1966, one sees that the independent variables together account for 78 per cent of the variance. Nevertheless, only three of the coefficients are statistically significant, in the sense defined above. As expected, the percentage married has a strong positive effect; density, reflecting urbanization, has a strong negative effect on fertility. From the standpoint of the evaluation of the family planning programme, particular interest centres on the sign and magnitude of the family planning variable which, in this case, is the cumulative acceptance rate. For 1966, the coefficient is negative, of substantial magnitude (in relation to the other coefficients) and statistically significant. This result is thus consistent with the view that the programme helped to reduce fertility even after taking into account the modernizing trends ongoing in the country. It should also be noted that although some of the other 1966 coefficients are of from moderate to large magnitude, they are not statistically significant, which illustrates a point made earlier about the limitations of small sample size. When this same equation was carried out for the larger number of areas for which these data are available, the coefficients for child mortality and child schooling were statistically significant. The regression equation for 1972 total fertility labelled "fixed", with the socio-economic indicators kept at their pre-programme levels, further highlights this point. Although the independent variables in total account for about half the variance, none of the coefficients is statistically significant.

The sensitivity of the results to the precise definition of the variables employed is brought out by the comparison of the "fixed" and "moving" forms of the regressions. In a number of instances the regression coefficients of a given variable vary widely from one specification to another, even though the interannual correlation among the indicators is very high, as mentioned in the discussion of the correlation. Though part of the problem can be attributed to small sample size, the same regressions with a larger number of areas still showed some lack of stability. It is likely that multicollinearity among the variables, also apparent from an inspection of the correlation matrix, contributes substantially to this type of instability. In so far as the inferences one would draw about the effect of the programme and other factors would be altered by changes in model specification of the sort illustrated here, it would be good strategy to estimate effects from a number of different models and use a weight-of-evidence approach in drawing conclusions.

[29] The relationship between the standardized regression coefficient and the unstandardized or metric coefficient can be expressed simply as

$$P_{ij} = b_{ij}\frac{s_j}{s_i}$$

where p_{ij} = the standardized coefficient;
b_{ij} = the unstandardized coefficient;
s_j and s_i = the standard deviations of the independent and dependent variables, respectively.

Situations where one may prefer the unstandardized coefficient are discussed in A. I. Hermalin, *loc. cit.*, pp. 287–288, with further citations to the literature given there.

TABLE 93. DEFINITIONS OF VARIABLES GIVEN IN TABLE 92

Variable No.	Description
1	Total fertility rate, per 1 000 women, 1966
2	Total fertility rate, per 1 000 women, 1972
3	Percentage of women currently married, ages 20–24, 1966
4	Percentage of women currently married, ages 20–24, 1972
5	Cumulative acceptances of loops from programme through March 1966, per 1 000 married women, ages 20–44
6	Cumulative acceptances of loops from programme through December 1971, per 1 000 married women, ages 20–44
7	Density: logarithm (to base *e*) of population per square kilometre (multiplied by 100), 1963
8	Density: logarithm (to base *e*) of population per square kilometre (multiplied by 100), 1970
9	Percentage of male labour force (aged 12 and over) engaged in agriculture and fishing, 1964
10	Percentage of male labour force (aged 15 and over) engaged in agriculture and fishing, 1970 (multiplied by 10)
11	Percentage of females aged 12 and over, not in school, who are primary-school graduates or higher, 1964
12	Percentage of females aged 15 and over, not in school, who are primary-school graduates or higher, 1970
13	Child mortality measure: weighted average of death rates, ages 0–4, in 1961 and 1963 (multiplied by 100)
14	Child mortality measure: death rate at ages 0–4, 1970 (multiplied by 100)
15	Child-schooling index: population aged 12 and over still in school per 1 000 persons aged 12–19, 1965
16	Child-schooling index: population aged 15 and over still in school per 1 000 persons aged 15–19, 1970
17	Family planning worker input measure: cumulative number of woman-months of programme field-work through March 1966 per 10 000 women aged 20–44
18	Family planning worker input measure: cumulative number of woman-months of programme field-work through December 1971, per 10 000 married women aged 20–44
19	Cumulative acceptances of loops from programme through December 1965 per 1 000 married women aged 20–44
20	Users of non-programme contraception per 1 000 married women, 1965, from 1965 KAP survey
21	Users of programme contraception per 1 000 married women, 1965, from 1965 KAP survey
22	Average number of months last-but-one child was breast-fed according to 1967 KAP survey (multiplied by 10)
23	Child mortality measure: weighted average of death rates, ages 0–4, in 1964 and 1965 (multiplied by 100)
24	Distance to nearest of five largest cities (kilometres)
25	Family planning worker input measure: cumulative number of woman-months of programme field-work to end of December 1965 per 10 000 married women aged 20–44.

Note: KAP = Knowledge, Attitude, Practice.

TABLE 94. CORRELATION (2) MATRIX OF VARIABLES USED FOR GENERAL DEVELOPMENT MODEL

Variable No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
1	–	82	73	82	−29	01	−72	−69	62	57	−51	−53	65	59	−72	−72	29	50
2		–	38	58	−28	−02	−55	−54	55	48	−54	−56	51	40	−65	−70	22	47
3			–	88	−05	12	−59	−56	40	41	−39	−42	51	54	−49	−45	23	29
4				–	−12	10	−65	−63	53	52	−46	−52	51	59	−64	−62	30	40
5					–	67	−09	−09	−01	06	12	13	−18	−12	23	11	32	11
6						–	−20	−19	09	12	03	05	07	08	01	−09	22	23
7							–	99	−86	−85	56	61	−57	−59	70	75	−38	−56
8								–	−88	−88	58	63	−55	−58	70	76	−41	−59
9									–	98	−67	−71	47	50	−74	−80	38	59
10										–	−64	−68	44	50	−72	−79	41	59
11											–	96	−39	−38	59	72	−20	−35
12												–	−42	−41	65	76	−22	−40
13													–	68	−62	−61	05	40
14														–	−56	−54	18	47
15															–	90	−19	−46
16																–	−26	−54
17																	–	80
Mean	4 666	3 412	58	47	118	573	707	728	45	392	45	52	1 150	556	540	484	38	190
Standard deviation	705	509	9	8	45	105	149	155	30	274	13	12	358	192	186	253	28	67

Notes: Correlations are shown to two places with decimal points omitted.
For definition of variables, see table 93. Means and standard deviations are shown in the units defined in table 93.

TABLE 95. DEFINITIONS OF VARIABLES USED IN REGRESSIONS OF TABLE 96

	Variable No. given in table 93		
		1972	
	1966	Fixed	Moving
Total fertility rate (Y_1)	1	2	2
Percentage married (Y_2)	3	4	4
Cumulative acceptance rate (Y_3)	5	6	6
Child mortality (Y_b)	13	13	14
Agriculture and fishing (X_c)	9	9	10
Child schooling (X_d)	15	15	16
Density (X_a)	7	7	8
Adult education (X_e)	11	11	12
Worker input (X_f)	17	18	18

TABLE 96. STANDARDIZED PARTIAL REGRESSION COEFFICIENTS (BETAS) AND COEFFICIENT OF DETERMINATION (R^2) FOR SPECIFIED COMBINATIONS OF VARIABLES ($N = 56$)

Independent variables	1966	1972 Fixed	1972 Moving
Dependent variable: total fertility rate			
Percentage married	0.371*	0.271	0.250
Cumulative acceptance rate	−0.232*	−0.061	−0.099
Child mortality	0.117	0.144	−0.072
Agriculture and fishing	−0.021	0.152	−0.329
Child schooling	−0.187	−0.291	−0.706*
Density	−0.340*	0.030	−0.191
R^2	0.78	0.49	0.56
Total fertility rate:			
Mean	4 666	3 411	
Standard deviation	705	509	
Dependent variable: percentage females married, aged 20–24			
Adult education	−0.192	−0.132	−0.133
Agriculture and fishing	−0.630*	−0.455*	−0.345
Child schooling	−0.190	−0.418	−0.262
Child mortality	0.166	0.039	0.280*
Density	−0.793	−0.655*	−0.488*
R^2	0.47	0.54	0.52
Percentage married:			
Mean	57.8	46.9	
Standard deviation	9.3	8.3	
Dependent variable: Cumulative acceptance rate			
Worker input	0.319*	0.259	0.237
Adult Education	0.098	0.114	0.304
Child schooling	0.388	0.213	−0.131
Agriculture and fishing	0.239	0.132	0.099
Child mortality	−0.033	0.082	−0.024
R^2	0.20	0.08	0.09
Cumulative acceptance rate;			
Mean	117.9	573.1	
Standard deviation	44.6	105.3	

Notes: For figures with an asterisk (*), the regression coefficient is two or more times its standard error.
For definitions of variables, see table 95.

The regressions for the percentage married suggest that the more modern and urbanized areas have lower proportions married, as expected. The sign of the labour force variable, however, is surprising and is not consonant with this view. It is possible that the multicollinearity mentioned above accounts in part for this effect. The equations in which the cumulative acceptance rate is the dependent variable indicate that worker input has a positive effect on acceptances, even after controlling for other factors, though the coefficient is statistically significant only for 1966.

When the effects of the programme can be tested at two or more points in time, as shown in table 96, it is also possible to make some inferences about changes in effects. Thus, the results presented would suggest that the programme had more effect at an earlier stage, 1966, than later, 1972; and that "worker inputs" were more important in obtaining family planning acceptors at the earlier stage. The reader is reminded, however, that the regressions shown in table 96 are for the purpose of illustrating the areal multivariate approach and that the results obtained here are somewhat different from those obtained from the larger set of areal observations.[30] The smaller set was chosen to facilitate presentation of the complete data set utilized (as given in table 92), so that the reader can replicate the results presented as well as test other models.

The models tested up to this point have been cross-sectional in nature and dynamic inferences from such models are severely limited. For example, despite the use of lagged socio-economic indicators, a finding that child schooling influences fertility does not mean that changes in schooling within an area are associated with intra-area changes in fertility over the time period specified; nor does the absence of a significant effect mean that this indicator had no influence on intra-area fertility changes.[31]

When cross-sections for several years are available, a method of utilizing pooled time series of cross-sections,[32] can yield improved estimates of the dynamic relationships. Towards this end, one might also employ a first-difference model in order to remove area-specific time-invariant effects, which can bias the results obtained in single cross-sections. To estimate such a model, observations of the dependent and independent variables are required at two points in time. The first 18 variables presented in table 1 meet this criterion. In a first-difference model, the change in fertility becomes the dependent variable; and the changes in the socio-economic, demographic and programme variables are the independent variables. It should be mentioned that typically first-difference models explain only a small proportion of the variance in the dependent variable, and few of the factors are statistically significant. This situation occurs, among other reasons, because variables in their first-difference form are likely to have much smaller

[30] Albert I. Hermalin, "An areal analysis of the effect of acceptances on fertility", *Studies in Family Planning*, No. 33 (August 1968), pp. 7–12.

[31] For illustrations of this point and further discussions of the limitations of dynamic inference, see A. I. Hermalin, "Regression analysis of areal data", *loc. cit.*, pp. 292–293.

[32] Described in Marc Nerlove and T. Paul Schultz, *Love and Life Between the Censuses: A Model of Family Decision-Making in Puerto Rico, 1950–1960*, report RH-6322-AID (Santa Monica, Cal., Rand Corporation, 1970), pp. 37–42.

variation than in their original form and hence are more likely to be sensitive to random measurement error, which attenuates the regression coefficient.[33]

2. *Models based on "intermediate variables"*

The models

In section A, it was stated that certain classes of variables, often considered central to the determination of fertility, are rarely available on an areal level. Reference was made in that discussion to biological factors or to what has been termed the "intermediate variables"[34]—factors affecting exposure to intercourse and conception and those affecting gestation and successful parturition. Clearly, most of the variables used in the examples given of areal multivariate analysis are at some remove from the microphysiological components of the reproductive process which figure largely in the births averted techniques for studying the effect of a programme. In so far as such variables as education or labour force have effects on fertility, they do so because they affect one or more of the "intermediate variables". Accurate measurement of the whole set of "intermediate variables" is difficult to achieve at any level, and certainly they are not available from the usual sources of areal statistics. It was stated earlier, however, that KAP and fertility surveys of sufficient size can be used to develop aggregate measures for the sampling points included of the surveys. This section illustrates this approach.

Data from two KAP surveys in the country of interest taken in the last quarters of 1965 and 1967 are used to form "intermediate variables" likely to affect fertility. Interviews were conducted in the 56 areas for which data in table 92 were presented. (Indeed, it was the knowledge that these areas were the sampling points of the surveys which led to their selection for the work mentioned above.) The method of stratifying the areas for sampling purposes assumed that these primary sampling points were representative in terms of levels of fertility, education and urbanization. The first survey contained about 3,700 interviews and the second close to 5,000 interviews.

From the 1965 survey, a measure of non-programme contraceptive use was developed, defined as the proportion of married women not using the loop (the programme method at that time) who reported using other forms of contraception (shown as variable 20 in tables 1 and 2). This survey also was used to develop a measure of programme use, based on the proportion of women who reported using the loop (variable 21 in tables 92 and 93). The 1967 survey was used to estimate the average months of breast-feeding in each area. Since the question dealt with the length of lactation of the next to last child, the reference period is indeterminate but is used for want of a better measure as representative of the situation in 1965. These results are given as variable 22 in tables 92 and 93. Along with these variables, use also is made of two characteristics appearing in the previous model which are available from the usual statistical sources for areas: the percentage married in 1966 (variable 3); and the cumulative acceptance rate to the end of December 1965 (variable 19), the latter taken as another indicator of programme contraceptive use. This set of variables is used as determinants of the total fertility rate in 1966 as a way of testing the adequacy of the "intermediate" model.

Interpretation of the results

Table 97 presents the correlation matrix of the above-mentioned set of variables along with a number of socio-economic characteristics that figure in the analysis. The matrix shows that there is a strong negative correlation between total fertility and non-programme contraception (variable 1 *versus* variable 20); that there is little correlation between programme and non-programme contraceptive use (variable 20 *versus* 21); and that the indicator of programme use taken from service statistics (variable 19) is only moderately correlated with the measure derived from the survey (variable 21). This latter result no doubt reflects differentials in continuation rates across areas as well as measurement error in estimating the level of use in an area from a relatively small number of interviews.

The results of the multivariate analysis are presented in table 98. The first two columns test whether the "intermediate" variables developed can adequately explain areal differentials in fertility. In these regressions, the total fertility rate in 1966 is regressed against the measure of non-programme contraceptive use, a measure of programme contraceptive levels, the proportion married and the average months of breast-feeding. Two forms are presented: in column (1) the measure of programme contraceptive use is taken from the survey; in column (2) the measure derived from service statistics is employed. Both sets of independent variables do quite well in explaining fertility differentials in that they account for 66 and 70 per cent of the variance, respectively, which is close to the proportion of variance accounted for by the general development model (see first column of Table 96).

The regression coefficients given in columns (1) and (2) indicate that both programme and non-programme contraceptive use as well as the proportion married have large and statistically significant effects on fertility in the expected directions. The sign of the breast-feeding coefficient is in the expected direction—prolonged breast-feeding reducing fertility – but it is not significant.

Columns (3)–(6) test whether areal differentials in the "intermediate variables" can now be accounted for by socio-economic factors as hypothesized in the earlier discussion. In columns (3) and (4), the two measures of programme contraceptive use are the dependent variable and it will be seen that a mix of worker input and socio-economic indicators explain about 20 per cent of the variance (similar to the result obtained in table 96 for

[33] N. Krishnan Namboodiri, Lewis F. Carter and Hubert M. Blalock, Jr., *Applied Multivariate Analysis and Experimental Designs* (New York, McGraw Hill, 1975), pp. 524–526.

[34] Kingsley Davis and Judith Blake, "Social structure and fertility: an analytical framework", *Economic Development and Cultural Change*, vol. IV (April 1956), pp. 211–235.

1966). These independent variables, however, explain about half the variance in non-programme contraceptive use and in months of breast-feeding, as shown in columns (5) and (6).

Although few of the coefficients are significant, the indicators generally are in expected directions. Worker input affects the level of programme contraception and higher levels of development or modernization are associated with higher levels of contraceptive use and shorter periods of breast-feeding.

The results of testing the "intermediate model" are encouraging from a number of aspects:

(a) From a methodological standpoint they illustrate the potential benefits of using survey data to enrich the range of variables employed in areal analysis, which opens up the possibility of testing a wider variety of models.

(b) They help to clarify the processes underlying the general development model. The socio-economic indicators are predictive of "intermediate variables" which one rarely can measure directly on an areal level; hence, it makes sense to include them along with measures of programme input in analysing areal differentials in fertility.

TABLE 97. CORRELATION (2) MATRIX OF VARIABLES USED IN "INTERMEDIATE MODEL"

Variable No.	*1*	*3*	*9*	*11*	*15*	*19*	*20*	*21*	*22*	*23*	*24*	*25*
1	–	73	62	−51	−72	−28	−60	07	28	69	54	29
3		–	40	−39	−49	−03	−42	36	20	58	49	23
9			–	−67	−74	−03	−62	04	63	49	56	40
11				–	59	15	51	04	−67	−36	−27	−22
15					–	23	69	−02	−50	−63	−53	−20
19						–	02	51	−10	−14	−09	34
20							–	−05	−49	−48	−36	−25
21								–	−10	18	26	27
22									–	35	25	16
23										–	52	19
24											–	16
Mean	4666	58	45	45	540	99	190	52	141	888	30	33
Standard deviation	705	9	30	13	186	39	106	39	20	266	30	25

Notes: Correlations are shown to two places with decimal points omitted.
For definition of variables, see table 93. Means and standard deviations are shown in the units defined in table 93.

TABLE 98. MODELS BASED ON "INTERMEDIATE VARIABLES": STANDARDIZED PARTIAL REGRESSION COEFFICIENTS (BETAS) FOR SPECIFIED COMBINATIONS OF VARIABLES ($N = 56$)

	Dependent variables					
			Programme contraceptive use			
Independent variables	*Total fertility rate, 1966 (variable 1)* (1)	(2)	*From survey (variable 21)* (3)	*From service statistics (variable 19)* (4)	*Other contraceptive use (variable 20)* (5)	*Breast-feeding (variable 22)* (6)
Programme contraceptive use:						
From survey (V 21)	−0.185*	–				
From service statistics (V 19)	–	−0.257*				
Other contraceptive use (V 20)	−0.355*	−0.376*				
Percentage married (V 3)	0.653*	0.570*				
Months of breast-feeding (V 22)	−0.040	−0.041				
Child mortality (V 23)			0.157	−0.031	−0.087	0.103
Adult education (V 11)			0.027	0.144	0.075	−0.430*
Child schooling (V 15)			0.139	0.323	0.481*	0.086
Agriculture and fishing (V 9)			−0.217	0.193	−0.183	0.469*
Distance to city (V 24)			0.330	−0.034	0.075	−0.123
Worker input (V 25)			0.302*	0.366*	−0.064	−0.106
R^2	0.66	0.70	0.18	0.22	0.51	0.53
Mean	4 666		0.052[a]	0.099[a]	0.190[a]	14.1
Standard deviation	705		0.039	0.039	0.106	2.0

Notes: For figures with an asterisk(*), the regression coefficient is two or more times its standard error. Numbers in parentheses represent the variable numbers as given in table 93.
[a] The mean and standard deviation of these variables are shown here as proportions rather than the rates defined in table 93.

At the same time, it should be mentioned that aggregated survey data will typically be possible for only a limited number of sampling points, which might aggravate the problem of having only a small number of areal observations, as discussed earlier.

D. Conclusions

This chapter has attempted to establish the rationale of areal multivariate analysis as a technique for evaluating the effects of a family planning programme, to point up the limitations of this approach and to describe in detail the mechanics of the analysis. A set of data have been provided so that the reader can replicate the results and test other models.

The viewpoint taken is that questions about the impact of a family planning programme have a form which is congruent with the structure of areal multivariate analysis. At the same time, a number of limitations that the technique shares with other multivariate studies have been stressed. Results are likely to vary with changes in the conceptual model, the operational definitions and the techniques of estimation. Some promising developments in causal analysis, of which multivariate areal analysis is a particular example, have been mentioned. To these developments may be added:

(*a*) In the general development model, socio-economic indicators are taken as indicators of the unobserved constructs of development or modernization. Through confirmatory factor analysis[35] it is possible to incorporate these unobserved constructs into the conceptual model by means of their multiple indicators and thus bring about concordance between theoretical reasoning and analysis of observable data;[36]

(*b*) The effect of measurement error has been alluded to at several points. It is possible to include assumptions about the patterns of non-random measurement error into the model and trace their implications;[37]

(*c*) It has been pointed out here that it is possible to aggregate survey data to develop additional areal variables. Another approach is to develop cross-level models which use both individual level characteristics from the survey and data on the areas in which respondents reside for evaluation purposes. Example that combine both the individual and areal modes can be found in Duncan[38] and in Rhodes.[39]

It should be clear from the exposition presented here that areal multivariate analysis is not a technique that can be applied mechanically. The investigator should have a close knowledge both of the data-producing procedures of a country and of its demographic, social and economic trends, which provide knowledge of any changes in statistical procedures, legislation or temporary phenomena which can affect salient variables in the model and thus confound the results of a short-range areal analysis. The investigator should also seek confirmatory evidence for the inferences developed from an areal analysis from other sources. These confirmations can be:

(*a*) Alternative approaches to studying the impact of family planning programmes, presented in other chapters of this *Manual*;

(*b*) Testing, as appropriate, of the results from the areal analysis on individual level data from KAP or other surveys;

(*c*) Given the sensitivity of areal analysis to model, operational definition and statistical procedure, checking on the results from any one specification against alternative specifications to see if they lead to the same inferences about programme effect.

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[35] K. G. Jöreskog and D. N. Lawley, "New methods in maximum likelihood factor analysis", *British Journal of Mathematical and Statistical Psychology*, vol. XXI, No. 1 (1968), pp. 85–96.

[36] For a general description of this approach, see A. I. Hermalin, "Regression analysis of areal data", *loc. cit.*; for further details of the methodology, see Otis Dudley Duncan, "Unmeasured variables in linear models for panel analysis", in Herbert L. Costner, ed., *Sociological Methodology* (San Francisco, Cal., Jossey-Bass Inc., 1972), pp. 36–82; and Charles E. Werts, Karl G. Jöreskog and Robert L. Linn, "Identification and estimation in path analysis with unmeasured variables", *American Journal of Sociology*, vol. 78, No. 6 (1973), pp. 1469–1484.

[37] Paul Siegel and Robert W. Hodge, "A causal approach to the study of measurement error", in H. M. Blalock and Ann B. Blalock, eds., *Methodology in Social Research* (New York, McGraw Hill, 1968), pp. 28–59; John J. Chai, "Correlated measurement errors and the least squares estimator of the regression coefficient", *Journal of the American Statistical Association*, vol. 66, No. 335 (July 1971), pp. 478–493; and Ronald Schoenberg, "Strategies for meaningful comparison", in Herbert L. Costner, ed., *Sociological Methodology* (San Francisco, Cal., Jossey-Bass Inc., 1972), pp. 1–35.

[38] Otis Dudley Duncan, "Residential areas and differential fertility", *Eugenics Quarterly*, vol. XI, No. 2 (June 1964), pp. 82–89.

[39] Lewis Rhodes, "Socioeconomic correlates of fertility in the metropolis: relationship of individual and areal unit characteristics", *Social Biology*, vol. 18, No. 3 (1971), pp. 296–304.

Chapter VII

SIMULATION

Jeanne Clare Ridley*

A. BACKGROUND INFORMATION

This chapter illustrates the use of computer simulation for studying the impact of family planning programmes on fertility. A number of simulation models have been developed by students in various parts of the world. These models differ in terms of their structure, the purposes for which they were developed and the techniques used to simulate data.[1] Two general types of simulation models should be distinguished: macro-simulation models; and micro-simulation models. The basic difference between these two types of models is in the way in which data are generated. With macro-simulation models, probabilities or proportions of different events are applied to subgroups of the population of interest and are permitted to operate for a specified period of time. In contrast, with micro simulation, probabilities are applied to individuals in the population.

1. *Purposes of simulation models*

The use of simulation models has a great deal of appeal and thus the advantages of these models tend to be stressed. As experimentation with human populations is not always feasible, a major advantage of simulation models is that they provide a vehicle for carrying out such experiments. Also, such models provide numerical results which thus may indicate the range of effects to be expected if certain factors affecting fertility are changed. Nevertheless, the disadvantages of the method are not to be overlooked; and consequently, this method should be used only with a great deal of caution.

To date, relatively few applications of simulation models to the problems of evaluating family planning programmes have been carried out.[2] Therefore, it is not surprising that the suitability of simulation models for such a purpose has yet to be convincingly demonstrated. Indeed, one view is that simulation models are appropriate primarily as a research tool.[3] Simulation can aid in the study of the basic biological factors affecting fertility which are not directly observable, such as fecundability; it also has a number of methodological uses, such as validating different methods of measuring the impact of family planning programmes on fertility and testing estimation procedures under different biological and demographic conditions.[4] Other methodological uses are studies of measurement error, response error, sample size and the role of chance. This chapter understandably does not illustrate the use of simulation models in general for evaluation purposes, but is concerned with one model, REPSIM-B. Others might also be adopted to advantage.

2. *Advantages of simulation models*

An important application of simulation models is undertaking experiments that differ in terms of the type of family planning programme assumed to operate. For example, a series of experiments can be run in which contraceptive effectiveness is varied. Such experiments can provide insights into the effects on fertility of different family planning programme strategies. In addition, simulation experiments can indicate the number of acceptors required to reduce fertility to specified levels. Simulation also affords a method for estimating the expected fertility of acceptors in a family planning programme that would have resulted if no means of fertility control were employed.

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* Professor, Center for Population Research, Georgetown University, Washington, D.C. Professor Ridley wishes to acknowledge comments by Alice S. Clague on an earlier version and to state that the development of REPSIM-B was a collaborative effort of the late Mindel C. Sheps, the late Joan W. Lingner, Jane A. Menken and Jeanne Clare Ridley. Her work on REPSIM-B was supported by a grant from the Ford Foundation and most recently by NICHD contract 73-2726.

[1] For a detailed description of various types of simulation models, see Jane Menken, "Simulation studies", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effects of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 351–380.

[2] Examples of such applications are discussed in J. Menken, *loc. cit.*; and in Kilambi Venktacharya, "Use of models for the study of internal parameters: illustrations and research issues", and Robert G. Potter, "Use of models in evaluating changing effects of conception behavior", both in *International Population Conference, Mexico, 1977* (Liège, International Union for the Scientific Study of Population, 1977), vol. 1, pp. 255–272 and 273–284.

[3] "Report of the Expert Group Meeting on Methods of Measuring the Impact of Family Planning Programmes on Fertility", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.XIII. 2), p. 156.

[4] Alice S. Clague and Jeanne C. Ridley, "The assessment of three methods of estimating births averted", in Bennett Dyke and Jean W. MacCluer, eds., *Computer Simulation in Human Population Studies* (New York, Academic Press, 1973), pp. 329–382.

3. *Disadvantages of simulation models*

The results obtained by simulation, however, are limited by the types of assumptions made in carrying out the experiments. Only in so far as the assumptions hold will the results from a simulation model hold. For instance, if one assumes that acceptance of family planning by women depends upon their desired family size, the assumptions regarding desired family size could lead to estimates of the probable effect of a family planning programme that never in fact are achieved.

A major difficulty in using simulation models is the volume of data required, a great deal of which are practically non-existent. Further, the more sophisticated and complex micro models, which employ Monte Carlo methods, require large-scale computers which are relatively expensive to use. Also, the structure, logic and assumptions on which the models rest is sometimes extremely complex. Consequently, users must devote a great deal of time to understanding fully a model if they are to use it appropriately.

4. *The REPSIM-B model: advantages and disadvantages*

In this chapter, REPSIM-B, a micro-simulation model, is employed as an example of the application of simulation to the problems of assessing the impact of family planning programmes on fertility. This particular model was not designed, strictly speaking, to assess programme impact from all sources of programme activity, for it recognizes only sterilization, contraception and abortion from whatever sources. To determine programme impact, some improvisation is required, as is also the case with the CONVERSE model illustrated in chapter III of this *Manual.* Thus, the choice of REPSIM-B for this general purpose is somewhat arbitrary, and it should be borne in mind that the selection of an appropriate model depends upon the particular purposes for which the measurement of the impact of a family planning programme is being undertaken.[5]

For example, because REPSIM-B is a cohort model, it does not lend itself to studying the effects of family planning programmes within a particular period of time. For this purpose a period model is necessary. Experiments similar to those run with REPSIM-B and reported in this chapter could be run with the micro-simulation model, POPREP,[6] which would give results for a cross-sectional population at specified points in time. Macro models provide vehicles for investigating different family planning programme strategies if one does not wish to manipulate a large number of variables. Although micro-simulation models are more flexible and realistic, many questions concerning the impact of family planning programmes do not require the detail available from micro-simulation models.

In section B, the basic structure and assumptions of REPSIM-B are described. In subsequent sections, the steps necessary for running experiments with REPSIM-B and the illustrative results obtained by simulating a limited number of experiments are presented.

B. Characteristics of REPSIM-B model[7]

1. *Type of model*

The model population of REPSIM-B is a hypothetical cohort of women between the ages of 15 and 50 years. The reproductive history of each woman is developed sequentially. The probability of such events as marriage, conception, contraceptive use and death may vary with age, parity and other characteristics of the woman.

The occurrence of the various events to each individual woman is treated stochastically by employing Monte Carlo methods. A random number, r, between zero and one is generated by the computer program and is compared with a probability, p, of an event occurring at a particular point in time, t. If r is $\leq p$, the event is assumed to occur at the particular point in time, t, being considered. The particular probabilities applied in the computer program of the model are those input by the user.

In most aspects, REPSIM-B may be characterized as a static or stationary model. Most of the probabilities do not change in terms of external time. Internally, however, the model is dynamic in that many of the probabilities change with age, parity or other aspects of the woman's history.

The unit of analysis in REPSIM-B is the individual woman and the unit of time is one month. Twelve calendar months make up a year of a woman's age and, for simplicity, all events occurring to a woman are assumed to take place in the middle of the month.

2. *Flexibility and options of the computer program*

The computer program is quite flexible. Either birth or marriage cohorts may be simulated. Also, the user may simulate any age period between 15 and 50. For example, interest may focus on the reproductive histories of young women and thus only ages from 15 to 20 or 25 are simulated. In addition, the user has the option of making any event inoperative. Thus, although the program provides for women to become widowed or divorced, the user may decide not to utilize these options if the particular problem being investigated concerns only women whose marriages are unbroken by widowhood or divorce.

The user also has the option of specifying the size of the cohort to be simulated. The computer program provides for cohorts of up to 100,000 women. In general, the user will find that simulating fewer than 100,000 women is more economical in terms of computer time and costs.

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[5] In many instances an analytical model may be more appropriate than a simulation model. For a discussion of the criteria in the selection of the appropriate type of model, see John C. Barrett, "Criteria for choosing between analytic approaches and simulation", in *International Population Conference, Mexico 1977* (Liège, International Union for the Scientific Study of Population, 1977), vol. 1, pp. 243–254.

[6] University of North Carolina, Department of Biostatistics, *User's Manual for POPREP and INTRVL* (Chapel Hill, N. C., 1975).

[7] For further details of the REPSIM-B computer program, see Jeanne Clare Ridley and others, *REPSIM-B Technical Manual*, 2 vol. (Washington, D.C., Georgetown University, The Joseph and Rose Kennedy Institute, 1976).

Experience to date with REPSIM-B has indicated that cohorts of 1,000 are generally sufficient for most purposes.

3. *Computer language, requirements and running time*

The computer program of REPSIM-B is written in FORTRAN IV and may be run on computers having a minimum core size of 65,000 words or 262,000 bytes.[8] By segmenting the program, minimum core size may be reduced to 48,000 words or 131,000 bytes. In addition, the REPSIM-B program requires a card-reader, a line-printer and a disc or tape to store temporarily approximately 3,000 words or 12,000 bytes.

The program has been run on the following computers: CDC-6500; CDC-6600; Univac-1108; IBM-50; IBM 360–91; IBM 370–145; and IBM 370–148. Computer running time varies with the computer being used, the size of the cohort being processed, the number of events being determined, the length of the period of observation and the number of output tables required. The running time for simulating a cohort of 1,000 women on an IBM 370–148 for the entire period of observation (i.e., ages 15–50), with all events being determined and all output tables being printed, is approximately 10 minutes.

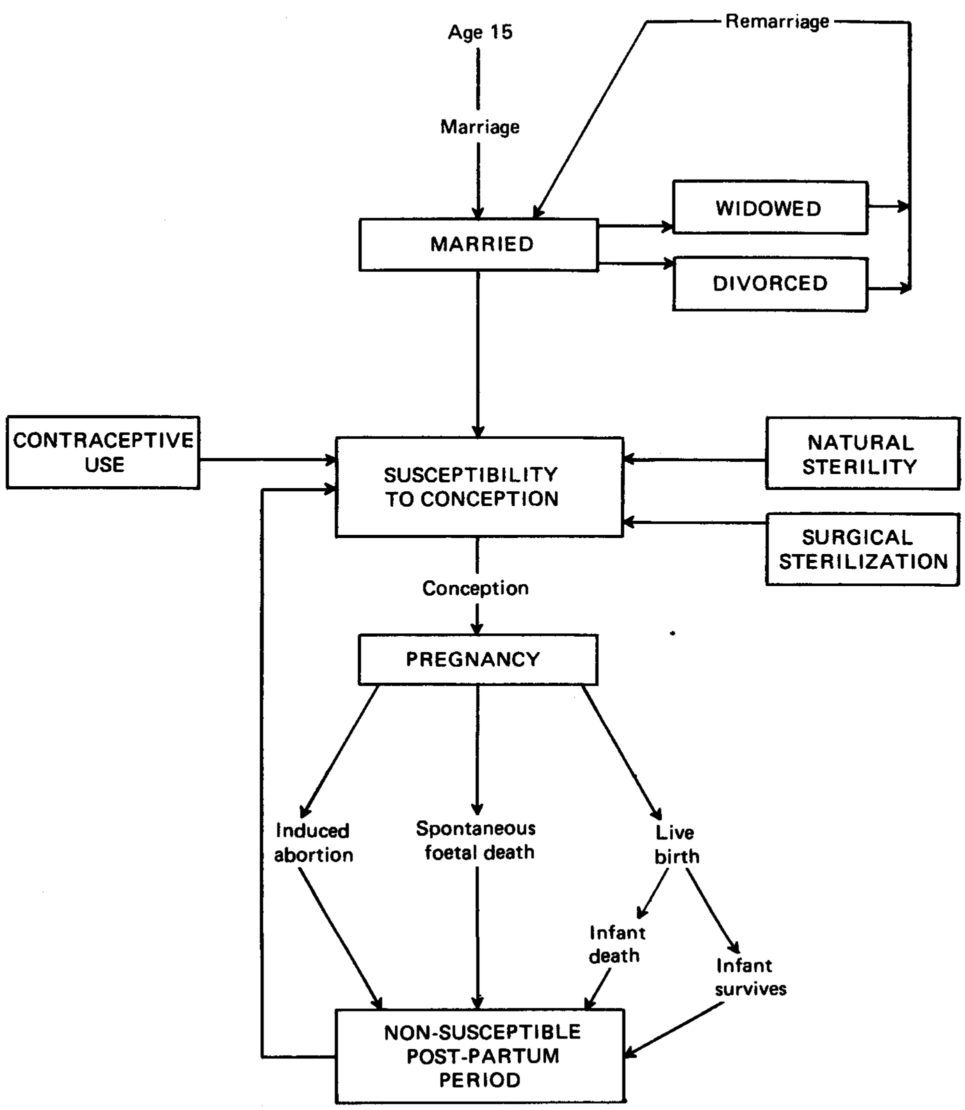
[8] *Ibid.*

C. OVERVIEW OF REPSIM-B COMPUTER PROGRAM

1. *Events and states*

Figure VIII indicates the sequence of events a woman may experience and the states into which she may pass during the reproductive period of from 15 to 50 years as

Figure VIII. Events and states for surviving women during reproductive ages from 15 to 50 years



specified in the REPSIM-B computer program. Not shown in figure VIII is the event of death, which may occur at any point in a woman's reproductive life. The various events and states can be classified as either temporary or permanent. The temporary states are marriage, divorce, widowhood, pregnancy, the non-susceptible post-partum period and the use of contraceptives. Many of the temporary states have associated probability distributions (determined by input) of the period in which a woman remains in each state. For instance, when a woman becomes pregnant, the number of months she remains pregnant is determined stochastically from the probability distribution which is an input dependent upon the outcome of the pregnancy. On the other hand, the number of months a woman remains in many of the other temporary states is determined by whether another specified event happens to her. For example, the duration of a woman's first marriage depends upon the input probabilities for death, divorce or widowhood. The permanent states are death, natural sterility and surgical sterility. The effect of these permanent states, of course, terminates the reproductive process of a woman.

2. *Fertility control*

The computer program provides for three types of fertility control: contraceptive use; induced abortion; and surgical sterility of the woman. In the case of contraceptive use, two different modules of family planning are provided for in the computer program—a developing country family planning module and a developed country module. In any particular simulation, only one family planning module may be used. Only the parameters used in the developing country module are described below, as this is the module utilized in the application of REPSIM-B[9] reported on in this chapter.

3. *Input*

Table 99 presents a summary of the input parameters specified by the REPSIM-B computer program. The user has several options in terms of the form that data are input to the program. For many of the events, parts or all of the input data may be in tabular form or part or all may be in the form of funcitional equations.

[9] *Ibid.* Details of the developed countries family planning module are given in this work.

TABLE 99. REPSIM-B PROGRAM INPUTS

Event	*REPSIM-B may vary with:* Age	Parity	GAP[a]	Other
Mortality				
Female	X[b]			
Male	X			
Child				Age of child
Infant				X[c]
Sterility				
Natural sterility	X			
Surgical sterility		X	X	
Marriage				
First marriage	X			
Age difference between spouses				Age of wife at marriage
Widowhood				Depends upon male mortality (see above
Divorce	X			Order of marriage
Remarriage from widowhood	X			
Remarriage from divorce	X			Order of marriage
Pregnancy and associated events				
Fecundability (conception)	X			Groups of women, age of natural sterility
Outcome of pregnancy:				
Spontaneous foetal death	X			Death of woman in first six months of gestation
Induced abortion		X	X	Applies only after month of availability
Live birth				Depends upon not a foetal death or induced abortion
Termination of pregnancy				Associated distributions of length of pregnancy depending upon outcome
Termination of post-partum non-susceptibility				Associated distributions depending upon outcome of pregnancy
Family planning and associated characteristics				
Month of availability				A constant
Desired family size				Individual woman
Developing countries pattern				
Initial use of contraception			X	Length of open birth interval, time since month of availability
Contraceptive effectiveness		X		A range of values
Length of practice			X	Spacing preference
Discontinuation of use			X	
Resumption of contraceptive practice			X	Length of open birth interval

[a] Difference between desired family size and number of living children. [b] Option.
[c] With associated distribution of month of death depending upon postulated level of infant mortality.

4. *Output*

The user may specify by means of the input the particular tables of output desired. In all there is provision for 38 tables of printed output. Table 100 summarizes the available output statistics of the REPSIM-B computer program. Another aspect of the output is the option through input of the program of printing out the individual reproductive histories of women or writing those reproductive histories on magnetic tape. These latter options permit the user to undertake further analyses not provided for in the printed output.

TABLE 100. SUMMARY OF OUTPUTS OF REPSIM-B PROGRAM

Measure	Comment
Mortality	
Number of women dying	By age
Number of child and infant deaths	By age of mother
Number of women surviving	By exact age
Number of women surviving	To end of simulation by order of marriage
Mean person-years lived	For total cohort and women in unbroken marriages
Infant mortality rate	
Surviving children:	
Cumulative distribution; Mean; Variance; Standard deviation; Coefficient of variation	By desired family/size and family planning status
Marriage	
Number of first marriages	By age
Number of divorces	By age
Number of marriages ending in widowhood	By age
Number of divorcees remarrying	By age
Number of widows remarrying	By age
Number single	By exact age
Number in first marriage	By exact age
Number in second marriage	By exact age
Number currently married	By exact age
Number divorced	By exact age
Number widowed	By exact age
Duration of marriage:	
Mean; Variance	For total cohort and women surviving to end of simulation
Duration of marriage:	
Mean; Variance	By order of marriage
Pregnancy	
Number of pregnancies by outcome	By age
Number of women pregnant	By exact age
Number of women pregnant	By planning status
Natality	
Number of live births	By age
Births per person-years lived	By order of marriage
Births per person-years married	By order of marriage
Age-specific birth rates:	
Single years; Five-years intervals	For all women and various marital status and family planning groups
Total fertility rates	For all women and various marital status and family planning groups
Cumulative birth rates:	
By marital duration and age at first marriage	For women in first marriage

TABLE 100 (*continued*)

Measure	Comment
Natality (continued)	
By age	For total cohort and for various marital status groupings
Completed parity:	
Cumulative frequency distribution; Mean; Variance; Standard deviation; Coefficient of variation	For total cohort, for various marital status groups, family planning groups, by level of fecundability and by desired family size
Gross reproduction rate	
Net reproduction rate	
Length of generation:	
Mean; Variance; Standard deviation	
Birth intervals by completed family size	For women surviving to end of simulation with first marriage unbroken
Birth intervals (life-table analysis):	
Mean; Variance; Standard deviation; Third moment; Fourth moment; Quartiles	For women in first marriage
Family planning	
Number of women becoming family planners	By age
Number of family planners	By exact age and current family planning status
Other	
Number of women in various states:	
Naturally sterile; Surgically sterile; Post-partum non-susceptible period	By age, by exact age and family planning status groups

D. DEFINITIONS OF PARAMETERS

The following discussion of parameters included in the computer program of the model REPSIM-B indicates the types of assumption (or rules) the computer program follows as the reproductive history of a woman is generated. Certain events may occur to a woman only if certain other events have previously occurred to her. For example, as stated above, a woman must have entered a marital union before she can experience widowhood or divorce. Secondly, some events must occur to a woman immediately before another event occurs to her. Thus, a woman can only enter the post-partum non-susceptible state if she has completed a pregnancy. Thirdly, some states have more than one possible termination. Thus, a pregnancy can be terminated by a live birth, a foetal death or an induced abortion. This latter circumstance is a competing risk situation and rules must be developed in the computer program for handling such contingencies.

The parameters included in the computer program are defined below:

(a) *First marriage.* Marriage is defined to include any type of sexual union. Inherent in the probabilities of first marriage is the assumption of an available partner. The probabilities of first marriage are a function of a woman's age. A marriage may be dissolved by a woman's death, widowhood or divorce;

(b) *Female mortality.* The time of a woman's death is determined by probabilities of dying which are a function of a woman's age. The program linearly interpolates between the yearly probabilities of dying to find the month of death;

(c) *Age difference between spouses.* The age difference between spouses may be a function of a woman's age at the beginning of a marriage. The age difference may also be specified as a constant for all married women in a cohort;

(d) *Widowhood.* The probability of a woman becoming widowed is a function of the husband's age. The husband's age is determined in the program by summing the woman's age and the age difference between a woman and her husband;

(e) *Divorce.* The probability of divorce may be a function of only a woman's age or a function of both a woman's age and the marriage order. If both widowhood and divorce are determined by the probabilities of occurring in the same month, widowhood has priority over divorce;

(f) *Remarriage.* The probabilities of remarriage following widowhood are a function of a woman's age. The probabilities of remarriage once a woman is divorced are a function of a woman's age or a function of a woman's age and the number of previous marital unions;

(g) *Fecundability.* Fecundability is defined as the monthly probability of conception. Exposure to the risk of pregnancy begins when a woman marries. As long as a woman is married, not sterile and in a fecundable state (i.e., not pregnant or in a post-partum state), she is subject to a probability of conception. Fecundability may vary with the age of the woman. It may also be adjusted to take into account a woman's age at natural sterility. Accordingly, the age at which a woman becomes naturally sterile may be preceded by a period of diminishing fecundability. In addition, at any age, fecundability may vary between women; and thus a cohort of women may be heterogeneous as to their fecundability, so that the cohort may be divided into a number of subcohorts. At any age, the members of a subcohort have the same fecundability but differ in terms of fecundability from the other subcohorts. The program provides for up to five subcohorts. The size of the subcohorts are defined by the user;

(h) *Pregnancy outcome and length of pregnancy.* When a woman conceives, the outcome of a pregnancy is determined (i.e., foetal death,[10] induced abortion or live birth). The probabilities of an induced abortion may be a function of parity or the difference between the family size desired by a woman[11] and the number of her surviving children. This difference is referred to as GAP. A pregnant woman is subject to probabilities of an induced abortion provided the woman is pregnant on or after the month of availability[12] of induced abortion defined for the cohort. The duration of a pregnancy depends upon its outcome. The length of any pregnancy may vary up to the specified maximum length defined for each outcome. Since any pregnancy may end in a live birth, foetal death or induced abortion (i.e., the probabilities for each outcome compete with one another) the computer program tests each pregnancy independently for either a spontaneous foetal death or an induced abortion. If neither occurs, a pregnancy is defined as ending in a live birth. If, however, the testing indicates that both a foetal death and an induced abortion occur (an impossibility in real life), the decision as to the outcome is made by comparing the durations of pregnancy associated with both outcomes. The duration that is shorter determines the outcome. If the durations are equal, the outcome is defined as a spontaneous foetal death. If a woman dies before the eighth month of a pregnancy that has been determined to end in a live birth, the outcome of the pregnancy is redefined as a foetal death. If the pregnancy has lasted eight months or more, the outcome is, as originally determined, a live birth;

(i) *Infant and child mortality.* Each live birth is subject to the probability of dying in its first year of life (i.e., an infant death). If the infant survives the first year of life, the child is also subject to the probabilities of dying at each successive month;

(j) *Time of infant and child death.* If the child dies in the first year of life, the month of death is determined from a distribution of probabilities of death by months. The time of a child death is determined in the same way as the other mortality parameters for the woman and her husband;

(k) *Post-partum non-susceptible period.* The length of the post-partum period of non-susceptibility to conception is a function of the outcome of the pregnancy. For a spontaneous foetal death or an induced abortion, the same distribution for the length of the post-partum period is used. A different distribution of the length of the post-partum period is used if the outcome is a live birth. If the child dies when the woman is in the post-partum period, the post-partum period is terminated one month after the child's death.

(l) *Natural sterility.* The probabilities of natural sterility are a function of a woman's age. The program permits a certain proportion of women in a cohort to be designated as sterile before the age at which the observation (simulation) begins;[13]

[10] A foetal death is defined as including stillbirths.

[11] Desired family size is defined as the total number of surviving children wanted by a woman. Desired family size may assume any value 0, 1, 2, . . . , 25. Desired family size may vary among women and is assigned stochastically to women at the beginning of a simulation from a distribution of desired family size.

[12] The month of availability is the month (age of women) on or after which women in the cohort are exposed to a probability of induced abortion.

[13] Natural sterility is assumed to be either a condition that develops

(m) *Surgical sterility.* Surgical sterility is assumed to occur only to women and is a permanent state.[14] For example, if a woman is surgically sterilized, and her marriage is subsequently broken and she remarries, she is still considered to be surgically sterile. Probabilities of surgical sterility are applied each month beginning with the specified month of the availability;[15] these probabilities may be either a function of a woman's parity or GAP. If a woman becomes surgically sterile when she is practicing contraception she ceases to practice contraception;

(n) *Family planning.* Family planning is defined as the use of any contraceptive and includes rhythm or coitus interruptus. Probabilities of a woman using a contraceptive are applied only to women who are currently married and not surgically sterilized or pregnant on or after the month of availability.[16] Because contraceptive use is restricted to those who are currently fecund, this eliminates the problem that other methods face, of correcting estimated contraceptive continuation for overlap with the onset of sterility while the woman is using a method; on the assumption that women may not realize they are naturally sterile or in a post-partum period, probabilities are applied even if a woman is naturally sterile or in the post-partum period;

(o) *Initial use of contraception.* The probability of a woman beginning contraceptive use may be a function of GAP, the open birth interval (i.e., the time since the last live birth or the time since marriage if no live birth) or the length of time elapsed since the specified month of availability;

(p) *Contraceptive effectiveness.* Contraceptive effectiveness may be a function of GAP or may vary over a range of values for each GAP;

(q) *Length of contraceptive practice.* The length of time a woman practises contraception may depend upon GAP or upon GAP and her spacing preference.[17] A woman terminates use as a result of an accidental pregnancy, having reached the end of her assigned length of contraceptive practice or having become surgically sterilized.[18] The distribution of the length of contraceptive practice, it should be noted, may reflect any assumption the user wishes to make concerning the lack of motivation on the part of a contraceptive user (i.e., by specifying short durations of contraceptive practice);

(r) *Discontinuation of contraceptive practice.* In addition to the above mentioned terminations of use, a woman may cease practising contraception to plan a birth if her GAP changes (i.e., if a child dies). Probabilities of discontinuing use are a function of GAP;

(s) *Resumption of contraceptive practice.* The probabilities of resuming contraceptive practice are a function of GAP or of the open birth interval. The time at which probabilities of resuming contraceptive practice are applied depends upon whether a woman has been classified as a "drop-out" or a "planner". Women who have ceased practice to plan a birth do not resume contraceptive practice until they have had a live birth. Women classified as "drop-outs" because of an accidental pregnancy may resume practice after they complete pregnancy. Women who drop out because they reach the end of their assigned length of practice may resume practice the beginning of the month after they "drop out".

E. Application of REPSIM-B

1. *Design of experiments*

The first step in applying a simulation model such as REPSIM-B is the design of the experiments to be run on the computer. To design the experiments the investigator must pose the questions to be asked. Also, decisions must be made as to the appropriate input parameters to be used in the simulations.

In the real world many of these aspects in the design of simulations may be provided by the particular type of family planning programme under way or being considered by administrators. For instance, the user may have family planning service statistics and/or survey data indicating the age and parity distribution of acceptors by type of contraceptive method used as well as data on discontinuance of use. Given such data, the administrator might ask whether the patterns of use being observed are likely to have the desired effect on the completed fertility of the acceptors. A related question might be whether the effect on the fertility of acceptors will be great enough to be seen if fertility measures based on all women are considered. Alternatively, the administrator may pose the question whether the provision of some types of fertility control are likely to have a greater effect than others.

This chapter gives guidelines for four REPSIM-B experiments designed to investigate the extent to which different strategies of family planning programmes would affect the fertility of a cohort of women, assuming that the objective of the family planning programme is

as a result of some pathological or congenital cause or that develops as a result of the aging process. The latter condition is more generally referred to as the "menopause". Women who are defined as sterile at the beginning of the simulation are women never capable of reproducing. This type of sterility is sometimes referred to as "primary".

[14] This assumption poses a problem in cases where family planning is effected also by male sterilization and particularly if the incidence is relatively high, as in India. In these circumstances, a cohort simulation model would not suffice, and a cross-sectional model providing for this input would be more appropriate.

[15] The month of availability specifies the month that contraceptives are available to the cohort. When this month occurs, a probability of beginning contraceptive practice is applied monthly to currently married women who are not pregnant or in a post-partum period.

[16] The month of availability specifies the month that contraceptives are available to the cohort. When this month occurs, a probability of beginning contraceptive practice is applied monthly to currently married women who are not pregnant or in a post-partum period.

[17] Spacing preference is defined as the desired interval in months between births. At the beginning of a simulation the proportions of women in a cohort desiring a certain interval between births are specified by the user.

[18] Women who cease contraceptive practice are classified in the computer program as "planners" or "drop-outs." A "planner" is a woman who has not achieved her family size and who has terminated use for purposes of planning a birth. A "drop-out" is a woman who ceased contraceptive practice for any reason other than to plan a birth (i.e., she has completed her assigned length of practice or she has become accidently pregnant).

the attainment of replacement level fertility among a cohort of 1,000 women at the end of their reproductive lives.[19] The design of these experiments is quite unrealistic in that the inputs relating to fertility control are not based on data from any actual programme. Rather, they are presented for illustrative purposes only. The experiments are designed so that the steps involved in this particular application may be more easily followed.

In the four experiments simulated, the basic demographic and biological parameters characterizing the cohorts are held constant. These basic parameters were selected as being similar to those characterizing Latin American women.[20] Accordingly, the selected female mortality schedule implied a life expectancy of 63.6 years and a probability of first marriage at an average age of 21.9 years. Details of these and other basic parameters held constant in the four simulated cohorts are discussed in more detail in the next section.

To provide a basis for comparing the effect on fertility of various strategies of family planning, the design of the first experimental cohort does not include any type of fertility control. The observed fertility of this cohort thus provides a measure of the fertility that would be expected if no fertility control measures were employed and may be taken to represent potential fertility. In table 102, this cohort is labelled "family planning strategy I". The other three simulated cohorts are designed to differ in terms of contraceptive practice and practice of induced abortion. These cohorts are labelled "family planning strategies II, III and IV". Family planning strategy II assumed a level of contraceptive effectiveness of 90 per cent. In family planning strategy III, the level of contraceptive effectiveness assumed is also 90 per cent and induced abortion is introduced. The probability of a woman having an induced abortion is set at 0.50. For family planning strategy IV, contraceptive effectiveness is raised to 99 per cent and no induced abortion is assumed, since the assumption is that it would be unnecessary if contraception were 99 per cent effective.

The probability of a woman initiating contraceptive use or having an induced abortion is a function of a woman attaining her desired family size. Desired family size is assigned to women from a distribution having a mean desired number of children of approximately two. Thus, in these experiments, once a woman achieves her desired family size and begins practising contraception, she is assumed to continue practising contraception unless she has an accidental pregnancy or one of her children died or, as mentioned above, becomes sterile or unmarried. It is also assumed that women experiencing an accidental pregnancy immediately resume contraceptive practice when the pregnancy ends. For women experiencing the death of a child, resumption of contraceptive practice occurs only when they have replaced the dead child with a live birth.

Once the basic design of the experiments is established, careful consideration must be given to the types of data required for analysing the results of the experiments. As the number of tables that may be produced from REPSIM-B is quite large, the investigator also must judiciously select only those tables which are relevant to the purposes of the simulated experiments.

2. *Selection of inputs*

To simulate the four experimental cohorts of women, data reflecting the design of the experiments are prepared for each of the parameters specified by the model. The selection of data for input and the sources of the data are described in table 101. Often, however, no data exist in the necessary form either for the population being simulated or for another population, and it is required to estimate input parameters.

[19] Because a Monte Carlo sampling method is used, successive runs with identical schedules of probabilities will not give identical results. Rather, the results will vary by chance. Estimates of the standard errors of the differences between mean number of live births indicate that a difference of 0.3 or larger for the total cohort or for ever-married women may be considered significant at the 5 per cent level.

[20] The choice of the basic demographic and biological parameters should as far as possible be based on data pertaining to the population being considered. The input data for these parameters used in the four experiments shown here were derived from unpublished data of Centro Latinoamericano de Demografía (CELADE), Santiago, Chile.

TABLE 101. INPUTS FOR FOUR EXPERIMENTS WITH DIFFERENT FAMILY PLANNING STRATEGIES

Input					
1. *Female mortality*[a]		2. *Male mortality*[a]		3. *Infant and child mortality*[a,b]	
$_nq_x$	q_x	$_nq_x$	q_x	$_nq_x$	q_x
$_5q_0$	0.1028	$_5q_{15}$	0.0118	$_1q_0$	0.0850
$_5q_5$	0.0108	$_5q_{20}$	0.0150	$_4q_1$	0.0300
$_5q_{10}$	0.0060	$_5q_{25}$	0.0182	$_5q_5$	0.0115
$_5q_{15}$	0.0096	$_5q_{30}$	0.0213	$_5q_{10}$	0.0066
$_5q_{20}$	0.0119	$_5q_{35}$	0.0263	$_5q_{15}$	0.0107
$_5q_{25}$	0.0141	$_5q_{40}$	0.0344	$_5q_{20}$	0.0135
$_5q_{30}$	0.0171	$_5q_{45}$	0.0482	$_5q_{25}$	0.0161
$_5q_{35}$	0.0214	$_5q_{50}$	0.0682	$_5q_{30}$	0.0192
$_5q_{40}$	0.0270			$_5q_{35}$	0.0240
$_5q_{45}$	0.0354			$_5q_{40}$	0.0307

TABLE 101 (*continued*)

Input

4. *Time of infant death*[c]

Month	Cumulative probability	Month	Cumulative probability
1	0.361	7	0.821
2	0.442	8	0.846
3	0.518	9	0.884
4	0.619	10	0.909
5	0.695	11	0.934
6	0.772	12	1.000

$\bar{X} = 4.7$ Standard deviation = 3.4

5. *First marriage*[d]

Age	Probability	Age	Probability	Age	Probability
15	0.151	25	0.243	35	0.164
16	0.064	26	0.119	36	0.022
17	0.088	27	0,129	37	0.044
18	0.097	28	0.135	38	0.070
19	0.115	29	0.180	39	0.125
20	0.136	30	0.219	40	0.086
21	0.112	31	0.085	41	0.031
22	0.139	32	0.080	42	0.032
23	0.164	33	0.087		
24	0.203	34	0.127		

$\bar{X} = 21.3$ Standard deviation = 5.3

6. *Age difference between spouses*[e]: 36 months

7. *Divorce*[f]

Age group	Probability: One union	Probability: Two or more unions
15–19	0.07	0.00
20–24	0.12	0.01
25–29	0.12	0.03
30–34	0.10	0.04
35–39	0.09	0.05
40–44	0.10	0.06
45–49	0.10	0.06

8. *Remarriage: widows*[e]

Age group	Probability
15–19	0.30
20–24	0.30
25–29	0.25
30–34	0.20
35–39	0.10
40–44	0.05
45–49	0.05

9. *Remarriage: divorce*[g]

Age group	Probability: One union	Probability: Two or more unions
15–19	0.46	0.26
20–24	0.41	0.23
25–29	0.25	0.26
30–34	0.08	0.12
35–39	0.00	0.03
40–44	0.09	0.03
45–49	0.00	0.00

10. *Fecundability*[h]

Age	Percentage of women: 15	25	25	20	15
15	0.040	0.080	0.120	0.160	0.200
20	0.100	0.200	0.300	0.400	0.500
25	0.100	0.200	0.300	0.400	0.500
30	0.080	0.160	0.240	0.320	0.400
35	0.060	0.120	0.180	0.240	0.300
40	0.040	0.080	0.120	0.160	0.200
45	0.021	0.040	0.060	0.080	0.100
50	0.000	0.000	0.000	0.000	0.000

11. *Foetal death: spontaneous abortion*[i]

Age	Probability	Age	Probability
15	0.26	35	0.40
20	0.20	40	0.47
25	0.24	45	0.50
30	0.33	50	0.55

$\bar{X} = 0.37$ Standard deviation = 0.12

12. *Foetal death: induced abortion*[h]

GAP	Probability
≤	0.50
≥	0.00
Month of availability:	01

Input

13. *Length of pregnancy: live birth*[j]

Month	Cumulative probability
1	0.000
2	0.000
3	0.000
4	0.000
5	0.000
6	0.009
7	0.022
8	0.041
9	0.957
10	1.000

$\bar{X} = 9.5$
Standard deviation = 0.4

14. *Length of pregnancy: spontaneous abortion*[k]

Month	Cumulative probability
1	0.514
2	0.771
3	0.895
4	0.935
5	0.954
6	0.965
7	0.975
8	0.987
9	1.000

$\bar{X} = 2.5$
Standard deviation = 1.5

15. *Length of pregnancy: induced abortion*[h]

Month	Cumulative probability
1	0.3000
2	0.7500
3	0.9700
4	1.0000

$\bar{X} = 1.98$
Standard deviation = 0.80

16. *Post-partum non-susceptible period: foetal death*[e]

Month	Cumulative probability
1	0.62
2	0.91
3	0.98
4	1.00

$\bar{X} = 2.00$
Standard deviation = 0.2

17. *Post-partum non-susceptible period: live birth*[e]

Month	Cumulative probability	Month	Cumulative probability
1	0.08	6	0.84
2	0.32	7	0.88
3	0.65	8	0.96
4	0.77	9	1.00
5	0.82		

$\bar{X} = 4.2$ Standard deviation = 2.1

18. *Natural sterility*[l]

Age	Probability	Age	Probability	Age	Probability
Under 15	0.005	26	0.010	38	0.039
15	0.004	27	0.011	39	0.046
16	0.004	28	0.012	40	0.058
17	0.005	29	0.012	41	0.066
18	0.006	30	0.014	42	0.081
19	0.006	31	0.015	43	0.133
20	0.007	32	0.017	44	0.164
21	0.007	33	0.018	45	0.219
22	0.007	34	0.025	46	0.358
23	0.007	35	0.026	47	0.658
24	0.008	36	0.028	48	0.853
25	0.009	37	0.034	49	1.000

$\bar{X} = 40.8$ Standard deviation = 7.8

19. *Desired family size*[h]

Number of children	Cumulative probability	Number of children	Cumulative probability
0	0.10	4	0.95
1	0.30	5	0.97
2	0.65	6	0.99
3	0.90	7	1.00

$\bar{X} = 2.1$ Standard deviation = 0.6

20. *Initiation of contraceptive practice*[h]

GAP	Probability
≤0	0.50
≥1	0.00

21. *Month of availability of family planning*[h]

Month 01

22. *Contraceptive effectiveness*[h]

	GAP	
(*a*)	≤0	0.90
(*b*)	≥0	0.99

TABLE 101 (*continued*)

Input				
	Five-year age group			
23. *Length of contraceptive practice*[h]	24. *Discontinuation of contraceptive practice*[h]		25. *Resumption of contraceptive practice*[h]	
Month 421	*GAP*	*Probability*	*GAP*	*Probability*
	≤0	0.000	≤0	1.000
	≥1	1.000	≥1	0.000

Note: GAP = difference between desired family size and number of living children.

[a] Centro Latinoamericano de Demografía, "Life tables: 1965–1970", Santiago, Chile, 1971 (unpublished).

[b] *Age and Sex Patterns of Mortality, Model Life Tables for Under-developed Countries* (United Nations publication Sales No. 55.XIII.9).

[c] *Foetal, Infant and Early Childhood Mortality, vol. I, The Statistics* (United Nations publication, Sales No. 54.IV.7), p. 37, table 18.

[d] Data derived by standardizing the mean proportions of women ever married reported in the fertility survey in metropolitan Latin America; see Centro Latinoamericano de Demografia and Community and Family Study Center, *Fertility and Family Planning in Metropolitan Latin America* (Chicago, Ill., University of Chicago, Community and Family Study Center, 1972); the method of standardization follows Ansley J. Coale, "Age patterns at marriage", *Population Studies*, vol. XXV (July 1971), pp. 193–214.

[e] Based on unpublished data from the fertility survey in metropolitan Latin America; for published report, see Centro Latinoamericano de Demografia and Community and Family Study Center, *op. cit.*

[f] Values shown are 50 per cent of those estimated by G. W. Roberts and L. Braithwaite, "A gross mating table for a West Indian population", *Population Studies*, vol. XIV (March 1971), pp. 198–217.

[g] Derived from data presented in J. Mayone Stycos and Kurt Back, *The Control of Human Fertility in Jamaica* (Ithaca, N.Y., Cornell University Press, 1964).

[h] Hypothetical.

[i] Estimated from Jean Bourgeois-Pichat, "Les facteurs de la fécondité non dirigée", *Population* (Paris), vol. 20, No. 3 (1965), pp. 383–424.

[j] Estimated from Harold Hotelling and F. Hotelling, "A new analysis of duration of pregnancy data", *American Journal of Obstetrics and Gynecology*, vol. 23 (1932), pp. 643–657.

[k] F. E. French and J. M. Bierman, "Probabilities of fetal mortality", *Public Health Reports*, vol. 77, No. 10 (November 1962), pp. 835–897.

[l] Louis Henry, *Fécondité des mariages: nouvelle méthode de mesure*, Institut national d'études démographiques cahier No. 16, Travaux et documents (Paris, Presses universitaires de France, 1953).

In the four experiments presented here all data were input in tabular form. In order to minimize the amount of input needed, the REPSIM-B computer program permits the user to run in one batch any number of related experiments in which only a few of the inputs are changed in successive experiments. The first simulated experiment of a set of related experiments is labelled the "reference run". A reference run requires all the data necessary for an experiment to be coded as input. For subsequent related runs only the changes in the parameters being varied from the reference run need to be input.

In table 101, the input data for the demographic, biological and family planning parameters for the four experiments are shown. The sources of data for each of the inputs are given at the end of the table.

While most of the sources are self-explanatory, a few comments on some of the inputs may be of help to the potential user. Rarely does one find that there are data pertaining to the population of interest for all the parameters. This is particularly the case with micro-simulation models such as REPSIM-B, in which the basic biological process of reproduction is being simulated. Accordingly, the user must decide whether to utilize either data derived from various studies of other populations or to input hypothetical data. As far as possible, however, the hypothetical data should be based on the available, although incomplete, evidence that does exist concerning a particular parameter.

As may be seen in table 101, data pertaining to some of the basic demographic parameters (i.e., mortality and first marriage) are based on data for Latin America. For most of the parameters, however, other data sources have to be used. This is the case for many biological parameters. For example, the inputs for age at which natural sterility occurs are based on estimates made by Henry[21] from data of historical European populations. In so far as these estimates differ from the true values in the population being simulated, the results, of course, will be affected. If the user, however, takes care in interpreting the results and is willing to accept the results of simulation as only indicative of the direction of change, the necessity of using estimates from other populations for some of the basic parameters should not lessen the value of the results.

Lastly, a number of inputs are purely hypothetical in that they either are not based on any observed data or are guided by very scanty evidence as to the true values. Thus, although several estimates have been made of fecundability in different populations, no estimates have been made for Latin American populations. Also, even though it is widely accepted that fecundability varies not only by age but among women, estimates of the variability of fecundability among women are generally not given in any great detail. Thus, in estimating the levels of

[21] Louis Henry, *Fécondité des mariages: nouvelle méthode de mesure*, Institut national d'études demographiques cahier No. 16, Travaux et documents (Paris, Presses universitaires de France, 1953).

fecundability the general guide followed is to have the average fecundability of the cohort at any age within the general range for which estimates exist. Furthermore, in the four experiments all of the inputs for the family planning parameters are completely hypothetical. As indicated previously, in any effort to investigate the effects of an actual programme, the inputs for these parameters should be based on actual data gathered as part of the family planning programme, i.e., family planning service statistics and follow-up surveys. The probabilities should be calculated on the basis of the frequencies observed from these data.

3. *Coding of output*

Once the input data are obtained, the required data are coded on coding sheets and then key-punched on to IBM cards.[22] As the design of the experiments specifies the running of four cohorts of 1,000 women each, this information is coded. In addition, because an objective of the experiments is to investigate the effects of birth control on completed fertility, the number of months for which the simulated cohorts are to be run is coded as 421 months (creating output when the cohort has reached age 50). In addition, the desired output tables are coded. The data shown in tables 102–105 are drawn from various output tables produced in runs of REPSIM-B. The output table source is given at the bottom of each table. For these experiments, only four output tables are necessary to carry out the required analysis.

[22] For detailed coding instructions for input, see J. C. Ridley and others, *op. cit.*

F. Results and discussion

To assess the impact of the different family planning strategies a number of fertility indices available from the output of REPSIM-B are examined.

1. *Replacement level fertility*

First, the net reproduction rates for the simulated cohorts are examined for an evaluation of which family planning strategy comes closest to replacement level fertility. The net reproduction rates are as follows:

(*a*) Family planning strategy I (49): 3.3;
(*b*) Family planning strategy II (34): 1.5;
(*c*) Family planning strategy III (35): 1.1;
(*d*) Family planning strategy IV (36): 0.9.

TABLE 102. MEAN AND STANDARD DEVIATION OF NUMBER OF LIVE BIRTHS FOR SIMULATED COHORTS WITH DIFFERENT STRATEGIES OF FAMILY PLANNING

Marital status	*Family planning strategy*			
	I[a] *(49)*	*II*[b] *(34)*	*III*[c] *(35)*	*IV*[d] *(36)*
All women	7.6 ± 5.1	3.4 ± 2.3	2.7 ± 1.8	2.2 ± 1.6
Ever-married women	8.2 ± 4.8	3.6 ± 2.2	2.8 ± 1.8	2.3 ± 1.6
Women surviving to age 50, first marriage intact	9.6 ± 4.8	4.0 ± 2.3	3.0 ± 1.9	2.4 ± 1.7

SOURCE: Table 13 of REPSIM-B output.
Note: Numbers in parentheses are actual run numbers.
[a] Zero effectiveness.
[b] Ninety per cent effectiveness.
[c] Ninety per cent effectiveness and 0.50 probability of abortion.
[d] Ninety-nine per cent effectiveness.

TABLE 103. ANNUAL BIRTHS AVERTED PER 1 000 WOMEN, BY AGE FOR SIMULATED COHORTS WITH DIFFERENT STRATEGIES OF FAMILY PLANNING

Five-year age group	*Family planning strategy*		
	II[a] *(34)*	*III*[b] *(35)*	*IV*[c] *(36)*
15–19	11	15	21
20–24	124	156	172
25–29	227	261	298
30–34	240	284	305
35–39	180	209	226
40–44	94	107	113
45–49	24	27	28
TOTAL[d]	4 500	5 292	5 804

SOURCE: Table 10 of REPSIM-B output.
Note: Numbers in parentheses are actual run numbers.
[a] Ninety per cent effectiveness.
[b] Ninety per cent effectiveness and 0.50 probability of abortion.
[c] Ninety-nine per cent effectiveness.
[d] Total births averted per 1 000 women living through ages 15–49.

TABLE 104. PERCENTAGE OF BIRTHS UNWANTED AND MEAN NUMBER OF UNWANTED BIRTHS FOR ACCEPTORS, BY DESIRED FAMILY SIZE FOR SIMULATED COHORTS WITH DIFFERENT STRATEGIES OF FAMILY PLANNING

Family planning strategy	*Desired family size (number of children)*						
	Zero	*One*	*Two*	*Three*	*Four*	*Five or more*	*Total*
			Percentage unwanted				
I[a] (49)	100	88	76	65	59	49	77
Strategy II[b] (34)	100	62	45	33	23	17	46
Strategy III[c] (35)	100	49	29	23	11	9	32
Strategy IV[d] (36)	100	16	10	5	3	4	9
			Mean number unwanted				
Strategy I[a] (49)	7.5	7.4	6.3	5.6	5.7	3.9	6.5
Strategy II[b] (34)	2.3	1.7	1.6	1.5	1.2	1.1	1.6
Strategy III[c] (35)	1.0	1.0	0.8	0.9	0.5	0.9	0.9
Strategy IV[d] (36)	0.4	0.2	0.2	0.2	0.1	0.2	0.2

SOURCE: Table 22A of REPSIM-B output.
Note: Numbers in parentheses are actual run numbers.
[a] Zero effectiveness.
[b] Ninety per cent effectiveness.
[c] Ninety per cent effectiveness and 0.50 probability of abortion.
[d] Ninety-nine per cent effectiveness.

TABLE 105. LIFE-TABLE ESTIMATES OF THE MEAN LENGTH OF BIRTH INTERVALS FOR SIMULATED COHORTS WITH DIFFERENT STRATEGIES OF FAMILY PLANNING
(*Months*)

Interval to live birth order	*Family planning strategy*			
	I[a](49)	*II[b](34)*	*III[c](35)*	*IV[d](36)*
1	16.6	18.6	20.8	18.4
2	20.1	31.4	33.8	28.8
3	20.4	40.0	42.2	32.2
4	20.3	45.1	62.4	45.9
5	21.2	45.6	56.6	36.4

SOURCE: Table 35 of REPSIM-B output.
Note: Numbers in parentheses are actual run numbers.
[a] Zero effectiveness.
[b] Ninety per cent effectiveness.
[c] Ninety per cent effectiveness and 0.50 probability of abortion.
[d] Ninety-nine per cent effectiveness.

It is thus seen that family planning strategy III is 10 per cent above replacement and family planning strategy IV is 10 per cent below replacement.

Next, reductions in completed fertility are assessed from the means and standard deviations of the number of live births per woman for the four simulated cohorts (table 102). As pointed out earlier, because no fertility control was postulated for it the cohort labelled "family planning strategy I" provides the basis for comparing other family planning strategies. The reductions in completed fertility observed for the total cohort for the three different strategies are 55 per cent (strategy II), 64 per cent (strategy III) and 71 per cent (strategy IV). The pattern of reductions in completed fertility for ever-married women and women in intact marriages is similar to that observed for all women. Not surprisingly, contraceptive practice at the highly effective level of 99 per cent effectiveness has the greatest impact on fertility. Of interest also is the increase in the variability of births as the efficiency in fertility control increases.

2. *Births averted*

A usual way of assessing the effects of a family planning programme is to calculate births averted. In table 103, the births averted per 1,000 women are shown by age. This measure of births averted is comparable to the age-specific fertility rate in that it is derived by subtracting the age-specific fertility rates observed for family planning strategy cohorts II, III and IV from the age-specific rates observed in the cohort for family planning strategy I. This latter cohort, it will be remembered, provides the estimate of the expected fertility of a cohort had it not practised family planning. The total births averted rate shown in the last row of table 103 is analogous to the total fertility rate. Thus, the number of births averted during the entire reproductive period is 4.5 per surviving woman for strategy II, 5.3 for strategy III and 5.8 for strategy IV. It is possible not only to estimate the total number of births averted but to determine how women in the different age groups contribute to the total number of births averted. Table 103 also indicates the age pattern of births averted. The age pattern is similar for the three family planning strategies, of course, because the inputs for the initiation of contraceptive practice is the same for all three cohorts. Very few births are averted at the youngest ages, with a peaking of births averted in the early thirties.

3. *Unwanted births*

Another way in which the efficacy of a particular family planning strategy can be judged is in terms of the reduction of unwanted births to acceptors in the hypothetical programmes.[23] In table 104, the percentage of births that are unwanted and the mean number unwanted are shown for acceptors by desired family size. As would be expected, the cohort practising contraception at 99 per cent effectiveness (strategy IV) has the fewest unwanted births.

But regardless of the type of family planning strategy, the larger the desired family size the lower the proportion and mean number of unwanted births. Thus, one could be easily misled if the proportion of unwanted births were compared for two groups of women differing only in terms of desired family size and efficiency of contraception. It would be quite reasonable to observe an increase in unwanted births in a population as contraceptive efficiency increases. This seeming paradox, of course, would be the result of a decline in the desired family size.

4. *Birth intervals*

Another indicator of programme impact viewed as useful by some students is the length of birth intervals. The data on birth intervals for the different family planning strategies shown in table 105, however, illustrate the difficulty of using birth intervals for this purpose. As stated earlier, in the REPSIM-B model, the mean desired family size is always two. Thus, women are distributed by their individual desired family size, around the mean of two, and also by the actual number of births they have. Crossing these two distributions generates the cell entries.

The effect of the different family planning strategies on birth intervals can be seen in table 105. Because contraception reduces fecundability and thus lengthens the time required for conception, one would expect that the length of intervals of cohorts with family planning would be longer than the intervals of the cohort where no fertility control is practised, which indeed is the case. The birth intervals of family planning strategies II, III and IV are all longer than family planning strategy I. One would also expect that the birth intervals would increase in length as the efficiency of family planning practice increases. This result, however, is not the case for these simulated cohorts. For the most effective cohort (strategy IV), the birth intervals tend to be shorter than in the cohorts with less effective fertility control (strategies II and III). The explanation for this situation is that although fewer women have unwanted births, the women who do have an unwanted birth are a highly select group in terms of their fecundability. That is, women with the highest fecundability are more likely to have accidental births.

The birth interval data given in table 105 point up the very severe problem of relying on birth intervals as an indicator of the success of a family planning programme. The longest birth intervals occur in the cohort for family planning strategy III. This group, however, is not the most successful cohort in terms of reductions in fertility but rather is intermediate. The explanation for this irregularity lies in the extra time being added to the intervals between births by induced abortions. Since the reproductive period is limited, an increase in foetal deaths due to abortion increases the amount of time between births.[24] It may be mentioned, however, that this is applicable where the analysis relates solely to completed birth intervals. If all those at risk of additional birth are included in a life-table format to show their movement towards the next birth, with many of them never experiencing it, this problem is removed.

G. Conclusions

The results of the four experiments presented in this chapter should be considered only illustrative of an investigation of alternative family planning strategies. As indicated earlier, these experiments are quite unrealistic. Noteworthy is the fact that the length of post-partum amenorrhoea assumed in the runs is quite short, even unrealistic for developing countries. Other more realistic experiments could be designed to take account of this short-coming and also to evaluate different acceptance patterns, drop-out rates, changes in methods of contraception or the substitution effects of a programme on the fertility of acceptors. In addition, one might wish to investigate how much contraception must be practised to replace the depressing effects on fertility of social and biological factors. For example, if the model were adjusted to assume a lengthy period in breast-feeding, assumptions of a decline in the practice of breast-feeding could have the effect of increasing fertility unless some form of fertility control were initiated.

Regardless of the type of model employed, the results obtained are limited by the assumptions inherent in the specifications of the model and the design of the experiments. Thus, the results obtainable from simulation models cannot be taken as predictive of what would happen but must be viewed as merely suggestive of what might happen.

[23] Unwanted births are equal to the difference between family size and the number of live births.

[24] For a more detailed explanation of the "truncation effect" on birth intervals, see Mindel C. Sheps and others, "The truncation effect in closed and open birth interval data", *Journal of the American Statistical Association*, vol. 65 (June 1970), pp. 678–693.

Chapter VIII

PRINCIPLES OF EXPERIMENTAL DESIGNS

*H. Bradley Wells**

Many field studies have been conducted to determine the impact of family planning programmes on fertility but, when examined carefully, few would qualify as true experiments. Some design features and limitation of the better known experiments are reviewed by several authors.[1] Another report[2] examines the design and methodological features of 40 selected studies of "fertility planning" and classifies them under eight categories. These categories are implicitly arranged more or less in order of design strength, in a range from strong to weak, from true randomized experiments to a series of non-randomized quasi-experiments.[3]

The aim in this chapter is to describe and illustrate the common elements of both types of designs, true randomized experiments and non-randomized quasi-experiments, and to amplify their major differences with particular reference to the way in which those experiments might be useful in determining the impact of family planning programmes on fertility levels. Before proceeding to the major purpose, an attempt is made to set the stage by describing the potential place of experiments and quasi-experiments in family planning programme evaluation.

In practice, evidence of programme effects is usually determined in a piecemeal fashion. The logical processes and data required for informed decision making are of such magnitude that an over-all evaluation plan is required as part of the programme itself. Such a plan could include a variety of different information systems including both randomized experiments and prospective and retrospective non-randomized quasi-experiments, all of them phased and carried out over time so that administrators, planners and politicians have the best available evidence at each point in time for programme planning and evaluation. Sound evaluation requires advance planning, which must be included as an integral component of programme management.

The 40 studies of fertility planning referred to above include a wide range of programmes or treatments intended to increase the acceptance or continued use of fertility regulating practices.[4] Although the ultimate aim was to reduce fertility rates, in these studies with few exceptions the outcome measures used for assessing programme impact were (short-term measures of) reported behaviour indicating acceptance of contraceptive methods rather than fertility rates. Use of such intermediate behavioural measures can be justified on the grounds that programme administrators need "useful information early"[5] for making decisions about programme organization. However, perhaps the major reason that intermediate impact measures are used is the difficulty of maintaining control over the experience of the different treatment and non-treatment groups for a period sufficiently long to provide useful measures of fertility.[6] This difficulty gives rise to the need to utilize one or more of the various indirect methods, which are described in the other chapters of this *Manual*,[7] in order either to convert such short-term measures as acceptor data into births averted or to correlate programme and non-programme variables with fertility measures. The uncertainties and ambiguities that must remain after even the most careful application of these non-experimental approaches to estimating fertility effects argue for more extensive use of randomized experiments. The over-all price in terms both of costs and of time requirements for conducting controlled randomized experiments may well be less than the costs of such non-experimental approaches. If it is sufficiently important to know more reliably the programme impact on fertility, then the experimental method may well be worth the added costs.

Unfortunately, practitioners use different terms more or less interchangeably to refer to the same principle or practice in design of randomized experiments as well as in non-randomized studies. In this chapter the following conventions, more or less consistent with the statistical

* Director, International Program of Laboratories for Population Statistics, University of North Carolina at Chapel Hill, North Carolina.

[1] W. Parker Mauldin and John A. Ross, "Family planning experiments: a review of design", in *Proceedings of the Social Statistics Section, 1965* (Washington, D.C., American Statistical Association, 1966); Roberto Cuca and Catherine S. Pierce, "Experimentation in family planning delivery systems: an overview", *Studies in Family Planning*, vol. 8, No. 12 (December 1977), pp. 302–310.

[2] E. T. Hilton and A. A. Lumsdaine, "Field designs in gauging the impact of fertility planning programs", in C. A. Bennett and A. A. Lumsdaine, eds., *Evaluation and Experiment* (New York, Academic Press, 1975), chap. 5.

[3] Somewhat along the lines given in Donald T. Campbell and Julian C. Stanley, *Experimental and Quasi-Experimental Designs for Research* (Chicago, Ill., Rand McNally, 1963).

[4] E. T. Hilton and A. A. Lumsdaine, *loc. cit.*

[5] W. P. Mauldin and J. A. Ross, *loc. cit.*

[6] E. T. Hilton and A. A. Lumsdaine, *loc. cit.*

[7] Some of the virtues and disadvantages of this general approach to evaluation are discussed in chapter II, "Standard couple-years of protection".

literature, are followed (this listing of definitions from experimental design literature is very limited):

(*a*) "Experiment" with no adjective is used in a restricted sense to refer to a "randomized (true) experiment", i.e., a study in which the experimental units (subjects) are allocated randomly to two or more treatment groups. As used by Campbell and Stanley,[8] this procedure helps to "control for" internal validity, i.e., within the experiment extraneous (non-treatment) variables are balanced at the beginning of treatment by prior randomization. The term "controlled trial" is sometimes used to refer to a "field experiment" where randomization is possible;

(*b*) "Control group" refers to the (randomly allocated) treatment group which gets no treatment although it sometimes refers to a known effective treatment. "Control", as a noun, is often used in lieu of control group;

(*c*) "Quasi-experiment" and "observational study" are used interchangeably to refer to studies or trials in which experimental units either cannot be or are not randomly assigned to treatments;

(d) "Comparison group" refers to a non-randomly selected group of experimental units in non-randomized studies. Comparison groups are analogous to control groups in experiments. They might better be called "pseudo-control groups";

(*e*) "Control", as a verb, refers to the use of statistical procedure(s) either to eliminate, adjust for or balance (average out) the influence of intervening (non-treatment) variables on the response(s) to the treatment variable. To "control" thus includes randomization in experiments as well as stratification, blocking, matching, covariance analysis and adjusted rates in both experiments and quasi-experiments.

A. Use of experimental designs

Measuring the impact of a family planning programme on fertility is analogous to any other scientific effort to determine cause and effect. In the language of research science a family planning programme can be described as a treatment applied to (a group of) people in order to produce (a response of) a lowered fertility rate. In this context the group of people, or the community, can be considered an experimental unit in which the hypothesized demographic effect is lowered fertility caused by the family planning programme.[9]

To determine the magnitude of the programme impact on fertility is not simple. Suppose that fertility rates do decline after the programme is initiated. How can it be "proved" that the programme caused the decline? Researchers generally agree that the most acceptable approach to the determination of cause-and-effect relationships is through the experimental method. Strict application of the experimental approach to measuring the impact of a family planning programme on fertility is of course very difficult. A brief review of the fundamentals may be useful in order to illustrate the strengths and weaknesses.

1. *The experimental approach*

The experimental design is a plan for carrying out an individual experiment.[10] An experiment is a test or a trial of the (hypothesized) response of the treatment units or subjects to two or more treatments. Because the essence of the experimental method is to compare results, two or more treatments are required. One of the treatments may be nothing, i.e., a presumably effective treatment may be compared with no treatment (a control group). The simplest type of true experiment would require assigning people or population (groups) at random either to receive the programme or to receive no programme. After the two treatments (programme and no programme) are administered, any differences in fertility levels between the two groups would be due to or caused by the programme. If a known treatment is effective, unknown treatment(s) can be compared with the known treatment rather than with no treatment.

The key requirement is random assignment of experimental units to treatment groups, prior to initiating treatments. When randomization cannot be done by definition the study is quasi-experimental. Contamination or spill-over effects can occur with either experimental or quasi-experimental designs. The evaluators must continuously be alert for such departures from desirable design practices. If they do occur, attempts must be made to adjust for them at the analysis stage and/or to temper the conclusions which are drawn from the results. After randomization all treatment groups should be handled alike in all respects except for differences in the treatments. These two requirements, randomization and maintaining uniformity of treatments (over time), are the prime reasons that pure experiments are difficult to conduct in human populations. Other elements of experimental designs include: stratification or grouping of subjects into more homogeneous groups; an increase of the number of subjects (sample size); replication of the experiment; controlling for the effect of intervening or related factors; use of unbiased measurement methods; taking of additional measurements; and application of appropriate analytical procedures. All these aspects of an experimental design are interrelated; for example, analysis is based on the design. A good general discussion of experimental design with emphasis on social action experiments is given in a recent publication,[11] and a more technical statistically oriented approach is provided in two other studies.[12] As the intent in this chapter is to illustrate principles rather than cover

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[8] *Op. cit.*

[9] The programme or demographic effect refers to the effect in the population. It should not be confused with clinical or method effectiveness in prevention of births to individuals.

[10] Henry W. Riecken and Robert F. Boruch, eds., *Social Experimentation: A Method for Planning and Evaluating Social Intervention* (New York, Academic Press, 1974).

[11] *Ibid.*, chap. III.

[12] W. G. Cochran and G. M. Cox, *Experimental Designs*, 2nd ed. (New York, John Wiley and Sons, 1957); and B. J. Winer, *Statistical Principles in Experimental Designs* (New York, McGraw Hill, 1962).

the details of experimental design, attention is focused on the logic of fundamentals and some of the difficulties in conducting experiments. An understanding of the rationale of the experimental method is essential in order to appreciate the requirements for making inferences from quasi-experimental studies.

Randomization of subjects to the treatments is done in an attempt to obtain balance between treatment groups of the influence of all the intervening variables which are not controlled by other design features, such as stratification, or through analysis. Randomization provides insurance against biases which might influence the subject or the investigator if non-random assignment procedures were followed.

Logically, then, after deliberate stratification on the important variables to control for their effect and randomly balancing on (all other) variables between treatment groups, differences in effects greater than those due to random error are attributed to treatment differences. If the subjects or experimental units are representative of the population about which one wishes to generalize, an experiment is, in theory, self-contained; i.e., all factors, other than treatments, that might affect the results are either controlled or balanced through randomization; hence, inferences can be made about the effect(s) of treatments.

Randomized experiments are used extensively with non-human subjects. However, random assignment of individual human subjects to specific treatments is not usually possible unless they volunteer for the experiments. The results of experiments that test treatments with volunteers are at best generalizable only to populations of such volunteers. Nevertheless, useful programme data can be obtained in this way, e.g., intrauterine device (IUD) acceptors who volunteer for an experiment can be randomly assigned to any of the IUDs being tested.[13]

However, experiments can be designed with groups of people as the experimental units, and the response of the group is the variable of interest. For example, the extent to which different education/propaganda efforts would influence women to accept different family planning methods was tested in the randomized experiment conducted in Country E and is reported as illustration A (see section B. 2).[14] Unfortunately, the experiment was not designed to measure the impact of the different approaches on fertility changes, although that measure presumably would have been possible by compiling fertility data for each small area. But the illustration does suffice as an example of a randomized experiment.

The strengths of experiments in reaching conclusions about cause and effect were briefly described above, but there are some serious limitations in the conduct of experiments for testing the effect(s) of social action programmes such as family planning.

[13] Christopher Tietze and Sarah Lewit, "Comparison of the copper T and loop D: a research report", *Studies in Family Planning*, vol. 3, No. 11 (1972), pp. 277–278.

[14] Bernard Berelson and Ronald Freedman, "A study in fertility control", *Scientific American*, No. 210 (May 1964), pp. 29–37.

2. *Limitations in use of experimental designs*

The following difficulties are important to bear in mind when attempting to design randomized experiments in family planning using groups of people in administrative areas or subareas as experimental units.

Randomization of areas

Randomization of areas either to receive a programme or not to receive the programme (serve as control group) presents political and sometimes ethical problems. Most politicians and the public are willing for their area to become the recipient of a new programme but will not willingly serve as a control group. It may also be unethical to withhold a potentially beneficial programme from those who want it. One approach to the latter problem would be to test planned variations in types or levels of programme rather than having no programme as one of the treatments.[15]

Maintenance of uniformity of programme

Maintenance of uniformity of programme (treatment) is especially difficult in human populations because of contamination or spill-over effects through communication, migration and shifts in political attitudes and in funding policies over time. Unless experimental areas are far enough apart so that very little communication or migration takes place during the course of the experiment, it is likely that differences between treatments will be diluted and the results therefore underestimated. Similarly, changes in local funding from other sources for related programme activities might cause changes in the programme.[16] Another pitfall is confounding the merits of the programme with the staff involved in it.[17] For example, programme staff members who personally prefer one type of contraceptive might, perhaps inadvertently, influence the choice of method accepted by individual patients. Many experiments have been damaged because a unique personality has created an exceptional effect in a particular group's performance. It is thus advisable to rotate leadership personnel among the experimental areas. It is essential that experiments and other evaluation methods take into account the time required for a response to show up—e.g., the time-lag of nine months from conception to live birth assures that the effects of a contraceptive programme show up, at the earliest, about a year after programme initiation.

Unbiased measurement methods

Unbiased measurement methods may be difficult to achieve unless the measurement system is independent of the programme being evaluated. For example, fieldworkers whose primary job is conducting educational

[15] Bernard G. Greenberg, "Evaluation of social programs", *Review of the International Statistical Institute*, vol. 36 (1968), pp. 260–278.

[16] Karl E. Bauman, "An experimental design for family planning and program evaluation", in J. Richard Udry and Earl E. Huyck, eds., *The Demographic Evaluation of Domestic Family Planning Programs* (Cambridge, Mass., Ballinger Publishing Co., 1975), pp. 67–79.

[17] B. G. Greenberg, *loc. cit.*

programmes to induce women or men to become family planning acceptors might well obtain different answers to a Knowledge, Attitude, Practice (KAP) and fertility survey than would interviewers hired and trained by the statistical office. The preferred source of data for measuring fertility levels is a civil registration system, which records all live births and tabulates and analyses the resulting data for the various administrative units and geographical areas of the country. (It is hoped that such units would be used in allocation of programme and control areas for experimental design purposes.) In addition to an adequate civil registration system, census data are required in the same geographical detail to serve as the denominators for calculation of the appropriate fertility indices for each area or combination of areas. A major requirement of the measurement system for most experimental designs is that it must be capable of measuring time trends. Unfortunately, most countries for which family planning programme evaluation is likely to be undertaken do not have adequate vital statistics registration systems and are thus lacking essential data for the design of experiments. In the absence of civil registration data, fertility measures may be derived from census data and/or special surveys. But these surveys are rarely conducted at sufficiently frequent intervals; and, at any rate, their use often introduces additional data problems.

Increase in size of experiment

Increasing the size of the experiment can be expensive, depending upon what programme is being tested. In measuring demographic response, the number of experimental units (subjects) is the number of areas rather than the number of persons involved in the experiments.

Controlling for effect of intervening variables

Controlling for the effect of intervening variables is usually difficult. Prior to randomization, stratification, blocking or matching on such factors as urban/rural residence, marital status, age and parity of women, educational level, prior use of contraception, desired number of children and other known factors related to fertility change can increase the precision of the results and increase the chances of detecting relatively small changes due to the programme. Similarly, post-stratification on such variables after the experiment and/or the use of such techniques as mean adjustment and covariance analysis can enhance precision in randomized experiments.

Attention is increasingly being given to the ways in which the experimental method can be used in evaluating field trials of social programmes.[18] It appears fair to conclude that, because of the difficulties of implementing true experiments plus the general lack of knowledge and experience of planners and decision-makers in using the experimental method, it is not used to the extent that it should be in evaluating social programmes including family planning. The same factors undoubtedly also operate to result in poorly designed non-randomized studies.

3. *Example of an experimental design for a hypothetical country*

To illustrate how experiments can be designed, consider a hypothetical country and make different assumptions about how a programme might actually be implemented. The hypothetical country is divided into 20 provinces and the provinces are further subdivided into an average of 10 districts per province. The central Government, president and legislature decide to implement a programme with the aim of reducing fertility rates. Programmes will be implemented through district health departments. Each province is administered by a governor and a local council which determines programme policy and allocates resources to the districts through the provincial health directorate. An agreement is reached by all concerned that an experiment will be conducted for three years, 1978–1980, and a formula for allocating the funds and resources to the provinces is accepted by all. Districts will be experimental units, thus yielding 200 units for experimentation.

Assume further that even in this politically utopian country civil registration of births is not complete in all districts but a national census is planned for 1981. All or a high proportion of district governments must be willing to abide by a random allocation to serve either as a control (no programme) or as a treated (programme) area for three years. (Note that if some but not all agree, randomization may be done within those districts, although this situation raises the question of representativeness of the "volunteers".) For simplicity, it is assumed here that all agree to participate.

Assume that resources are such that the programme can be conducted only in 100 districts and the experimental objective is to determine what the programme impact will be over a three-year period. The simplest experimental design in the absence of time-series data or fertility data would be an "after only" randomized experiment. To accomplish this design, there is first stratification by province. Then a selection is made as nearly random as possible, one half of the districts within each province to be either treatment or control group. By collecting the required data for each district in the 1981 census, fertility can be measured for each experimental unit (district). After the 1981 census data are processed, the (minimal) extent to which the family planning programme has influenced the fertility measure would be as shown in table 106.

[18] R. L. Light, F. Mosteller and H. S. Winokur, Jr., "Using controlled field studies to improve public policy", in *Report of the President's Commission on Federal Statistics* (Washington, D.C., Government Printing Office, 1971), chap. 6; Carl A. Bennett and Arthur A. Lumsdaine, eds., *Evaluation and Experiment: Some Critical Issues in Assessing Social Programs* (New York, Academic Press, 1975); and Robert B. Boruch and Henry W. Riecken, eds., *Experimental Testing of Public Policy, Proceedings of the Social Science Research Council Conference on Social Experiments, 1974* (Boulder, Colo., Westview Press, 1975).

TABLE 106. DESIGN NO. 1: AFTER ONLY-TWO GROUP RANDOMIZED

Sample size (number of districts)	*Treatment (type of programme)*	*Fertility index, 1981*
100	No family planning	R_0
100	Family planning	R_1
Treatment difference		$R_1 - R_0$

Thus, $R_1 - R_0$ would be a measure of the programme impact. Note that R_0 and R_1 can refer to any fertility measure whether based on a census or on other data, for example, civil registration or survey data.[19] However, if time-series data on fertility measures are available, better designs are possible and desirable, as discussed below.

Advantages of the design

The major advantage of this experimental design is that random allocation should balance out such pre-programme and concurrent factors as:

(*a*) Levels of fertility;

(*b*) Previous use of contraception;

(*c*) Non-programme use of contraception;

(*d*) Quantity and quality of health staff and facilities;

(*e*) Access of people to services;

(*f*) Desire to practise contraception;

(*g*) Type of economy;

(*h*) Practice of abortion;

(*i*) Registration level(s) of births;

(*j*) Other factors that may have an influence on the fertility measure.

Another advantage is that each province is allocated a certain amount of money, although only half of the districts will receive any of it.

Disadvantages of the design

Aside from the ethical question whether a family planning programme can be withheld from some districts, the major problems of this design are mainly administrative and political; for three years the districts are arbitrarily defined as "programme" and "no programme" regardless of what is actually done. Some "no programme" districts may begin providing services without any provincial support; some "programme" districts may provide no family planning services even if the money is included in their budget. Records should be kept of these deviations from the experimental design, where they are known, so that they may be taken into account in analysis of the results. Another short-coming of this deisgn is the possibility of contamination and spill-over effects. If services are not available in a district, people may be sufficiently motivated that they would travel to an adjoining district for services or put pressure on their own government to provide them. Contamination would tend to cause underestimation of the overall impact of the programme. A serious limitation of this experiment is that only the short-term impact of the particular programme on fertility would be measured.[20] Another short-coming is that no variation in type or intensity of programme, except those which would result from unplanned district-to-district variations in implementation, can be studied. Design No. 2 does permit study of planned variation in programmes.

It probably is unrealistic to test "programme" *versus* "no programme"; and as has been pointed out,[21] it would be more acceptable to test different types of programme. Types of programme could be defined as offering different services or, alternatively, as different levels of funding in the district. (Ideally, one type of programme should still be "no programme" in order to take full advantage of the randomized design.) If four different types of programme are tested in a randomized design with stratification by province, the results in 1981 could be depicted as shown in table 107.

TABLE 107. DESIGN NO. 2: AFTER ONLY-FOUR GROUP RANDOMIZED

Sample size (number of districts)	*Treatment (type of programme)*	*Fertility index, 1981*
50	Type A: no family planning	R_0
50	Type B: family planning	R_1
50	Type C: family planning	R_2
50	Type D: family planning	R_3

Thus, $R_1 - R_0$, $R_2 - R_0$ and $R_3 - R_0$ would be measures of the impact of the respective programmes. All of the advantages and disadvantages described above for design No. 1 still apply, except that an additional advantage is gained in that administrators and policy-makers have information that may be useful for deciding which type of programme among those tested is best.

More complex after-only designs are available which would usually require more "treatment" groups, but they are beyond the scope of this discussion.[22]

Additional data either in the form of time-series measures of fertility or of related measures of associated variables, if available, can often be utilized with appropriate statistical techniques[23] to strengthen conclusions in after-only designs. In particular, pre-programme measures of fertility levels and trends by district used as

[19] Although time trends in fertility over the course of the programme would not be available from (a single) census, recent trends may be estimated from "own children" or related techniques. See Lee-Jay Cho, "The own-children approach to fertility estimation: an elaboration", in *International Population Conference, Liège, 1973* (Liège, International Union for the Scientific Study of Population, 1974), vol. 2, pp. 263–280.

[20] Far-sighted planners and evaluators would plan for longer range studies based on the 1991 census and/or on interim measures of fertility.

[21] B. G. Greenberg, *loc. cit.*

[22] For a good illustration of the logic of factorial designs, see N. K. Namboodiri, "A statistical exposition of the before-after and after-only designs and their combinations", *American Journal of Sociology*, vol. 76 (July 1970), pp. 83–102.

[23] Discussion of appropriate statistical techniques is beyond the scope of this chapter. The regression techniques discussed in chapter VII might also be appropriate for experimental designs. See also, for example, W. G. Cochran and G. M. Cox, *op. cit.*, for appropriate techniques.

covariables may strengthen conclusions and increase the precision of analysis.

Also, when districts are randomly assigned to experimental groups, time trends in numbers and rates for births recorded in the civil registration system, even though coverage is not 100 per cent, might prove to be a useful indicator for post-programme comparisons. This indicator or any other that is influenced by the family planning programme might, however, be of limited value. For example, if the programme emphasizes infant care after delivery, birth registration levels might improve more in programme than in non-programme districts, thus tending to underestimate programming effects.

After-only experimental designs are appropriate when no fertility measure is available nor can be made prior to randomization. If fertility levels can be measured prior to randomization, a number of alternative before-after designs can be used. One possibility would be to stratify districts within provinces on fertility level before randomization, but this experiment would be more complex to conduct than simply using before measures as covariables in the analysis of after results. For example, if in addition to the 1981 census, 1976 census fertility measures were available by district for our hypothetical country the overall results for design No. 3, a "before-after-two group" randomized design, could be represented as shown in table 108.

TABLE 108. DESIGN NO. 3: BEFORE-AFTER-TWO GROUP RANDOMIZED DESIGN

	Fertility measures derived from:	
	1976 census	*1981 census*
No programme	R_{01}	R_{02}
programme	R_{11}	R_{12}

The before measures, R_{01} and R_{11}, could not be influenced by the programme; and because of randomization procedures they should be equal except for random error. Hence, little will be gained unless either post-stratification or statistical procedures which take into account the district-to-district variation in 1976 fertility are used in analysis. Addition of 1976 census data, as in design No. 3, to design No. 2, will yield design No. 4, which is a "before-after-four group" randomized design.

Another and perhaps a more realistic situation could result if no district agreed to serve as a control and resources for mounting a full-fledged programme were limited. Suppose that policy-makers and administrators decide that a four-year phased implementation will be followed. Phased implementation can be done in a randomized design utilizing all the districts that meet eligibility criteria in each of the three years. Thus, each district would be randomly assigned to begin its programme in one of the first four years so that the national programme would be completely implemented by the end of the fourth year. Randomized phase-in is a fair way of deciding who begins when. It is assumed here that 50 new districts could be initiated each year and that all other previously established programmes would continue each year. The results in 1981 could be depicted as shown in table 109.

TABLE 109. DESIGN NO. 4: FOUR GROUP RANDOMIZED BEFORE-AFTER DESIGN WITH PHASED IMPLEMENTATION

Sample size (number of districts)	*Year of implementation*	*Fertility 1976*	*Fertility 1981*
50	First year (1978)	R_{11}	R_{12}
50	Second year (1979)	R_{21}	R_{22}
50	Third year (1980)	R_{31}	R_{32}
50	Fourth year (1981)	R_{41}	R_{42}

For example, in formula (1) given below the percentage difference in crude birth rates due to three years of programme activities is derived as:

$$\frac{40-30}{40} \times 100 - \frac{41-39}{41} \times 100$$

Where R_{11} and R_{41} for 1976 and R_{12} and R_{42} for 1981, the crude birth rates are 40, 41, 30 and 39 per 1,000 population, respectively. Accordingly, 25 per cent – 5 per cent is equal to a 20 per cent decrease over the three-year period:

$$\left[\frac{R_{11}-R_{12}}{R_{11}} \times 100\right] - \left[\frac{R_{41}-R_{42}}{R_{41}} \times 100\right] \qquad (1)$$

would be a measure of the percentage difference due to three years of programme. Similarly,

$$\left[\frac{R_{21}-R_{22}}{R_{21}} \times 100\right] - \left[\frac{R_{41}-R_{42}}{R_{41}} \times 100\right] \qquad (2)$$

measures the two-year impact and

$$\left[\frac{R_{31}-R_{32}}{R_{31}} \times 100\right] - \left[\frac{R_{41}-R_{42}}{R_{41}} \times 100\right] \qquad (3)$$

measures the one-year impact.

Design No. 4 differs from the other designs in that: (*a*) there is no real control group except that those districts in which programmes begin only during the fourth year presumably would not be affected by the programme by 1981; and (*b*) every district government knows that it will have a programme within four years.[24] Otherwise, except that it lacks "before measurement", it has all the advantages and disadvantages of design No. 2. It should be noted that policy-makers and administrators must be strong supporters and advocates of randomized phased implementation if this or a similar design is to be implemented as planned.

Thus far, districts have been assumed to be the experimental units because presumably programmes would be implemented at that level and the ultimate

[24] Ideally, districts should not be told the year in which they will begin; but because of lead times required for funding and planning, this requirement would be impractical.

outcome measure—fertility—would be available at that level. As stated previously, intermediate measures of acceptance and use of contraceptives, rather than fertility measures, have been the "variable of interest" in some notable experiments. Individuals, clinics, villages, towns, cities or other units may be taken as experimental units depending upon the purpose of the experiment and how the results will be used.

B. Use of quasi-experimental designs

Quasi-experimental designs (non-randomized studies) require essentially the same degree of rigour as randomized experiments, and the logic of quasi-experimental designs is the same as the logic of experimental design with the single important exception that pre-treatment randomization is not done. The other principles are the same with the focus being on control of extraneous sources of variation.

The terms "quasi-experiment"[25] and "observational study"[26] generally are used to refer to a trial or test in which experimental units either are not or cannot be randomly assigned to a treatment. Whereas experiments are necessarily designed prospectively, observational studies may be designed either prospectively or retrospectively. A prospectively designed study is likely to be better than a retrospectively designed study because the evaluator has the potential for incorporating the desirable design principles other than randomization. Prospective design also forces the designer to plan for the measurement and processing of the required data on both response and intervening variables. Whether a retrospective or prospective design is used, measurements should ideally be made at the same time in all treatment units in order to help assure that the influence of common events shall apply equally to all.

Statisticians and experimental social scientists agree rather closely about the methodology and interpretation for true experiments,[27] but there is no such agreement in the area of quasi-experimental design. Indeed, statisticians tend to use the term "observational study", whereas social scientists appear to prefer "quasi-experiment" in referring to non-randomized studies. A review article[28] traces the development of statistical methods for analysing observational data and clearly distinguishes between randomized experiments and observational studies; and another study,[29] which reviews examples specific to estimation of births averted, includes a less extensive discussion of the same issues: the authors of these two works agree that Cochran,[30] of all the writers on the subject, has come closest to a clear statement of problems and approaches to their solution.

At their best, quasi-experimental designs would include all the required features of true experimental designs except randomization of subjects prior to treatment. At worst, a quasi-experimental design might be planned and carried out retrospectively, several years after the trial has been finished; the evaluator then must work with whatever data—regardless of the quality—are available. In quasi-experimental designs, efforts to control extraneous sources of variation usually are made to reduce known potential sources of bias; balancing of the unknown sources is not possible. For example, it has been found[31] that the fertility rates of IUD acceptors for three years prior to acceptance were more than 50 per cent higher than the fertility of married women in general. For a more general discussion of the procedures followed to reduce biases due to these differences, see illustration B in section C.3. Other factors, in addition to the demographic factors, that may influence fertility levels are listed.

Clearly, unless it is impossible to randomize subjects before treatment, true experiments are much to be preferred. Next most desirable would be prospectively designed quasi-experiments which incorporate all elements of true experiments except randomization. Less desirable, but sometimes all that can be done, would be retrospectively designed quasi-experiments which incorporate as many desirable design features as possible. Thus, the relative strength of quasi-experimental designs or observational studies will depend upon the extent to which they are based on the established principles of experimental design.

Results of even the best possible quasi-experimental designs are equivocal in greater or lesser degree; hence, interpretation of the results must be much more tentative than in true experiments. Consistency of results in replication of similar quasi-experiments at different places and different times are therefore much more important than for true experimentation. In addition, greater use must be made of information from sources outside the quasi-experiment. Hence, the analysts and evaluators must be experts in the subject field, in this case, demography and family planning in general, as well as in the particular family planning programme being studied.

1. *Example of a quasi-experimental design for a hypothetical country*

Design No. 4. was included as an experiment because districts were randomly assigned to different years for beginning a programme. If districts are not randomly assigned but none the less differ, for whatever reasons, in the time at which they begin programmes, they may also differ in the type of programme implemented. The year of initiation and the type of programme are likely to be associated with changes in fertility in later years and

[25] D. T. Campbell and J. C. Stanley, *op. cit.*

[26] S. M. McKinlay, "The design and analysis of the observational study: a review", *Journal of the American Statistical Association*, vol. 70 (1975), pp. 503–520.

[27] As pointed out by H. W. Riecken and R. F. Boruch, *op. cit.*

[28] S. M. McKinlay, *loc. cit.*

[29] H. Bradley Wells, "Matching studies", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975), pp. 215–244.

[30] W. G. Cochran, "The planning of observational studies of human populations", *Journal of the Royal Statistical Society*, section A, vol. 128, No. 2 (1965), pp. 234–265.

[31] M. C. Chang, T. H. Liu and L. P. Chow, "Study by matching of the demographic impact of an IUD program", *Milbank Memorial Fund Quarterly*, vol. XLVII, No. 2 (April 1969), pp. 137–157.

hence provide a logical basis for grouping districts for study purposes. Thus, the results of a (reasonable) quasi-experimental design might be depicted in the same way as is done in design No. 4. The major difficulty would be the interpretation of results. Without randomization one could always argue that districts that were late in implementing a programme were also different in other variables associated with fertility change. Hence, the evaluator should attempt to strengthen conclusions by taking into account as many other important associated variables as possible through analytical adjustment procedures and/or such design approaches as stratification, blocking or matching.

Quasi-experimental designs are not so self-contained as randomized experiments. It is therefore essential that programme *versus* non-programme comparisons be made within as many subgroups of the population as possible. In this way evidence regarding fertility changes can be accumulated.

Because of communication and spill-over effects, experiments using administrative areas as experimental units tend to underestimate programme effects. Quasi-experimental studies are also subject to spill-over effects and hence to underestimation of programme impact. Whether the self-selection implicit in the timing and type of programme implementation by different units causes underestimation or over-estimation of programme impact in quasi-experimental designs may be difficult to determine but the evaluator(s) should attempt to obtain such evidence as part of the study process. Time-series measures of fertility levels and programme inputs are much more critical for sound quasi-experimental studies than for experiments.

C. Actual studies

In this section an experiment and two quasi-experimental studies are reviewed in some detail. Illustration A is a randomized after-only experiment. Its purpose was not to measure programme impact on fertility indices, but to determine the cost of acceptors in money and time. It is presented here only for methodological purposes, as applications of such experiments for the measurement of births averted have been infrequent and examples suited for the present purposes are few. To illustrate further the shared features and the differences between the two types of study, use is made of the outline given below, which is very general but is intended to cover the range of design features discussed in the first part of this chapter:

1. Objectives of the study;
2. The setting;
   (*a*) Geographical frame;
   (*b*) Time frame;
   (*c*) Other (clinics etc.);
3. Experimental or study unit;
4. Response (dependent) variables;
5. Independent variables:
   (*a*) Treatments;
   (*b*) Other related (intervening) variables;
6. Experimental or study design:
   (*a*) Randomization;
   (*b*) Other design features;
7. Measurement methods;
8. Data management methods;
9. Analytical methods;
10. Limitations of the design;
11. Interpretation of results.

The three studies reviewed below illustrate differences in experimental units, experimental *versus* quasi-experimental design and balancing through randomization and through matching. Related types of matching studies[32] have been reviewed and compared by the present author.[33]

1. *Illustration A: randomized-after only experiment, Country E, 1963*[34]

Illustration A may be reviewed as follows, according to the outline given above.

Objective

The objective of the experiment was to learn how much family planning (acceptance) could be achieved at how much cost in money, personnel and time.

Setting

Geographical

The principal city of Country E was divided into 2,389 *lins*, or neighbourhoods, and these units were grouped into three large sectors as described below under "Experimental design".

Time

The experiment was done during the period from February to October 1963.

Experimental unit

The experimental unit was a *lin* or neighbourhood comprising 20–30 families.

Response variable

The response variable was the number of acceptors of programme contraception per 1,000 maried women aged 20–39 years.

[32] J. T. Johnson, Tan Boon Ann and Leslie Corsa, "Assessment of family planning programme effects on births: preliminary results obtained through direct matching of birth and programme acceptor records", *Population Studies*, vol. XXVII (March 1973), pp. 85–96; L. M. Okada, "Use of matched pairs in evaluation of a birth control program", *Public Health Reports*, vol. 84 (May 1969), pp. 445–450; Roger W. Rochat, Carl W. Tyler, Jr. and Albert K. Schoenbucher, "The effect of family planning in Georgia on fertility in selected rural countries", in A. J. Sobrero and R. M. Harvey, eds., *Advances in Planned Parenthood*, vol. 6 of *Proceedings of Eighth Annual Meeting of the American Association of Planned Parenthood Physicians*, Boston, Mass., 9–10 April 1970, International Congress/Series No. 224 (New York, Excerpta Medica Foundation, 1971), pp. 6–14.

[33] H. B. Wells, *loc. cit.*

[34] B. Berelson and R. Freedman, *loc. cit.*

Independent variables

Treatments

Four different "treatments" were defined by the kind of neighbourhood activities to be carried out in each *lin* to promote acceptance of contraceptive methods. The entire city was exposed to a general distribution of posters and a series of meetings was held with community leaders to "inform them about the programme and enlist their support". The remainder of the programme effort consisted of one of the following treatments being applied to each *lin*:

(a) *Nothing:* in these *lins* nothing further was done in promotional efforts;

(b) *Mail*: in these *lins* direct-mail materials promoting family planning were sent to newly-weds and to couples with two or more children;

(c) *Everything wife only (EW)*: in these *lins* the home of every married woman aged 20–39 years was visited by specially trained nurse-midwives who provided information, answered questions, provided contraceptive supplies and made appointments for people at the field-stations;

(d) *Everything husband and wife (EHW)*: these *lins* received the same "treatment" as the EW *lins* except that the visits also included the husband either with the wife or separately. Within each of the three sectors of the city, the proportion of *lins* that received treatments (c) and (d) were varied in order to estimate how much "circulation effect" could be expected. Twelve groups were thus defined although the density of effort was arbitrarily rather than randomly assigned to each *lin*. Berelson and Freedman,[35] quite correctly, refer to only four treatments, the types of promotional effort.

Other related variables

The other related variables in the experiment were:

(*a*) Acceptor reports could be classified by type of contraceptive, age of acceptor, parity, number of children by sex, time of acceptance, residence and education of wife;

(*b*) The city was divided into three sectors roughly equivalent in urban-rural distribution, socio-economic status and fertility. This division can be considered an attempt to control for these variables by balancing them between sectors;

(*c*) A before and after fertility survey was conducted with a random sample of 2,452 women from the entire city. Pregnancy rates for the entire city before and after treatment were therefore available. It is not clear whether these results were ever subdivided and compared across the 12 experimental groups although that would have been desirable.

Experimental design

Each of the three sectors was arbitrarily designated to receive either light, medium or heavy degrees of effort. Within each sector, each *lin* was randomly assigned to receive one of the four treatments. Table 110 shows the number of *lins* in each group.

TABLE 110. DISTRIBUTION OF TREATMENT

Type of effort	Sector (density of effort)			
	Heavy (one half)	Medium (one third)	Light (one fifth)	Total
Nothing	232	243	292	767
Mail	232	244	292	768
Everything (wife only)	232	122	73	427
Everything (wife and husband)	232	122	73	427
Total number of *lins*	928	731	730	2 389

In the heavy sector half of the *lins* were assigned to receive "everything"; in the medium sector, one third and in the light sector, one fifth were so assigned. Half of the "everything" *lins* were for wife only and half were husband and wife. Each *lin* received the same type of treatment regardless of which sector it was in.

Measurement methods

The following measurement methods were used:

(*a*) The records kept by field-workers and field-stations provided service statistics and data on acceptors;

(*b*) The before-after fertility survey of a sample of women provided knowledge, attitude and practice data as well as pregnancy rates;

(*c*) Official birth statistics presumably would be available through the household register system.

Data management methods

Data management methods were not described in the reference.

Analytical methods

Acceptor data permitted analysis by *lin* and hence aggregation into the four treatment groups within sectors for analysis. The extent to which this procedure was possible with data from the fertility survey and/or the birth statistics is unclear from the reference.

Limitations of the design

The design was limited as follows:

(*a*) Density of effort was not randomly assigned;

(*b*) Results for all four types of treatment are confounded with word-of-mouth and other types of diffusion from *lin* to *lin*;

(*c*) Results cannot take account of non-programme use of contraceptives or whether acceptors switched from non-programme to programme contraception.

Interpretation of results

The percentages of married women aged 20–39 years who accepted programme contraception are given in table 111.

[35] *Ibid.*

TABLE 111. RESPONSE TO TREATMENTS

(*Percentage*)

Type of effort	*Sector (density of effort)* Heavy (one half)	Medium (one third)	Light (one fifth)	*Total*
Nothing	7	5	5	5
Mail	7	5	6	6
Everything (wife only)	16	13	11	14
Everything (wife and husband	18	10	12	15
All types	12	7	7	9

SOURCE: Bernard Berelson and Ronald Freedman, "A study in fertility control", *Scientific American*, No. 210 (May 1964), pp. 29–37.

This display of results illustrates how any type of response statistics could be displayed for this design.

Even with light density, the "everything" efforts resulted in a substantial proportion, i.e., 11–12 per cent of women accepting. Wife and husband *lins* had slightly higher acceptance rates than for wife only in light and heavy sectors but not in the medium sectors. Unfortunately, the design does not permit an unequivocal answer about what would have happened with no programme. The "nothing" and "mail" treatments are confounded with the results of word-of-mouth diffusion from the "everything" treatments. Thus, it cannot be determined what the effects of "nothing" and "mail" would have been in the absence of diffusion effects. Interpretation of contrasts between heavy, medium and light densities is also equivocal because they were not randomly assigned to *lins*. As has been pointed out,[36] another design using more widely dispersed experimental units would be required to minimize the "dilution" or diffusion effects and get better estimates of the "nothing" and "mail" effects.

2. *Illustration B: post treatment—retrospective matching quasi-experimental design, Country E, 1966 and 1967*[37]

Objective

The objective of the experiment was to measure the demographic (fertility) impact of an IUD programme. That goal was approached in two stages: the estimation of reductions in fertility levels and conversion of those reductions to births averted for a selected group of acceptors; and the ultimate application of those quasi-experimental estimates to country level data to obtain national estimates of impact.

Setting

Geographical

Three townships in two counties of Country E comprised the study area. (The three townships of one county had also been included as part of an earlier matching study of the impact of conventional contraceptives on fertility levels.)

Time

Acceptors and matching non-acceptors for calendar years 1964, 1965 and 1966 were compared with respect to fertility levels during three years before acceptance and from 18 to 42 months after acceptance.

Study unit

Individual married women who were aged 20–44 years and who were listed in household registers in the township office on January 1968 were the experimental units.

Response variable

The response variable was the change in the number of births per 1,000 women aged 20–44 for the period between first acceptance during the period 1964–1966 and 1 January 1968. Different acceptor cohorts were followed for different periods of time because the cut-off date for follow-up was 31 December 1967.

Independent variables:

Treatments

Treatments were defined to be: first acceptance of a programme IUD during the period from 1 January 1964 to 31 December 1966; and non-acceptance of a programme IUD during the same time period. Note that the second "treatment" definition is ambiguous because a non-acceptor in 1964 might have become an acceptor in 1965 or 1966. The two "treatment" groups were formed in the following manner:

(*a*) Names of first acceptors during the period were obtained from the central IUD registry listed in order of administrative subdivisions, i.e., by village and section of village;

(*b*) From the township household registry office a worker copied the names of all married women aged 20–44 years of age as of 1 January 1968. At the same time, the worker recorded for each woman her date of birth and education as well as the date of birth of each of her live-born children;

(*c*) The acceptor lists were then compared with the lists of married women in order to identify the two groups, IUD acceptors and IUD non-acceptors, during the three-year period, 1964–1966. IUD acceptors who could not be found on the list of married women of the same township were apparently omitted from the study.

Other related variables

All information about acceptors and non-acceptors was punched into computer cards. Within each township acceptors were sorted into groups using the following variables in the sequence listed:

(*a*) Year of first acceptance (1964, 1965, 1966);

(*b*) Age group years (30, 30–34, 35–39, 40–44);

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[36] E. T. Hilton and A. A. Lumsdaine, *loc. cit.*

[37] M. C. Chang, T. H. Liu and M. P. Chow, *loc. cit.*

(*c*) Education (no formal, primary, junior high school and above);

(*d*) Open birth interval (6 months, 7–12 months, 13–24 months, 25 months or longer);

(*e*) Number of live births (1–2, 3, 4, 5, 6 or more). Thus (3x4x3x4x5) = 720 groups of acceptors were formed for each township. Three "open intervals" were calculated for each non-acceptor on the assumption that had they accepted they would have accepted on 1 July of each calendar year 1964, 1965 and 1966. Non-acceptors were then sorted into 720 groups in the same way as acceptors. Matching of acceptors and non-acceptors was done by selecting an equal number of non-acceptors from the corresponding (matching) group within each country. Apparently matching was done first for 1964 acceptors, then 1965 and then 1966. Thus, the two treatment groups were group matched or "mean matched" (as contrasted with individual case by case matching for each acceptor) in order to take account of (five) extraneous variables which could have been related to post-acceptance fertility rates. Any matched case (acceptor) that had a live birth within nine months of 1 July of the year was disqualified. Just how this factor might bias comparisons of post-acceptance fertility rates between the two groups is unclear.

Study design

This design attempts to compensate for the fact that IUD acceptors differ from non-acceptors in many important variables. By group-matching on related variables as described above before comparing fertility changes, these variables were balanced.

Measurement methods

Measurement of fertility for the study units for the three years before acceptance and for varying time periods after acceptance was determined from the data on number and date of each live birth for each woman as copied from the township household registers in January 1968. Since 31 December 1967 was the cut-off date for the follow-up study, the reported averages for length of observation for acceptors by year were:

Year	Months of observation: Average	Range
1964	39.2	36–47
1965	31.2	24–35
1966	18.4	12–23

The national register of contraceptive acceptors was used to identify acceptors from the household register listings but also provided data on time of first acceptance for acceptors.

Data management methods

Data from household registers were transcribed by a clerk. Treatment groups were identified by linking this list with the acceptor list. The data were then coded. Editing and coding procedures other than the classifications used for matching variables are not described. The reference does not describe the procedures for the national register of contraceptive acceptors, but the data on listings obtained from this source were apparently combined with birth data for acceptors and punched into computer cards. Apparently, the sorting for matching and tabulation of results were done on a computer although this is not clear from the reference. It is not clear whether calculations for analysis were made by hand or by computer.

Analytical methods

For each cohort of acceptors (or cases) the average number of births per 1,000 women per year was calculated for the three years prior to date of acceptance and for the variable period between acceptance and the cut-off date for the study, 1 January 1968. Thus, the before-acceptance fertility rates for the 1964 cohort of acceptors refer to the calendar years 1964–1967 etc. Similarly, the rates for matches (non-acceptors) refer to the same calendar years although it was assumed that every match "accepted" on 1 July of the year. The rates are shown in table 112.

TABLE 112. FERTILITY BEFORE AND AFTER FIRST ACCEPTANCE OF INTRA-UTERINE DEVICE AND BIRTHS AVERTED, BY YEAR OF FIRST ACCEPTANCE

Year of first acceptance (1)	Sample size (2)	Fertility rates (per 1 000): Before: Acceptors (3)	Before: Matches (4)	After: Acceptors[a] (5)	After: Matches (6)	Average number of births averted per 1 000 acceptors per annum (7)
1964	463	384	390	70	172	99
1965	1 434	375	370	82	193	113 (114)
1966	1 284	387	377	74	227	158 (159)

SOURCE: Adapted from M. C. Chang, T. H. Liu and L. P. Chow, "Study by matching of the demographic impact of an IUD programme. A preliminary report", *Milbank Memorial Fund Quarterly*, vol. XLVII, No. 2 (April 1969), p. 144, table 3.

[a] Nine months were deducted from each case for calculation of post-insertion fertility because, when the loop was inserted, the woman was not pregnant. She could not have a live birth within the following nine months. The same deduction was made for the "matches" also because they were selected in such a way that they could not have live births within nine months.

The estimates of births averted, X, shown in the last column of table 112, were made using the following formula for each cohort:

$$X = A_1\left(\frac{M_2}{M_1}\right) - A_2 \qquad (4)$$

Where A_1 = fertility rate of acceptors before first acceptance;

A_2 = fertility rate of acceptors after first acceptance;

M_1 = fertility rate of "matches" corresponding to the before fertility rate of acceptors;

M_2 = fertility rate of "matches" corresponding to the after fertility rate of acceptors.

The numerical results based on rates in table 112 are:

Cohort	Average annual number of births averted per 1 000 IUDs inserted during period of follow-up
1966	$387\left(\frac{227}{377}\right) - 74 = 159$
1965	$375\left(\frac{193}{370}\right) - 82 = 114$
1964	$384\left(\frac{172}{390}\right) - 70 = 99$

These results were interpreted to mean that the number of births averted per 1,000 IUDs inserted after the first, second and third years following year of insertion were, respectively, 159, 114, and 99.[38]

A conversion to estimated births averted per 1,000 IUDs inserted during ordinal years was made, assuming that insertion occurred at the beginning of the year, as follows:

$$X_1 = \left(\frac{3}{12}\right) \text{ births averted in 1966 cohort}^{39} \qquad (5)$$

$$X_2 = \left(\frac{6}{12}\right) \text{ births averted in 1966 cohort } + \frac{6}{12} \text{ births averted in 1965 cohort} \qquad (6)$$

$$X_3 = \left(\frac{6}{12}\right) \text{ births averted in 1965 cohort } + \frac{6}{12} \text{ births averted in 1964 cohort} \qquad (7)$$

$$X_4 = \left(\frac{6}{12}\right) \text{ births averted in 1964 cohort} \qquad (8)$$

The numerical results are as follows:

Calendar year after acceptance	Births averted per 1 000 IUDs inserted	
1	$X_1 = 159\left(\frac{3}{12}\right) = 40$	(5)
2	$X_2 = 159\left(\frac{6}{12}\right) + 114\left(\frac{6}{12}\right) = 136$	(6)
3	$X_3 = 114\left(\frac{6}{12}\right) + 99\left(\frac{6}{12}\right) = 107$	(7)
4 (first six months)	$X_4 = 99\left(\frac{6}{12}\right) = 50$	(8)

These estimates of births averted were then used with national data on IUD acceptors to estimate births averted by IUD for all of Country E.

An alternative approach not used by Chang and his colleagues[40] to estimate births averted by calendar years including the year of insertion rather than assuming all insertions at the beginning of the year would be as shown in table 113, using only the after acceptance rates from table 112.

As described earlier, the average months of observation in the study were 39.2, 31.2 and 18.4 months, respectively, for the 1964, 1965 and 1966 cohorts. These periods are expressed in years in column (5) of table 113. The estimates of total births averted in each cohort of acceptors for the period of time they were followed is obtained as indicated above. By subtraction, estimates of births averted per 1,000 acceptors in years 3 and 4 can be obtained as follows, under the assumption that all three cohorts are similar:

(*a*) Births averted in year 4 (1967) = 333 − 289 = 44/1,000;

(*b*) Births averted in year 3 (1966) = 289 − 235 = 55/1,000.

[38] Note that the average annual number of births averted refers to periods of variable length, 1964–1967, 1965–1967 and 1966–1967, respectively, for the 1964, 1965 and 1966 cohorts of acceptors.

[39] Birth not possible during first nine months of the year, because the intra-uterine device was inserted in a non-pregnant woman on 1 January of the year.

[40] M. C. Chang, T. H. Liu and M. P. Chow, *loc. cit.*

TABLE 113. FERTILITY AFTER ACCEPTANCE OF INTRA-UTERINE DEVICE AND BIRTHS AVERTED, BY YEAR OF FIRST ACCEPTANCE

Cohort (1)	Average annual fertility rate per 1 000 after insertion: Matches (2)	Cases (3)	Average births averted per 1 000 acceptors per annum (4) = (2) − (3)	Average duration of follow-up for cohort (years) (5)	Total births averted per 1 000 acceptors during follow-up period (6) = (4) × (5)	Ordinal years represented in cohort (7)
1964	172	70	102	3.267	333	1 +2 +3 +4
1965	193	82	111	2.60	289	1 +2 +3
1966	227	74	153	1.533	235	1 +2

Unfortunately, there is no such straightforward way to obtain estimates for years 1 and 2 from the available data. (Ordinal year results presumably could be obtained for each cohort by reanalysing the data, but they were not shown in the published paper.) However, nine months must elapse before a birth can be averted; thus, only one fifth of this "eligible" time period of years 1 and 2 falls in the year of acceptance, i.e., the last three months of year 1. Thus, an estimate of births averted during year 1 would be $(1/5) \times 235 = 47$. Then $235 - 47 = 188$ births averted in year 2. Whether this estimate would be acceptable depends upon how one perceives the decline in births averted over time.

Note that the estimated cumulative total number of births averted is very close using the two estimates. For this approach, $47 + 188 + 55 + 44 = 334$ per 1,000, as compared with $40 + 136 + 107 + 50 = 333$ per 1,000 for the procedure actually used in the paper. It should be mentioned that if one assumes that insertions all occurred on 1 July of the calendar year, the two approaches should yield the same results.

Limitations of the design

Unfortunately, as the report states, it was not possible to match on the strength of motivation for family planning; and, thus, the study is subject to the criticism that fertility of the acceptors might have declined more rapidly than that of married women in general and implicitly of the matched non-acceptors even if there had been no IUD programme. Certainly, other contraceptive methods had been available in most of the townships for a number of years prior to the IUD programme and probably were being used to some extent by the matched non-(IUD)-acceptor group(s), which would tend to underestimate the effectiveness of an IUD programme alone if other methods were being used by the non-IUD group. The extent to which the IUD acceptor group might have resorted to other methods, perhaps even abortion, to reduce their rates without the IUD programme cannot be determined by this particular study design.

As pointed out in the report, this study could have been improved by end-of-study interviews to measure strength of motivation and current use of contraception and abortion among both the IUD and the matched non-IUD acceptor groups. An even better prospective design would have included: (*a*) the interviewing of acceptors at time of first acceptance; and (*b*) the selection of the matching non-acceptors at the same time and their interviewing as soon thereafter as possible. The end-of-study interview should also be included in this design. Thus, it would have been possible to estimate and perhaps adjust for the effect of motivation to practise family planning. Clearly, improved design features such as these require much more strict adherence to current time frames and work schedules and therefore more resources and technical staff. Unfortunately, even such improved study designs would still have limitations. One difficulty reported by the authors was that 26 per cent of acceptors and matches were lost to follow-up. This might have been somewhat lessened with improved designs, but it would not have been completely eliminated. Both the reported study and the suggested improved designs are short term. A considerably longer period of observation would be required in order to assess the total impact of the IUD programme. Also, it has been pointed out that other methods of analysis, which take account of time trends of fertility for separate cohorts of acceptors and non-acceptors by time of acceptance and time duration after acceptance, could yield somewhat different estimates of births averted from those reported.[41]

Interpretation of results

This study was an attempt to recreate a before-after design controlling for a number of important variables. The matched subgroup design yielded the over-all results given in table 114.

TABLE 114. ANNUAL LIVE BIRTHS PER 1 000 WOMEN AGED 20–44 YEARS

Study group	*Three years before acceptance*	*After acceptance*	*Change (percentage)*
Intra-uterine device acceptors	381	77	−77
Matched non-acceptors....	377	195	−48

Thus, "short-term" post acceptance rates drop considerably more rapidly for acceptors than for non-acceptors. Perhaps the most striking result is that the rate for matched non-acceptors dropped 48 per cent. Although the latter decline may have been due in part to some phasing within the birth interval, it none the less indicates a need to take account of what might have happened without the IUD programme to women with the same demographic characteristics as the acceptors. The authors used the quasi-experimental design results to estimate births averted as described above in the section on analytical methods.

These results were then applied to acceptor data to estimate the short-term impact of the IUD programme for the whole of Country E. Thus, the illustrated matching study yielded estimates of births averted similar to those described in chapter VI. The assumption that results found in the selected study townships were applicable to all of Country E may be questioned.

3. *Illustration C: three group-longitudinal quasi-experimental design, Country F, 1956–1969*[42]

Objectives

The aims of this design were:

(*a*) To test the power of existing contraceptive methods to change birth rates in a pre-industrial population;

(*b*) To inquire into factors within that population influencing the frequency of births, deaths, migrations etc.

[41] H. B. Wells, *loc. cit.*

[42] J. B. Wyon and J. E. Gordon, *The Khanna Study: Population Problems in the Rural Punjab* (Cambridge, Mass., Harvard University Press, 1971).

Setting

Geographical

A district with a total of 811 villages was selected as the study area. A total of 18 villages, four clusters of from three to four villages and two single villages, were involved in the pre-test, action and control phases of the programme, as described below under "Experimental design".

Time

Preliminary planning and exploratory work for organizing the study programme began in October 1953. A pilot study was conducted and the design of the definitive study was completed in March 1956. The full-scale test study of the contraceptive programme was carried out during the period from April 1956 to March 1960. The follow-up study to observe the long-term results was conducted from February to September 1969.

Study unit

Implicitly it appears that the unit of study was defined as a married woman in the fertile ages and her spouse, which may be inferred because one of the major dependent variables was used on contraception. However, the treatments (programmes) were essentially applied to whole villages.

Response variables

Ultimately, a large number of response variables were analysed in the project. For present purposes, those demographic and contraceptive response variables which are especially important are: crude birth rates; crude death rates; net migration rates; and contraceptive use rates. Age-specific fertility rates and general fertility rates were also studied.

Independent variables

Treatments

Three different "treatments" were defined by the type of contraceptive/health programme conducted in the experimental areas:

(*a*) *Test*. In the definitive study ("experiment"), test areas were exposed to a programme that was designed to inform villagers about contraceptive methods and to encourage them to practice contraception in order to prevent live births. That programme included regular weekly visits to each home having a wife of childbearing age by male and/or female fieldworkers who resided in the village. During that visit the field-worker(s) were supposed to "record information about illnesses, obstetric and medical practices, and related interests", including menstrual dates, practice of breast-feeding and data about vital events. They also discussed and gave instructions about five contraceptive methods: vaginal foam tablets; rhythm; withdrawal; contraceptive paste; and pads soaked with a saturated salt solution. Condoms, cervical caps and diaphragms were not recommended at the time, because of government proscriptions; and intra-uterine devices and pills were not available. In addition to the resident field-workers, two physicians, a male and a female, were supposed to spend one day each week in each village to encourage the use of contraception and to see patients. Health problems that occurred at other times were referred to other physicians or clinics by the field staff. Contraceptive supplies were provided by the field staff. A regular monthly visit was also made to each house to record births, deaths and migrations;

(*b*) Control A. Villages assigned to serve as control A received the same treatment by the same type of field and medical staff as test villages, except that no information on contraception was given nor were supplies or contraceptives provided;

(*c*) Control B. Villages assigned to serve as control B received nothing except a monthly visit by a nurse to record vital events.

Other related variables

"Family record cards" in test and control A villages included listings of household members with sex, marital status, relation to head, age, change in family status (nature and date) and columns indicating whether each person was present at the time of annual censuses in 1957–1960. "Menstrual record cards" for each married female in the fertile ages included basic identification as in the "Family record card" plus ethnic identity, age (current, at menarche, at marriage, at cohabitation), cohabitation status and year of cohabitation. For each previous or current delivery space was provided to record: month and year of delivery; amenorrhoea (duration of pregnancy, post-partum, other); abstinence (pregnancy, post-partum, other); duration of lactation; and result of pregnancy (sex of child, current age, age at death). In addition, a number of questions related to knowledge, attitude and practice of contraception were asked. Details about menstruation were collected every month. Additional details about each illness and each death of young children were also recorded. In the final census of January 1960, the additional data collected included occupation and education of individuals, couple use of contraception and an economic index of households. In the follow-up Census conducted in 1969, 10 years after termination of the field-work, an effort was made to determine, retrospectively, the yearly status of each person who was a resident during 1960–1969 as well as details about the outcome of each delivery after 1 January 1960 and the family planning methods used during 1960–1969.

Study design

The design provided for the comparison of three types of "programme" groups of non-randomly selected villages. Exploratory and pilot studies were conducted to find what field procedures would work and what data collection methods could be used prior to beginning the definitive study. The study design for the field-work is summarized in tables 115 and 116. Field-work for the programme was discontinued after 1959; but in 1969, a follow-up census/survey was conducted to observe long-term consequences of the programme for contraception.

TABLE 115. POPULATION OF VILLAGES, COUNTRY F, 1957, 1959 AND 1960

Study category and village	*Year*			
	1954	*1957*	*1959*	*1969*
Exploratory				
Village A	1 087	...	...	...
Test (contraceptive)		(7 748)	(7 883)	(9 041)
Village B	...	1 466	...	...
Village C	...	1 377	...	...
Village D	...	1 004	...	...
Village E	...	1 727	...	...
Village F	...	700	...	...
Village G	...	495	...	...
Village H	...	979	...	...
Control A (no contraceptive)		(4 194)	(4 354)	(4 823)
Village I		1 361	...	...
Village J		655	...	...
Village K		283	...	...
Village L		1 895	...	...
Control B (Nothing) (six villages)		...	4 934[a]	...

SOURCE: J. B. Wyon and J. E. Gordon, *The Khanna Study: Population Problems in the Rural Punjab* (Cambridge, Mass., Harvard University Press, 1971).

Note: Three dots (...) indicate that data are not available in the source used.

[a] No details for the six villages are available in the source used. See study design in table 116 for list of village names.

Measurement methods

The following measurement methods were used:

(*a*) Records compiled for each home included a "family roster", with annual updating at time of census and the collection of additional details in 1959;

(*b*) A "fertility history" was completed for each married woman in the fertile ages and monthly visits were made to record menstruation and amenorrhoea, details as well as family planning practice;

(*c*) Monthly visits were made by field-workers to record births, deaths and migrations;

(*d*) Field-workers and physicians maintained service records and diaries for test and control A villages;

(*e*) A follow-up census/survey was carried out in the test and control A villages only 10 years after the programme was concluded.

Data management methods

Field-workers and statistical and clerical staff maintained records, edited and coded data. Edge-marked cards were utilized for most of the data analysis in Country F; but, in addition, some records were microfilmed and mailed to Harvard University (United States of America), where the information was coded and punched out on to cards. Punch-card equipment and computers were used for tabulation and analysis.

Analytical methods

Conventional demographic methods were used to analyse time trends in birth, death and migration rates in the test and control A villages. In some analyses, control B villages were included in comparisons. Life-table and other techniques were applied to the analysis of amenorrhoea and contraceptive effectiveness.[43]

TABLE 116. STUDY DESIGN, COUNTRY F, STUDY OF POPULATION DYNAMICS, 1953–1960

Study category and village	*Oct. 1953–May 1954*	*June 1954–March 1955*	*April 1955–March 1956*	*April 1956–March 1960*
Exploratory:				
Village A	Preliminary	I	II	III
Test (contraceptive):				
Village B Village C Village D Village E Village F Village G Village H	...		Pilot	Definitive full-scale test of the programme of contraception Apr. 1956–Mar. 1960. Treatment: weekly visits to each village by senior male and female physicians who supervised resident staff and encouraged use of contraception; saw patients on request. Resident staff visited each house once each month to record births, deaths and migrations.
Control A (no contraceptive):				
Village I Village J Village K Village L	...		Pilot	Control A: Treatment: same as in test villages except for omission of contraceptive instruction. Same recording of births, deaths and migrations
Control B (nothing):				
Village M Village N Village O Village P Village Q Village R	...		Pilot	Control B: Treatment: none except a nurse visited each village once a month to record births and deaths.

SOURCE: J. B. Wyon and J. E. Gordon, *The Khanna Study: Population Problems in the Rural Punjab* (Cambridge, Mass., Harvard University Press, 1971).

Limitations of the design

Limitations of the design included:

(*a*) Villages were not randomly assigned to treatments

[43] *Ibid.*, a bibliography of the study papers, giving the complete range of the demographic and epidemiological methods applied, is found in this source.

because it was impractical to do so; hence generalizations to other populations are of questionable value;

(*b*) Clusters of villages were the unit of study for treatment and the number of villages actually included in the study was relatively small. The design would have a large sampling error for vital rates based on a cluster sample design with villages considered to be clusters;

(*c*) It is possible that the type of "treatment" administered to the test and control A villages changed with time;

(*d*) It is possible that the test (contraceptive) programme might have been confounded with the measurement process because the birth control programme began as the initial census was being taken; that is, the field staff, which presumably had a vested interest in the programme, carried out the measurement process for the first four years and also for the 1969 census. This fact was recognized by the researcher, who states: "Irregular fluctuations in estimated birth rates were more marked . . . in control A villages . . . consistent . . . with a less intimate acquaintance between the control A population and the field workers who made the 1969 survey."[44]

Strong features of the design included: test and control groups and time-series measures were made in the same manner in both test and control villages so that presumably any time change biases in measurement would be the same in all groups, subject of course to the possible interaction described above in subparagraph (*d*).

Results

Contraceptive acceptance/use

Although the exploratory studies indicated that a substantial proportion of couples would accept the methods of contraception offered, these levels were not achieved in the test villages during the 1957–1959 period of study. Furthermore, the changes in acceptance of contraceptives in the test and control A villages were essentially the same during those periods as in the 1969 census/survey. About 30 per cent of couples with the wife aged 15–44 years, in 1959 as well as in 1969, claimed to practise some form of birth control, the major difference being that about 7 per cent in 1969 reported using a "medical" (modern) method other than foam tablets as compared with none in 1959.

Fertility indicators

Based on monthly visits for data collection during the three years of the definitive study, no differences could be detected in fertility trends for the three "treatment" groups. Results were as follows:

Measure and "treatment"	*Year* 1957	1959
Crude birth rate (per 1 000 population):		
Test	37.5	38.8
Control A	36.3	38.4
Control B	45.4	39.2
Fertility rate (per 1 000 women aged 15–44 years):		
Test	197	203
Control A	177	183
Control B	203	196

In the 1969 census/survey, one aim was to collect retrospectively fertility data through a single survey for estimating rates for each year of the period 1960–1969. The estimated crude birth rate for 1960 obtained in this way for test and control A villages was about 30 per 1,000, an implausibly low estimate. Nevertheless, the estimated levels were about the same for test and control A villages in 1960 and in subsequent years as shown by three-year periods in table 117.

TABLE 117. ANNUAL CRUDE BIRTH RATES BY THREE-YEAR PERIODS, BY TREATMENT GROUP, COUNTRY F, 1957–1968

(*Per 1 000 population*)

Treatment group	*1957–1959*[a]	*1960–1962*[b]	*1963–1965*[b]	*1966–1968*[b]
Test	38	33	34	32
Control A	38	30	32	29

SOURCE: J. B. Wyon and J. E. Gordon, *The Khanna Study: Population Problems in the Rural Punjab* (Cambridge, Mass., Harvard University Press, 1971), p. 301, table 40.

[a] Based on regular monthly visits and annual censuses.

[b] Based on single 1969 retrospective follow-up survey covering the years 1960–1968.

It should be mentioned that the differences between the birth rates in 1957–1959 and 1966–1968 might be due at least partially to differences in measurement techniques. Other evidence cited to support the conclusion that birth rates had declined was that the proportion of the population under age 10 was 15 per cent lower in 1969 than in 1959.

The authors concluded that the birth control programme in 1956–1959 had little cumulative effect on the test population. This conclusion was reached because the apparent decline in birth rates over the 12-year period, as estimated, was slightly greater for the control A population than for the test population. Although the authors do not show estimates of the quantitative effect of the various factors responsible for the decline, they mention a number of factors, including increasing age at marriage for women and somewhat greater use of modern contraceptives, as a result of the spread of such birth control methods through means other than the study programme.

[44] *Ibid.*, p. 299.

Chapter IX

OVERVIEW

*C. Chandrasekaran**

When family planning programmes were first initiated, there was considerable distrust as to their effectiveness. A sceptical attitude has continued to prevail in respect of the acceptance and effective use of contraceptive methods provided by the programmes and hence of their effect on fertility.[1] In effect, the necessity for evaluating family planning programmes has been generally recognized and some type of evaluation has formed part of the administrative activities of most family planning programmes. As in the case of several social programmes, including health programmes which affect another component of population growth—mortality—family planning programmes have had to develop rather sophisticated evaluative techniques to meet their specific needs. In this effort family planning evaluators have not only borrowed methodologies from allied disciplines but have devised new methods. The progress made during the short span of the past two decades in the field of family planning evaluation is striking, although the techniques developed so far cannot be said to provide unequivocal answers to all the questions that are raised.[2]

As family planning evaluation began to assume a wider perspective, the questions asked became progressively more demanding of resources and skill. At first, interest was centred on acceptability of contraceptive methods in different groups of the population, and their effectiveness, as used, in preventing pregnancies in these groups. The duration of use then began to attract attention, particularly as the intra-uterine device (IUD) was made available through family planning programmes; and the possibility of sustained use of effective contraceptives shifted the emphasis from "protection of pregnancy" to "births averted" during the period of use. The likelihood of the methods obtained from family planning programmes "substituting" in part for those which might have been obtained otherwise was soon recognised. Allied to this concept of "substitution" was the realization that even in the absence of the programme, fertility might have shown a decline as a result of economic and social development.

The tasks of evaluating the effects of family planning programmes also became more difficult because of the increase in the number of types of contraceptive provided by the programme and the need to develop evaluative procedures appropriate for each type. The provision of facilities for induced abortion by some programmes introduced a new dimension in evaluation: contraceptives prevent births by causing women to avoid pregnancy; the contribution of abortion, however, is not the avoidance but the termination of pregnancy. Hence the assessment of the demographic impact of a programme that provided facilities for abortion required a different approach.

Changes in programme emphasis also had an impact on evaluative methodology. For instance, acceptance shortly after a pregnancy termination was increasingly supported through post-partum programmes, thus increasing the overlap of the periods of contraceptive use of acceptors with their infertile periods of post-partum amenorrhoea. New methods for assessing the period of exposure to risk of pregnancy had to evolve to cope with the changed situation.

Professionals in the evaluation field took up the task of developing new methodologies and measurement techniques applicable to situations in which they were most interested. In the absence of good communication channels, it was not always easy for workers in this field to obtain information on these developments. Also, because of lack of close contact and open discussion, there were no agreed views on the new concepts, methodologies and techniques which had emerged from different settings.

These lacunae have to some extent been removed in recent years. In 1969, the United Nations published the report[3] of an Expert Group meeting which attempted to standardize definitions and to recommend techniques

* Population Specialist, Resident Staff in Indonesia, World Bank. The views expressed are his own and not necessarily those of the World Bank. Mr. Chandrasekaran was chairman of the Committee on Demographic Aspects of Family Planning Programmes of the International Union for the Scientific Study of Population (IUSSP), during the period in which the committee co-operated in the development of this *Manual.*

[1] Such scepticism was most forcefully expressed by Kingsley Davis in "Population policy: will current programs succeed?", *Science*, vol. 158 (November 1967), pp. 730–739.

[2] Even if the questions are straightforward it might not be possible to give clear-cut answers. In this context one might recall the challenge given by George Bernard Shaw to Major Greenwood, a noted English epidemiologist, to prove that smallpox vaccination was responsible for the disappearance of smallpox in western countries.

[3] *Assessment of Acceptance and Effectiveness of Family Planning Methods*, report of an Expert Group meeting, Bangkok, 11–21 June 1968, Asian Population Studies Series No. 4 (United Nations publication, Sales No. E.69.II.F.15).

related to acceptance and effectiveness of family planning methods. As a follow-up of that meeting, a regional seminar arranged by the Economic Commission for Asia and the Far East[4] worked out detailed recommendations for adoption by countries in the region.[5] Further developments have included the publication by the International Union for the Scientific Study of Population (IUSSP), for the Development Centre of the Organisation for Economic Co-operation and Development (OECD), of a work[6] that discusses at a fairly high technical level the methods that could be used in the study of acceptance and use-effectiveness of contraceptives supplied and of the births prevented by the programme.

The United Nations took up the task of critically examining the methods that were available for assessing the impact of the family planning programme on fertility, essentially in terms of births prevented. In an Expert Group meeting arranged for this purpose, methodological issues were examined in depth; and the outcome of the discussions and the recommendations are given in the report published by the United Nations.[7] As a follow-up of that Expert Group meeting, and with the collaboration of the IUSSP Committee on Demographic Aspects of Family Planning Programmes, which also provided assistance to the Expert Group meeting, the United Nations has prepared this *Manual* to facilitate the wider application of the various methods available for estimating births prevented by a family planning programme.

A. Contents of the *Manual*

The *Manual* presents nine methods which are useful in dealing with the problem of estimating births prevented by a family planning programme:

(*a*) Standardization;

(*b*) Standard couple-years of protection (SCYP);

(*c*) Component projection approach:

- (i) Computerised model;
- (ii) Model for desk calculators;

(*d*) Analysis of reproductive process;

(*e*) Multivariate areal analysis;

(*f*) Simulation;

(*g*) Experimental designs;

(*h*) Fertility projection/trend analysis.

Not all these methods are equally helpful in throwing light on the effect that can be attributed to the programme, often referred to as the "programme effect". Programme effect can be split into two parts, direct programme effect and indirect programme effect, the former referring to the effect produced on those who accepted a method and/or advice from the programme. Indirect programme effect refers to the effect produced on those who were motivated by the programme to use family planning methods but obtained supplies from sources outside the programme.[8] In contrast to programme effect is the non-programme effect attributable to contraceptive use generated by such non-programme factors as education or employment of women, which are sometimes referred to as "factors related to social and economic changes". The total effect on fertility is the sum of the programme and non-programme effects. A major contribution of the *Manual* is clearly to identify the role of the different evaluative methods in assessing the different effects.

As the *Manual* is intended as a guide to middle-level professionals, the presentation of the techniques to be used should be simple and perferably should be self-contained, and authors of various chapters have taken great pains to meet these needs. However, not all the methods of evaluation are equally easy to handle and a lack of homogeneity in presentation between chapters has inevitably resulted. The reader will find it useful to keep the above-mentioned publications of IUSSP/OECD and of the United Nations, which are frequently referred to in the *Manual*, as handy references.[9]

In a field like family planning evaluation, in which rapid developments are taking place, a manual such as this work has to strike a balance between well-tried and proven methods and others which have been used only to a limited extent. The professional using the *Manual* should keep in mind that conceptual and methodological problems are likely to arise more frequently in the case of the latter methods.

B. Methods presented

The treatment of the different methods in the *Manual* can now be examined against these considerations.

1. *Assessment of total effect*

Standardisation approach

Standardisation is a familiar device used to separate the real change in an index from that due to other factors.

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[4] Now the Economic and Social Commission for Asia and the Pacific.

[5] *Evaluation of Family Planning Programmes, Report of a Regional Seminar*, Bangkok, 24 November – 12 December 1969, Asian Population Studies Series No. 5 (United Nations publication, Sales No. E. 70.II.F.20).

[6] C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, published by the International Union for the Scientific Study of Population for the Development Centre of the Organisation for Economic Co-operation and Development (Dolhain, Belgium, Ordina Editions, 1975).

[7] *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, sales No. E.78.XIII.2).

[8] It is usually difficult to identify the persons who switched from private sector supply to programme supply. The effect resulting from such acceptances is usually credited to direct programme effect. The direct programme effect, as used in practice, also includes the effect on acceptors who in the absence of the public programme would have obtained supplies from the private sector. As such, what is normally assessed as the direct programme effect is the same as the gross effect defined in chapters III and V of the *Manual*. In the overview, direct programme effect is used as synonymous with gross effect. Even programme effect has sometimes been used to refer to gross effect, as the indirect programme effect still remains only a conceptual nicety.

[9] C. Chandrasekaran and A. I. Hermalin, eds., *Measuring the Effect on Family Planning Programmes on Fertility*; and *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues*.

In chapter I of the *Manual*, the standardisation approach is explained using the crude birth rate and the general fertility rate as the indices. A change in the crude birth rate is assumed to result from changes in: (*a*) the proportion of women of reproductive ages in the total population; (*b*) the age structure of women of reproductive ages; (*c*) the proportion of women of reproductive ages; and (*d*) age-specific marital fertility. Changes in general fertility rate are assumed to be affected by (*b*), (*c*) and (*d*). Only the changes in the birth rate or general fertility rate resulting from the effect of (*d*), changes in age-specific marital fertility rates, are considered to be real changes.

The presentation in chapter I has the following sequence. The formulae for decomposing changes in the crude birth rate or in the general fertility rate as due to each of the factors listed above are first worked out. This procedure is followed by an explanation of the assumptions underlying the development of these formulae. The use of the standardisation approach is then explained with a numerical example. The chapter concludes with a treatment of the steps to be taken for determining the amount of impact.

The change in the birth rate attributable to changes in age-specific marital fertility rates when weighted by the population gives the number of births averted during the year due to the change in fertility.[10] This real change, in the terminology used above, gives the total effect and is therefore the sum of programme and non-programme effects.

The standardisation approach does not include any procedures for separating programme and non-programme effects. A rather simple method of estimating programme effect has been included in chapter I. Its purpose has been to check whether the total effect obtained by using the standardization approach stands well in comparison with the programme effect as estimated by a different procedure and exceeds it. The country and time span of family planning experience used for illustration in chapter I are the same as those used for in chapter IV illustrating component projection approach II, a model for desk calculators, for assessing programme effect. The method used in chapter I is taken up in the discussion of the method covered in chapter IV.

Even the application of such a relatively simple procedure as the standardisation approach calls for the exercise of good judgement. Assumptions involved, data needs, interaction effect between non-programme factors and interpretation problems are fully dealt with in chapter I, which illustrates with great clarity the steps to be used.

2. *Assessment of programme effect with special reference to acceptors*

Pioneering methods

The assessment of programme effect focuses attention on acceptors, period of contraceptive use and births prevented during such use. Three methods of assessment had been well recognised before the *Manual* was prepared: that developed by Lee and Isbister; and those developed by Potter and by Wolfers.

Method of Lee and Isbister[11]

This method uses a component projection approach in which account is taken of the age of acceptor and of the contraceptive method chosen. Contraceptive use in one year is assumed to affect the births in the following year. In estimating the contraceptive use of IUDs, which is the method mainly considered in the original paper, insertions in the previous years are taken into account and losses due to such factors as expulsions, removals, aging and widowhood are also accounted for. Effective use in different years following insertions was estimated on the basis of the meagre data on continuation that were available at that time.

The authors draw attention to the more than average fertility of acceptors when compared with that of women of their age group and make suitable adjustments in their assessment.[12] However, no account is taken of the loss in effective use due to overlap of use with post-partum amennorhoea. One of the merits of the method is its ability to give indications of the number of births prevented by calendar years. The fertility measure used in the calculation of births permits determination of the age-specific marital fertility rate.

Methods of Potter and of Wolfers[13]

In developing his method, which was primarily directed to IUDs, Potter introduced several new concepts and estimation procedures. His method uses segment of contraception as the basis for assessment and corrects the period of contraceptive coverage for couples sterile at time of acceptance, for overlap of use with post-partum amennorhoea and for accidental pregnancies. To take account of accidental pregnancies, a penalty is imposed against coverage. In measuring mean length of a contraceptive segment by the usual life-table analysis recognizing pregnancy, expulsions and removals as reasons for discontinuing the intra-uterine device, he includes the extra competing risks of marital dissolution by death of a spouse and onset of secondary sterility. The duration of childbearing that was interrupted is reckoned against the

[10] The change in the general fertility rate can also be used for this estimation, using appropriate methodology as described in chapter I of the *Manual.*

[11] B. M. Lee and John Isbister, "The impact of birth control programmes on fertility", in Bernard Berelson and others, eds., *Family Planning and Population Programs: A Review of World Development* (Chicago, University of Chicago Press, 1966), pp. 737–758.

[12] It has been argued that a good part of the noticed high fertility of acceptors could be due to chance factors and that if observed longer their fertility would have regressed towards the mean. See J. C. Barrett and W. Brass, "Systematic and chance components in fertility measurement", *Population Studies*, vol. XXVIII (November 1974), pp. 473–493.

[13] Robert G. Potter, "Estimating births averted in a family planning program", in S. J. Behrman, Leslie Corsa, Jr. and Ronald Freedman, eds., *Fertility and Family Planning: A World View* (Ann Arbor, University of Michigan Press, 1969), pp. 413–434; and David Wolfers, "The demographic effects of a contraceptive programme", *Population Studies*, vol. XXIII (March 1969), pp. 111–140.

average duration per birth required in the absence of the contraceptive. This duration, which measures the potential fertility of acceptors while using a contraceptive, although basic to the assessment of "births averted", cannot be estimated directly. Potter shows three alternative estimates using the specific fertility rates of acceptor groups during the three years before acceptance, one based on the experience of acceptors who reported no contraceptive practice during the three years; another based on the average experience of the acceptors and the third based on the experience of acceptors who reported ever-use of contraception during those three years.

Wolfers' scheme embodies the same logic as Potter's, operationalizes the same list of factors; and, like the other scheme, estimates births averted for acceptor cohorts. It also is directed to the assessment of births averted by an IUD programme. A major procedural contrast is that Wolfers proceeds month by month with the various corrections being imposed on each successive ordinal month of IUD wearing-time and with the cumulations of childbearing interruption and births averted carried along. Another difference is that durations per potential birth are estimated by means of "age-specific prospective birth intervals".

As Potter remarks, "the procedural details of the two schemes are not only specialized to intra-uterine contraception, but each is tailored to a unique constellation of data that is not repeated elsewhere; and perhaps mainly for this reason, neither of the published schemes has ever seen replication" (chapter V, section A.3). At the same time, the publication of Potter's paper and its criticisms of the Lee and Isbister method put the latter method in the background.[14]

Although these three methods were well known, in practice many programme evaluators were satisfied with applying simple techniques, which consisted of calculating the duration of protection through contraceptive use by applying life-table techniques for continuation and of assessing "births prevented" by using reasonable values of birth intervals.[15]

Methods presented in the Manual

The *Manual* presents five methods relevant to the problem of estimating births prevented by the programme: (*a*) component projection approach II: a model for Desk Calculators (chapter IV); (*b*) the method described in section D of chapter I, "Standardization", for determining amount of impact; (*c*) standard couple-years of protection (chapter II); (*d*) analysis of reproductive process (chapter V); and (*e*) component projection approach I: a computerized model (chapter III).

These methods are based largely on the ideas underlying the methods of Lee and Isbister, of Potter and of Wolfers described above, but they have been modified in different ways to take account of the criticisms that have been levelled at them. The major criticisms have included:

(*a*) The evaluation methods are more appropriate for a semi-permanent type of contraceptive, such as IUD, but are less relevant to recurrent methods, such as oral contraceptives and condoms;

(*b*) The procedures proposed in Potter's and Wolfers' methods for estimating potential fertility, which when applied to the duration of effective contraceptive use would give the number of births prevented, are not easily applicable. It is also not easy to work out a factor for adjusting marital fertility rates, such as that used by Lee and Isbister;

(*c*) Potter's method and Wolfers' method estimate "births averted" for each 12-month period following IUD insertion. Administrators are more interested in the number of births prevented in successive calendar years. The Lee and Isbister method achieves this purpose.

The significant features of the methods presented in the *Manual* can be seen against some of the criticisms of the older methods.

Component projection approach II: a model for desk calculators

This component projection method, as its title implies, is intended for use when computer facilities or skills are not available; and it therefore is designed to avoid complicated calculations. The method builds on the Lee and Isbister method and attempts to assess the impact for each calendar year of programme performance from the beginning up to the present. "Potential fertility" is assessed using age-specific marital fertility rates of all women or age-specific fertility rates of acceptors prior to acceptance, and assessment is done by five-year age groups.

The births prevented in a calendar year 1971, for example, as given in the illustration in chapter IV, are due to effective protection against pregnancy between 1 April 1970 and 1 April 1971, which is equated to contraceptive users as of 1 October 1970. The estimation of IUD users on 1 October 1970 follows closely the method given by Lee and Isbister and is based on data of acceptors by age group and year of acceptance, and on estimated continuation rates derived by life-table techniques from information obtained in sample surveys. Users of oral contraceptives, condoms and jellies as of 1 October 1970 are estimated from the supplies provided to acceptors from 1 April 1970 to 1 April 1971. These figures can be derived from the number of supply visits made by acceptors, and the procedures prescribed in respect of the amount of supply to be provided at each visit. Age distribution of users of these methods during the 12-month period is estimated from reasonable assumptions. Methods for estimating births averted by sterilization and induced abortion are also provided in the chapter.

The method does not take account of the post-partum and post-abortion amennorhoea. Nor does it concern

[14] A certain degree of respectability was restored to the Lee and Isbister method by the publication of the paper by C. Chandrasekaran, D. V. R. Murty and K. Srinivasan, "Some problems in determining the number of acceptors needed in a family planning programme to achieve a specified reduction in the birth rate", *Population Studies*, vol. XXV (July 1971), pp. 303–308.

[15] These methods are similar to those applied for fixing targets for acceptors, described in John A. Ross, "Acceptor targets", in C. Chandrasekaran and Albert I. Hermalin, eds., *Measuring the Effect of Family Planning Programs on Fertility*, pp. 55–92.

itself with indirect programme effect. What it attempts to do is to estimate the direct programme effect.

Method given in chapter I for determining amount of impact

The method for determining amount of impact, as described in chapter I ("Standardization"), is essentially the same as that described in component projection approach II, a model for desk calculators, except that some simplifications have been introduced. The five-year age grouping is discarded. The protection given by IUD insertions is determined from a "retention schedule", worked out on the basis of a follow-up study. Effective use through oral contraceptives, condoms and jellies is, estimated from supply statistics. Survival rates are taken into account in estimating women protected by tubal ligations. With respect to estimating the influence of abortions, it is assumed each induced abortion prevented 0.65 births.[16]

Standard couple-years of protection

The standard couple-years of protection method relies on the concept of couple-years of protection (CYP) recommended by Wishik and Chen[17] for calculating the protection achieved through a programme but first modifies it to overcome certain deficiencies. These modifications include: (*a*) taking into account the ages of the acceptors and weighting the protection obtained for various age groups by fertility rates appropriate for those ages; (*b*) allowing for overlap of periods of protection and post-partum amenorrhoea; (*c*) introducing a penalty factor for accidental pregnancies; and (*d*) adjusting for differences in fertility levels between countries or between areas and population groups within the country. The standard couple-years of protection when multiplied by 0.4 gives the births averted.

Combining as it does the CYP concept with the methods given by Potter and Wolfers for estimating births averted, the method does not attempt to estimate births averted in a calendar year. It attempts to estimate the total number of births averted over the years by programme acceptances in a year. This estimation is done by calculating separately the number of births averted by each contraceptive method provided by the programme.

The SYCP method relies on supply statistics for calculating protection by recurrent methods, such as oral contraceptives, condoms, spermicides and injections. The application of the method is made easier by the provision of reference tables and an illustrative example.

Analysis of reproductive process

Analysis of reproductive process is another attempt to overcome some of the criticisms that have been made of the Potter and Wolfers methods and to evolve a simpler procedure by sacrificing some niceties. The "potential fertility" of acceptors is estimated on the basis of age schedules of marital fertility rather than either age-specific pre-acceptance birth rates or prospective birth intervals. Not only are marital fertility rates more easily available, but schedules based on these rates automatically allow for the effects of some acceptor couples being sterile on acceptance or becoming sterile during contraceptive use. Discontinuation of practice due to marital dissolution because of separation or divorce or death of a spouse is more elegantly taken into account in the new method. The new method tries to assess gross births averted and therefore makes no allowance for alternative contraceptive use to which the acceptors might have resorted.[18]

The method is illustrated by IUD use and is capable of extension to any other contraceptive for which it is possible to postulate a continuation schedule. This task is more easily accomplished for a permanent or semi-permanent method. The method is capable of estimating births averted through programme effort in 12-month periods after acceptance or in calendar years.

Component projection I: a computerized model

Component projection I, a computerized model, is described in chapter III as a "macro-deterministic, one-sex, computerized, age-component population model". This method attempts to assess births averted on a calendar-year basis using the gross births averted concept. A special attribute of this method is that it also measures the impact of the programme on the crude birth rate based on the female population. For this purpose, the demographic profile of the female population in terms of its changing size and age distribution is kept up on a calendar-year basis. Various demographic indices, including age-specific fertility rates, become available from year to year as a by-product of the population projection exercise.

The method treats each contraceptive method separately. Length of protection is worked out using "continuation" schedules for all methods, including induced abortion. The method accounts for loss in protection due to post-partum amenorrhoea. No penalty in length of protection is made for accidental pregnancies. Expected fertility of fecund women in the absence of a deliberate attempt to control birth provides the basis for estimating "potential fertility", which is applied to length of effective protection to calculate births averted. The estimation of births averted is done in five-year age groups.

The computer program for the method is available in the form of a computer tape and accompanying documentation. Ancillary programs for estimating parameters of the "continuation curve" etc. also are available.

The methods described in the *Manual* for assessing programme effect show a distinctive trend towards

[16] Although not well documented in the past, many programme evaluators have made use of simple means such as this method in assessing direct programme effect.

[17] Samuel M. Wishik and Kwan-Hwa Chen, *The Couple-Year of Protection: A Measure of Family Planning Program Output*, Manuals for Evaluation of Family Planning and Population Programs, No. 7 (New York, Columbia University, International Institute for the Study of Human Reproduction, 1973).

[18] Gross births averted refers to births averted as calculated from the data of all those who obtained supplies from the programme and therefore also includes those births which were averted by persons who switched from private sector supply to public sector supply.

developing simpler techniques of measurement by giving up some conceptual niceties and by limiting data requirements to those which are more readily available.

The utilization of the concept of gross effect in two of the methods described—analysis of reproductive process and component projection approach I (a computerized model)—gives status to an approach that has been used rather widely but hitherto has been considered crude. In this approach, the programme effect is assessed by estimating the births averted by acceptors without making any allowance for the substitution that the programme might be making for private sector services and supplies or for the catalytic effect the public programme might be having on the private sector. Although not stated specifically as such, the other three methods described above, including the standard couple-years of protection, also attempt to measure the gross effect.

A feature common to three of the five methods discussed above—and also acceptable to Potter, who has described the analysis of reproductive process—is that of determining births averted by calendar years. The assessment of births averted by years of use of cohort of acceptors is valuable in comparing the effectiveness of different contraceptives when used by different populations. On the other hand assessment by calendar years is often a necessity for programme administrators and planners and is also useful in making population projections.[19]

Duration of use has been basic to making assessments of births averted. Its measurement in the case of intra-uterine devices is usually done by estimating continuation rates through acceptor follow-up surveys. The estimation of continuation rates for recurrent methods, such as pills and condoms, presents many difficulties.[20] An alternative set of data for estimating users during a month or a year is the quantities of contraceptives supplied for use by clients. Programmes normally keep a record of the contraceptives supplied to each client, and the total amounts of each of contraceptive method supplied during specific periods be obtained routinely from these records. The standard couple-years of protection method discussed above uses supply statistics as the basis for assessing the extent of protection secured through recurrent methods, as does component project approach II (a model for desk calculators) and the simple method given in section D of chapter I. However, the other two methods—analysis of reproductive process and component projection approach I (a computerised model)—rely heavily on the use of continuation rates.

The use of supply statistics for estimating current users makes it unnecessary to adopt rigid and often unrealistic definitions for acceptors. There will no longer be the need, when studying duration of use, to relate acceptance to first-time acceptance of a method or of taking any method from the programme, if the switch to supply statistics for estimating current users is found workable. The change in concept of acceptors may relate not only to recurrent methods but to a semi-permanent method, such as IUD. In line with this changing concept, the procedures for maintaining service statistics in a family planning programme could also change.

Potential fertility, signifying the fertility that acceptors would have recorded if they had not made use of the family planning methods obtained from the programme, has been a vexatious topic. Factors affecting it include the selectivity of acceptors with respect to fertility; and what contraceptive practice, if any, they would have adopted had they not obtained methods from the programme. In estimating these phenomena, all five procedures discussed above attempt to make use of age-specific marital rates either directly or after making some adjustments. Simplification of procedures for estimating potential fertility has been achieved in part through modifications in methods for calculating the period of protection and in part through changing the nature of the programme effect that is assessed.

3. *Assessment of programme effect with special reference to non-programme effect*

Three methods described in the *Manual*—fertility projection/trend analysis (annexes I and II) experimental and quasi-experimental designs (chapter VIII) and multivariate areal analysis (chapter VI)—stress the importance of taking into consideration non-programme factors and their influence in assessing programme effect. With respect to fertility projection/trend analysis and to experimental and quasi-experimental designs, the programme effect is inferred as a residual between total effect and non-programme effect. Multivariate areal analysis, on the other hand, is designed to provide a direct indication of the influence of programme factors after allowing for the influence of non-programme factors. Simulation is used when experiments are desirable but not possible.

Fertility projection/trend analysis

The fertility projection/trend analysis approach is illustrated by two examples. In one case, it is applied to the secular data on crude birth rate. In the other, it is applied to the crude birth rate and general fertility rate. In applying this method, it is necessary to estimate on the basis of reasonable assumptions the way in which the fertility of the population under study would have evolved had the family planning programme not been undertaken. This potential trend, which is influenced by non-programme factors, is then compared with the actual trend, which is influenced by both programme and non-programme factors. The major difficulty lies in the estimation of the potential trend. Once this trend is determined, it is easy to estimate the number of births averted through a programme by the application of this method.

Experimental and quasi-experimental designs

The experimental designs method, using control and

[19] This need is emphasized in C. Chandrasekaran, D. V. R. Murty and K. Srinivasan, *loc. cit.*

[20] See C. Chandrasekaran and M. Karkal, "Continuation rate, use-effectiveness and their assessment for the diaphragm and jelly method", *Population Studies*, vol. XXVI (November 1972), pp. 487–494.

treatment groups and incorporating the statistical principles of randomization and replication, offers a valuable approach for assessing programme effect after allowing for the effect of non-programme influences. When the investigation is properly designed, the control group bears the effect of non-programme factors while the treatment group bears the effect of both programme and non-programme factors, and the difference between the treatment and control groups gives the programme effect. The need for adhering to the principles of the experimental method if the programme effect is to be properly assessed is discussed in chapter VIII. Since, in reality, the experimental designs method cannot be fully followed, in that the principle of randomization cannot be applied, it is necessary to resort to quasi-experimental designs. These designs are discussed in the light of three illustrations.

Multivariate areal analysis

Multivariate areal analysis consists in determining an equation or system of equations where the dependent variable is a fertility indicator and the independent variables are programme and non-programme factors. Through such a functional model, an attempt can be made to have quantitative estimates of the weights of the various independent variables in explaining differences in the dependent variables. The weights so obtained can be used to estimate programme effect as contrasted with non-programme effect. Chapter VIII of the *Manual* brings out the advantages and disadvantages of multivariate areal analysis, explains the underlying theory and illustrates the method with a numerical example.

Of the methods discussed above, the experimental design approach was evolved expressly to take account of non-programme influences and has found wide application in the agricultural and biological fields. The quasi-experimental design is a comparatively recent innovation to deal with problems that arise when the conditions of the experimental design approach cannot be fully satisfied, as is the case when dealing with human populations. The fertility projection trend analysis approach has also been widely applied in other fields, although not always for segregating non-programme effect. In contrast, the multivariate areal analysis method, as outlined in the *Manual*, was developed primarily to take note of criticisms levelled against early attempts to attribute the total effect to the family planning programme. These methods, which emphasize non-programme effect, offer alternative approaches to those discussed above in section B.2, which deal more directly with the assessment of programme effect.

Simulation

Because experimentation with human populations is not often possible, simulation models provide a vehicle for carrying out such experiments. In chapter VII of the *Manual*, the use of computer simulation for studying the impact of family planning programmes on fertility is discussed and illustrated with REPSIM-B, a micro-simulation model.

The model population of REPSIM-B is a hypothetical cohort of women between the ages of 15 and 50 years. The illustration takes the form of four experiments designed to investigate the extent to which different strategies of family planning programmes would affect the fertility of a cohort of women, assuming that the objective of the programme was the attainment of replacement levels of fertility at the end of reproductive life.

Many of the findings of the illustration fit in with what might reasonably be expected. A rather unexpected finding is that birth intervals are not found to increase in length as the efficiency of family planning practice increases. Although the reasons for this finding have to be fully investigated, the finding itself is but a reminder that computer simulation can provide insights for the planning and evaluation of family planning programmes which otherwise might not be available.

C. Conclusion

The *Manual* is a landmark in the promotion of efforts for assessing the births averted by family planning programmes. For purposes of the *Manual*, some of the well-known techniques have been simplified with a view to bring data needs to manageable proportions. The newer techniques presented in the *Manual* have also been tailored to suit wider application. Greater efforts in assessing the impact of family planning programmes, especially in developing countries, are to be expected as a result of the publication of the *Manual*.

The overview has shown that no one method of assessment is foolproof and that attempts to improve the methods of measurement have to be continued. In this endeavour, lessons learned from actual applications are as important as theoretical considerations. The *Manual* can therefore serve as an important agent in the further development of techniques for assessing births averted through family planning programmes.

ANNEXES

Annex I

FERTILITY PROJECTION/TREND ANALYSIS*

*W. Parker Mauldin***

In the absence of a secular decline in fertility, it seems reasonable to attribute to the program any decline that follows soon after the introduction of the program. It is possible, however, that fertility is also affected by other aspects of modernization that take effect at about the same time as the family planning program. Modernization may increase as well as reduce fertility; for example, a reduction in venereal disease, or improved nutrition is likely to increase fecundity. Although we cannot measure precisely the effects of the different forces at work, a reasonable approach is to attribute to the family planning program fertility declines over and above those that were "expected" prior to introduction of the program.

Expected and Actual Births in an Area

The approach concerns the difference in expected and actual number of births in a population living in a family planning program area. This approach involves a determination of the level and trend of fertility prior to the introduction of the program. Suppose, for example, that fertility had been declining two per cent per year before the program, but declined by five per cent after introduction of the program. Most analysts would conclude that the family planning program caused a three per cent annual decrease in fertility.

This conclusion attributes to the program whatever fertility reduction occurred among new contraceptors in the program as well as among persons who, by entering the program, switched from less to more efficient methods of contraception. This approach also credits to the program any catalytic effect that may have been generated by the increased flow of information and heightened interest in population. For example, if private doctors talk to their patients about family planning more often after the program begins than before, any resultant decrease in fertility is attributed to the program. If local family planning associations become more active and more effective, this too is attributed to the program, at least in a statistical sense.

The indirect credits may not all be positive, however. If fertility were to rise among some segments of the population—because of better health, better nutrition, an increase in marriage rates, an increase of remarriage among widows, etc.—the program effects might well be larger than the difference between actual and expected number of births, based on past trends.

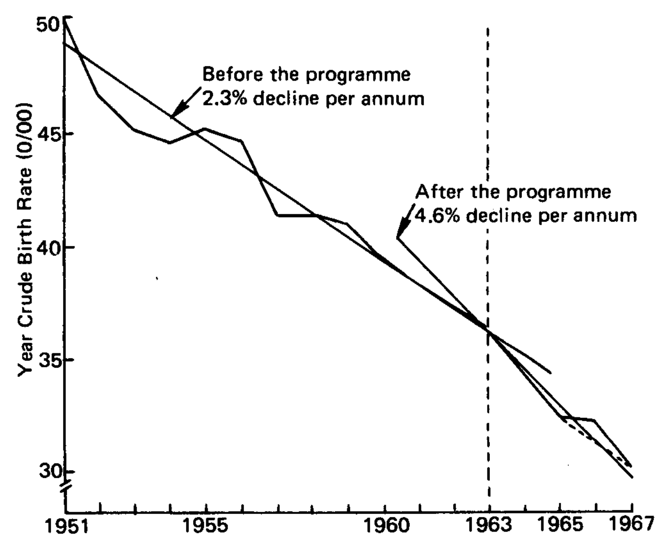
As the table and chart show, the secular decline in fertility rates was about 2.3 per cent per annum prior to inauguration of the program, and is estimated to be about 4.6 per cent a year since the program began. Thus, it would appear that the family planning program has increased the rate of decline by about 2.3 percentage points per year.

Crude birth rates 1951–1967 and percentage decline between two successive years

Year	*Rate*	*Percent decline*	*Year*	*Rate*	*Percent decline*
1951.....	50.0		1960.....	39.5	−4.1
1952.....	46.6	−6.8	1961.....	38.3	−3.0
1953.....	45.2	−3.0	1962.....	37.4	−2.3
1954.....	44.6	−1.3	1963.....	36.3	−2.9
1955.....	45.3	+1.6	1964[a]....	34.5	−5.0
1956.....	44.8	−1.0	1965.....	32.7	−5.2
1957.....	41.4	−7.6	1966.....	32.4 (31.3)[c]	−0.9 (−4.3)[c]
1958.....	41.6	+0.5	1967[b]....	30.3	−6.5 (−3.2)[c]
1959.....	41.2	−1.0			

[a] Island-wide family planning program started.
[b] Rate estimated based on first four months' registered live births adjusted by seasonal fluctuation.
[c] In December, 1966 registered births were considerably in excess of the expected number, due apparently to earlier and more complete registration of births as a result of activities connected with a census taken in that month. The figures in parentheses in the table are adjusted to account for the excess births registered in December, 1966, births that otherwise would have been registered in 1967.

Chart 1. Crude Birth Rate 1951–1967



* Reprinted with the permission of The Population Council from "Births averted by family planning programs", by W. Parker Mauldin, *Studies in Family Planning*, vol. 1, No. 33 (August 1968), pp. 1–7.
** Senior Fellow, The Population Council, Inc., New York.

Annex II

FERTILITY PROJECTION/TREND ANALYSIS*

Yolande Jemai** and Hedi Jemai***

A. The projection method

1. *The estimates*

On the basis of the corrected birth rates for the period 1956–1973,[a] a determination was made of the level and trend of fertility before the family planning programme was introduced. By treating in the same manner the period after the programme began, a measurement was made of the extent of the decline which, on the basis of this method, can be attributed to the family planning programme (see table 118).

In 1964, however, the exceptional birth rate registered (46.2 per 1,000) was in fact a result of the rush of marriages in 1963, the year preceding that in which the age of marriage for women was fixed at 17 years. Because the rate for 1964 distorted the general trend of the curve, that rate was eliminated in the estimates for measuring the percentage of annual decline in the birth for the period 1956–1971.

Table 119 shows the estimates on the basis of which the fertility trend for the period 1956–1963 was determined; table 120 shows those for the period 1965–1971 (see also figure IX).

TABLE 118. CRUDE BIRTH RATES AND PERCENTAGE OF DECLINE IN SUCCESSIVE YEARS, 1956–1971

Year	Rate	Decline (percentage)	Year	Rate	Decline (Percentage)
1956	46.4		1964	46.2	+3.6
1957	46.5	+0.2	1965	43.5	−5.8
1958	46.3	−0.4	1966	43.8	+0.7
1959	46.2	−0.2	1967	40.8	−6.8
1960	45.7	−1.0	1968	40.3	−1.2
1961	45.4	−0.7	1969	40.7	+1.0
1962	44.2	−2.6	1970	38.2	−6.1
1963	44.6	+0.9	1971	36.8	−3.7

SOURCES: For 1956–1959, A. Marcoux, "La croissance de la population de la Tunisie: passé récent at perspectives", *Population* (Paris), vol. 26, special issue on the Maghreb (March 1971), pp. 105–123; for 1960–1971, official figures of Institut national de la statistique, Tunis.

2. *The results*

With respect to the birth rate, the estimates and figure IX show: (*a*) for the period 1956–1963, a slow decline of 0.32 points per annum; (*b*) after the 1964 peak, resulting from the large number of marriages in 1963, a more rapid decline of 1.17 points per annum.

In this method, it is assumed that prior to the introduction of the family planning programme in 1964–1965, the decline was 0.32 points per annum and that the birth rate was influenced by urbanization, industrialization and all the other factors of economic and social development in general. It might have been expected that the trend

TABLE 119. ESTIMATE OF TREND OF CRUDE BIRTH RATE, 1956–1963

x	y	x^2	y^2	xy
1	46.4	1	2 152.9	46.4
2	46.5	4	2 162.2	93.0
3	46.3	9	2 143.6	138.9
4	46.2	16	2 134.4	184.8
5	45.7	25	2 088.4	228.5
6	45.4	36	2 061.1	272.4
7	44.2	49	1 953.6	309.4
8	44.6	64	1 989.1	356.8
36	365.3	204	16 685.3	1 630.2

$n = 8$
$\bar{x} = 4.5$
$\bar{y} = 45.7$

$$a = \frac{\Sigma\, xiyi - n\bar{x}\bar{y}}{\Sigma (xi)^2\, n\bar{x}^2}$$

$$a = \frac{1\,630.2 - 1\,643.8}{240 - 162} = -\ 13.6/42 = \mathbf{-0.32}$$

$$b = \bar{y} - a\bar{x} = 45.7 - [(-0.32)(4.5)] = 47.14$$

$$\mathbf{Y_1 = -0.32X_1 + 47.14}$$

TABLE 120. ESTIMATE OF TREND OF CRUDE BIRTH RATE, 1965–1971

x	y	x^2	y^2	xy
10	43.5	100	1 892.25	435.0
11	43.8	121	1 918.44	481.8
12	40.8	144	1 664.64	489.6
13	40.3	169	1 624.09	523.9
14	40.7	196	1 656.49	569.8
15	38.2	225	1 459.24	573.0
16	36.8	256	1 354.24	588.8
91	284.1	1 211	11 569.39	3 661.9

$n = 7$
$\bar{x} = 13$
$\bar{y} = 40.6$

$$a = \frac{3\,661.9 - [(7)(13)(40.6)]}{1\,211 - 7(13)^2} = \frac{[3\,661.9 - 3\,694.6]}{1\,211 - 1\,183} = \frac{-32.7}{28} = \mathbf{-1.17}$$

$$b = \bar{y} - a\bar{x} = 40.6 - [-1.17(13)] = [55.81]$$

$$\mathbf{Y_2 = -1.17X_2 + 55.81}$$

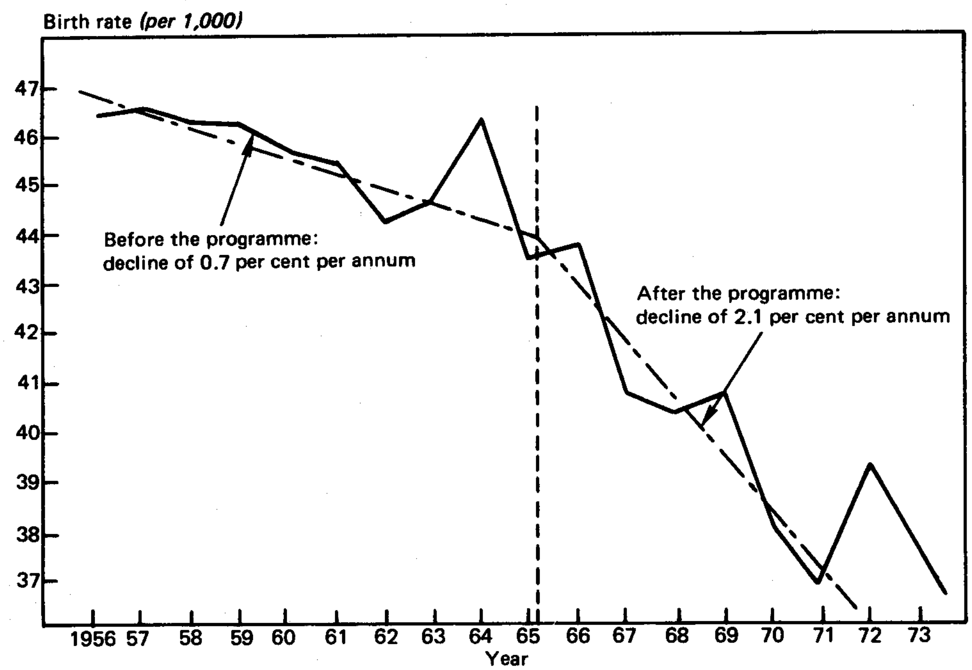
* The original version of the paper containing this section appeared as document ESA/P/AC/7/3. For a detailed discussion of this case study, see Yolande Jemai and Hedi Jemai, "Application of methods of measuring the impact of family planning programmes on fertility: the case of Tunisia", in *Methods of Measuring the Impact of Family Planning Programmes on Fertility: Problems and Issues* (United Nations publication, Sales No. E.78.VIII.2), pp. 66–106.

** Office national du planning familial et de la population, Tunis.
*** Centre d'études de recherches économiques et sociales, Tunis University.

[a] For the period 1960–1973, official figures of Institut national de la statistique, Tunis, have been used; for 1956–1959, those of A. Marcoux, "La croissance de la population de la Tunisie: passé récent et perspectives", *Population* (Paris), vol. 26, special issue on the Maghreb (March 1971), pp. 105–123.

would continue to be slow and linear in the subsequent years; however, after family planning activities had begun and the circumstantial effects of the law of 1964 raising the age of marriage began to be felt, the decline accelerated, reaching 1.17 points per annum. Consequently, the increase in the decline of the crude birth rate must be attributed to the family planning programme.

Figure IX. Tunisia: trends in the crude birth rate, 1950–1973



Appraisal of method

Although it may be stated that the interruption in the trend of the crude birth rate between 1956 and 1971 is very marked and that it can confidently be deduced that this change is due to the introduction of the family planning programme, one must, for a number of reasons, proceed very cautiously in making a quantified estimate of the impact of the programme.

First, the method used to estimate the trend is very approximate and is based on a mathematical technique which is often challenged in its application to economic and social phenomena.

Secondly, the downward trend of the crude birth rate must be viewed in the light of trends in the general fertility rate, shown in table 121 and figure X.[b]

Up to 1961, the rate of increase in fertility appears to have been steady because the female population of reproductive ages was growing at a markedly lower rate than the population as a whole, owing to emigration and the arrival at reproductive ages of the "diminished birth cohorts". However, that situation had only a very slight effect on fertility, because women in the 15–19 age group have a low fertility rate. Thus, those two phenomena did not appreciably decrease the birth potential, which explains the rise in general fertility rates (15–54 years).

In a second phase, 1964–1966, the circumstantial fluctuation caused by the rush of marriages in 1963 in anticipation of the law of 1964, led to an exceptional increase in births and hence, to particularly high fertility rates. In the period 1966–1971, the general trend was unquestionably downward for both fertility rates and birth rates. But to the effect of the family planning programme, which has certainly been considerable, must be added the "braking" effect on fertility exercised by the "diminished birth cohorts" upon reaching the age of high fertility (in 1970, they formed the 25–29 age group). Thus, the projection method provides a very crude means of determining trends in the period in question.

[b] This comment is based on the analysis of A. Marcoux, *loc. cit.*

TABLE 121. TRENDS IN THE GENERAL FERTILITY RATE, 1958–1974

(*Rate per 1 000 women aged 15–54 years*)

Year	*General fertility rate*	*Year*	*General fertility rate*
1958	186.6	1967	178
1959	188.7	1968	175
1960	189.5	1969	177
1961	190.6	1970	164
1962	187.0	1971	157
1963	188.6	1972	165
1964	198.1	1973	156
1965	187.2	1974	149
1966	193		

SOURCES: For 1958–1965, rates estimated by A. Marcoux, "La croissance de la population de la Tunisie: passé récent et perspectives", *Population* (Paris), vol. 26, special issue on the Maghreb (March 1971), pp. 105–123; for 1966–1971, official rates; see Tunisia, Institut national de la statistique, *Naissances, décès, mariages, divorces, 1970; statistiques détaillés*, Demographic series, No. 5 (Tunis, 1973–1974).

Lastly, unlike the standardization method, this method does not permit estimation of the relative impact of the various factors contributing to the decline in fertility and does attribute to the programme a considerably greater impact than it actually has had. If one considers not only family planning activities *per se* but the aggregate of the indirect effects of the programme, and then the Tunisian demographic policy, it is clear that this method enables one to measure in a much more significant way the results of the policy implemented by the authorities.

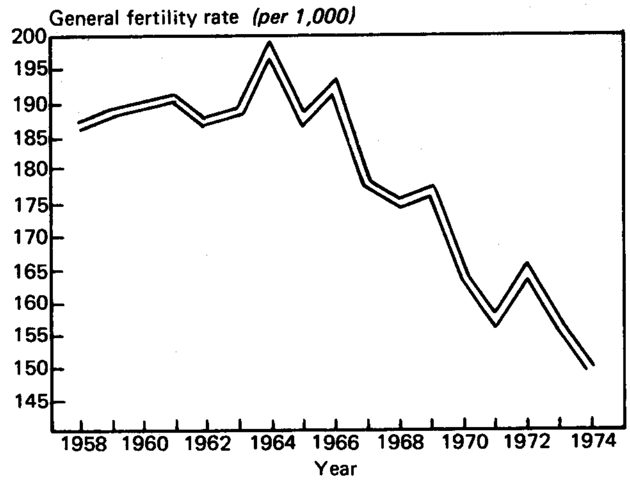
As in the case of the standardization method, it is necessary in this method also to be able to judge the reliability of the data used. With respect to births, this aspect has already been commented upon. As concerns total population (see table 122), the estimates of Institut national de la statistique (INS) were used by means of interpolation of the censuses between 1956 and 1966 and extrapolation for the period 1966–1971.[c]

TABLE 122. TRENDS IN PROPORTION OF THE TOTAL POPULATION OF TUNISIA REPRESENTED BY FEMALE POPULATION, 1958–1971

Year	*Total population at 1 July (thousands)* (1)	*Female population aged 15–54 years (thousands)* (2)	*Proportion of women aged 15–54 years (percentage)* (2)/(1)
1958	4 040.0	1 002.0	24.8
1959	4 117.0	1 007.0	24.4
1960	4 198.5	1 013.0	24.1
1961	4 268.5	1 018.0	23.8
1962	4 335.0	1 027.0	23.7
1963	4 422.0	1 039.0	23.5
1964	4 523.0	1 050.0	23.2
1965	4 619.5	1 063.0	23.0
1966	4 717.5	1 071.3	22.7
1967	4 825.0	1 103.7	22.9
1968	4 928.0	1 135.2	23.0
1969	5 027.5	1 165.1	23.2
1970	5 126.5	1 194.3	23.3
1971	5 228.4	1 229.3	23.5

SOURCE: Tunisia, Institut national de la statistique.

Figure X. Tunisia: trend in the general fertility rate, 1958–1974



[c] The forecasts of Institut national de la statistique for the period 1971–2001 (drawn up in 1972) are based on several hypotheses:

(i) *Mortality*: according to United Nations studies made in countries at a level of development similar to that of Tunisia, life expectancy at birth is increasing by about six months per annum;

(ii) *Fertility*: it should drop steadily, reaching in 2001 the rates per age prevailing in Italy in 1970;

(iii) *External migration*: it should gradually become negligible.

Annex III

MEMBERS OF THE COMMITTEE ON DEMOGRAPHIC ASPECTS OF FAMILY PLANNING PROGRAMMES* OF THE INTERNATIONAL UNION FOR THE SCIENTIFIC STUDY OF POPULATION

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K.C. General Hospital Complex
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India

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(Associate Member)
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Fertility and Family Planning Studies Section
Population Division
Department of International Economic and Social Affairs
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* The Committee on Demographic Aspects of Family Planning Programmes co-operated with the United Nations in the development of *Manual IX. Methods of Measuring the Impact of Family Planning Programmes on Fertility*. The persons listed comprised the Committee over the period 1975–1977, during the last two years of which this *Manual* was developed. In 1978, the International Union for the Scientific Study of Population (IUSSP) altered the composition of the Committee.

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