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

[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.

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-

[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.

[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:

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

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

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

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]

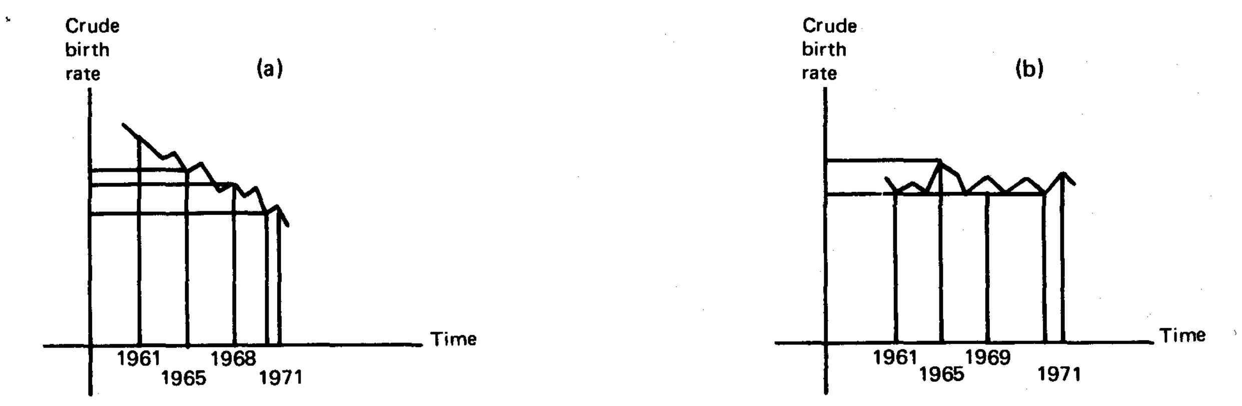
Evaluation of causal factors in short-term trends has many hazards: every effort should be made to determine whether the change is a mere fluctuation. A rule of thumb is to establish a time series of crude birth rates, if possible, extending beyond the time period under study in order to permit a graphic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

[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.

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:

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

[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).

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.

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

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

[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 $A_{2i}.M_{2i}(F_{2i}-F_{1i})$ (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.

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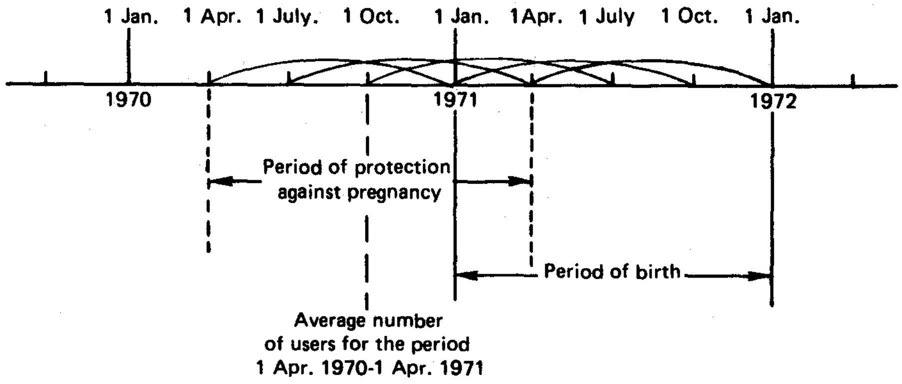
[33] The joint effects are obtained as the difference between the amount of change accounted for by the standardization and the amount of change observed.

[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.

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

[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.

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]

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[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.