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Population and Development Review, Volume 4, Issue 1 (Mar., 1978), 105-132.

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Fri Jan 24 07:59:01 2003

A Framework for Analyzing the Proximate Determinants of Fertility

JOHN BONGAARTS

Studies of the causes of fertility levels and their changes often seek to measure directly the impact of socioeconomic factors on fertility. Such procedures have a broad appeal to policymakers, offering as they do to pinpoint mechanisms susceptible to manipulation by official policy. Despite this appeal, such approaches are considerably more problematical in their application. Not infrequently, relationships are found to differ not only in magnitude but even in direction in different settings and at different times.

Substantial insights can be gained if, in addition to the socioeconomic factors influencing fertility, the specific mechanisms through which these factors operate are identified. For example, the level of education of women is a socioeconomic indicator that is frequently found to be negatively related to fertility. A more detailed analysis may show that among educated women marriage is relatively late or the use of contraception more frequent, thus clarifying the relationship between education and fertility. In general, the biological and behavioral factors through which socioeconomic, cultural, and environmental variables affect fertility are called intermediate fertility variables. The primary characteristic of an intermediate fertility variable is its direct influence on fertility. If an intermediate fertility variable, such as the prevalence of contraception, changes, then fertility necessarily changes also (assuming the other intermediate fertility variables remain constant), while this is not necessarily the case for an indirect determinant such as income or education. Consequently, fertility differences among populations and trends in fertility over time can always be traced to variations in one or more of the intermediate fertility variables. The following simple diagram summarizes the relationships among the determinants of fertility:

Indirect determinants		*Direct determinants*		
Socioeconomic, cultural, environmental variables	⟶	Intermediate fertility variables	⟶	Fertility

Although these relationships have been recognized since the pioneering work of Kingsley Davis and Judith Blake in the mid–1950s, efforts to quantify the link between a set of intermediate fertility variables and fertility have proven difficult and have thus far only resulted in highly complex reproductive models.[1] This paper presents a simple, but comprehensive model for analyzing the relationships between intermediate fertility variables and the level of fertility. The model includes only a small number of conceptually distinct and quantitatively important intermediate fertility variables. The model is used to analyze recent fertility changes in Korea and the United States; and guidelines for its wider use are provided.

Overview of the Intermediate Fertility Variables

To allow simple quantification, this study collapses the set of 11 intermediate fertility variables proposed by Davis and Blake into eight factors grouped in three broad categories:

I Exposure factors
1. Proportion married

II Deliberate marital fertility control factors
2. Contraception
3. Induced abortion

III Natural marital fertility factors
4. Lactational infecundability
5. Frequency of intercourse
6. Sterility
7. Spontaneous intrauterine mortality
8. Duration of the fertile period

The meanings of the first two categories are self-evident. The third needs explanation. As defined by Louis Henry, the term "natural fertility" applies to a population in which couples do not practice deliberate fertility control dependent on the number of children they have.[2] Practices that are independent of parity (number of children ever born) are considered to be natural fertility factors. An example would be the practice of postpartum abstinence to space births for the benefit of the health of mother and child.[3] Even among natural fertility populations, fertility does not reach the biological maximum because of the influence of the five factors listed above.

Each of the intermediate fertility variables may be described briefly as follows:

1. Proportions married: This variable is intended to measure the proportion of women of reproductive age that engages in sexual intercourse regularly. All women living in sexual unions should theoretically be included, but to circumvent difficult measurement problems, the present analysis deals only with the childbearing of women living in stable sexual unions, such as formal marriages and consensual unions. For convenience, the term "marriage" is used to refer to all such unions.
2. Contraception: Any deliberate parity-dependent practice—including abstention and sterilization—undertaken to reduce the risk of conception is considered contraception. Thus defined, the absence of contraception and induced abortion implies the existence of natural fertility.
3. Induced abortion: This variable includes any practice that deliberately interrupts the normal course of gestation.
4. Lactational infecundability: Following a pregnancy a woman remains infecundable (i.e., unable to conceive) until the normal pattern of ovulation and menstruation is restored. The duration of the period of infecundity is a function of the duration and intensity of lactation.
5. Frequency of intercourse: This variable measures normal variations in the rate of intercourse, including those due to temporary separation or illness. Excluded is the effect of voluntary abstinence—total or periodic—to avoid pregnancy.
6. Sterility: Women are sterile before menarche, the beginning of the menstrual function, and after menopause, but a couple may become sterile before the woman reaches menopause for reasons other than contraceptive sterilization.
7. Spontaneous intrauterine mortality: A proportion of all conceptions does not result in a live birth because some pregnancies end in a spontaneous abortion or stillbirth.
8. Duration of the fertile period: A woman is able to conceive for only a short period of approximately two days in the middle of the menstrual cycle when ovulation takes place. The duration of this fertile period is a function of the duration of the viability of the sperm and ovum.

Fertility and the Intermediate Fertility Variables

While fertility variations can always be traced to variations in one or more of the intermediate variables, the scope for variation differs among the variables as does their degree of influence in different societies and over time within societies. In this section we construct a set of equations for measuring the influence of the intermediate fertility variables on fertility in different settings by parcelling out the separate influences of each of the variables in turn.

Proportions Married Demographers have long recognized marriage as one of the principal proximate determinants of fertility. In most societies women spend substantial proportions of their potential reproductive years out of marriage, either before first marriage or after a marriage has ended due to divorce, separation, or death of the husband. In addition, some women never marry. To make a quantitative assessment of the fertility effect of different marriage patterns, a simple method proposed by Ansley Coale is available.[4] Coale calculates three indexes, one for the level of overall fertility, one for the fertility of married women, and one for the proportion married. These indexes are constructed so that the index of overall fertility equals the product of the other two. A similar approach will be taken here but a different set of indexes for overall fertility (TFR), marital fertility (TM), and proportion married (C_m) will be employed, defined as follows:

TFR = total fertility rate, equal to the number of births a woman would have at the end of the reproductive years if she were to bear children at prevailing age-specific fertility rates while living throughout the reproductive period (excluding illegitimate births but based on all women of reproductive age whether married or not);

TM = total marital fertility rate, equal to the number of births a woman would have at the end of the reproductive years if she were to bear children at prevailing age-specific marital fertility rates and to remain married during the entire reproductive period (based on the fertility of married women aged 15–45);

C_m = index of proportion married.

The index of proportion married is calculated as the weighted average of the age-specific proportions married, m(a) (a = age), with the weights given by the age-specific marital fertility rates, g(a)[5]:

$$C_m = \frac{\Sigma\, m(a)g(a)}{\Sigma\, g(a)} \tag{1}$$

Equation (1) can also be written as $C_m = TFR/TM$, so that

$$TFR = C_m \times TM \tag{2}$$

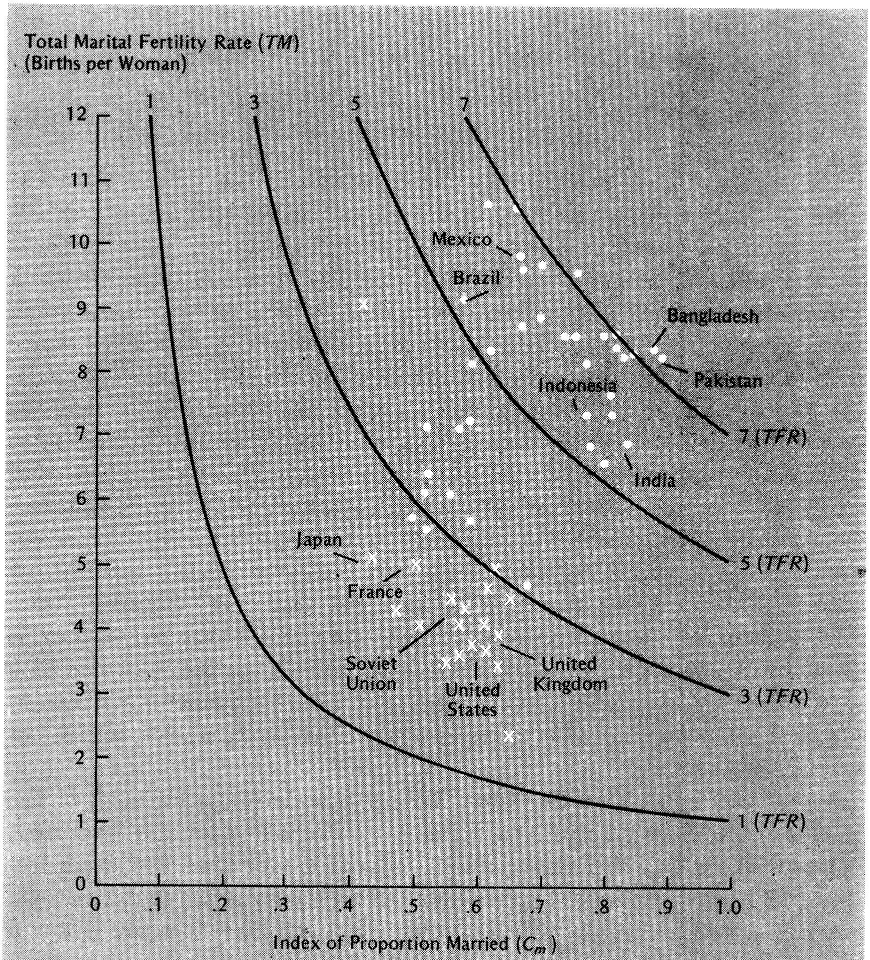
The index C_m gives the proportion by which *TFR* is smaller than *TM* as the result of nonmarriage; $C_m = 0$ if nobody is married and $C_m = 1$ if all women are married during the entire reproductive period. These indexes and the relationship between them in equation (2) provide a convenient way to separate overall fertility (*TFR*) into two determining components: (1) the prevailing marriage pattern among women of reproductive age (C_m); and (2) the fertility level within marriage (*TM*).

The three indexes *TFR*, *TM*, and C_m were calculated for 59 countries for the period 1970–75.[6] The results are presented in Figure 1. The index of proportion married is plotted along the horizontal axis and the total marital fertility rate along the vertical axis. Each curve drawn in Figure 1 is an "isoquant" in which the total fertility rate is at a fixed level. Different points on an isoquant are associated with the same overall fertility because different combinations of C_m and *TM* can yield the same total fertility rate. For example, a total fertility rate of 4 births per woman is found in a population in which $TM = 10$ and $C_m = 0.4$, but also in a population in which $TM = 8$ and $C_m = 0.5$. Four isoquants are shown in Figure 1, representing total fertility rates of 1, 3, 5, and 7 births per woman, respectively.

The data assembled in Figure 1 show a wide range for each of the three indexes: from 1.7 to 7.2 for *TFR*, from 3.3 to 10.6 for *TM*, and from 0.41 to 0.88 for C_m. It is interesting to note that countries with high fertility (*TFR* greater than 5) typically have high proportions married (C_m over 0.65), while virtually all countries with a total fertility rate below 5 have values for the index of proportion married that are less than 0.65. The large differences among populations in the index of proportions married demonstrate the importance of the marriage pattern as a proximate explanation for fertility variations.

Contraception Among populations today, contraceptive practice is the intermediate fertility variable primarily responsible for the wide range in the levels of fertility within marriage. (In a few countries induced abortion is more important.) In the traditional developing countries the

Figure 1
Total Marital Fertility Rate
and Index of Proportion Married
for Developed (x) and Developing (•)
Countries During 1970–75



NOTE: Only countries with populations of over 50 million are labeled.
SOURCE: See note 6.

practice of contraception is rare or virtually absent, and marital fertility is relatively high, while in the economically developed nations, where marital fertility is lowest, well over half the married women in the reproductive years are current users of contraception. To estimate the effect of contraception on marital fertility, the following equation expresses marital fertility as the interaction of contraceptive practice and natural fertility:

$$TM = C_c \times TNM \tag{3}$$

where

$TM =$ total marital fertility rate;
$TNM =$ total natural marital fertility rate, equal to TM in the absence of contraception and induced abortion;
$C_c =$ index of noncontraception.

Equation (3) simply states that TM is smaller than TNM by a proportion C_c, with the value of C_c depending on the prevalence of contraception, that is, the extent of use and the effectiveness of contraception (induced abortion is assumed absent for the moment). When no contraception is practiced, C_c equals 1.0; when all nonsterile women in the reproductive years are protected by 100 percent effective contraception, $C_c = 0$ and $TM = 0$. In a technical note appended to this article, it is shown that, if all couples who practice contraception are assumed nonsterile, the index C_c can be estimated as

$$C_c = 1 - 1.18ue \tag{4}$$

where

$u =$ average proportion of married women currently using contraception (average of age-specific use rates);

$e =$ average contraceptive effectiveness (average of use-effectiveness levels by age and method).[7]

For most populations, calculation of the index of noncontraception is difficult because detailed information on the age patterns of current contraceptive practice and its effectiveness is lacking. In the absence of age-specific use rates, however, the proportion of all married women of reproductive age that currently uses contraception—a variable for which data are more widely available—can be employed as an estimate for u.[8]

As to the effectiveness of different contraceptive methods, comparative data are only available for the United States. Table 1 presents recent average US figures.[9] Since effectiveness depends on the motivation of the user as well as on the method itself, these US figures can serve only as rough estimates for other populations.

Values for TM, TNM, and C_c were calculated for 30 countries under the simplifying assumption that average contraceptive effectiveness is 0.85 for the developing nations.[10] The results are summarized in Figure 2. (The arrows in this figure represent corrections for induced abortion as explained in the next section.) The curves in Figure 2 are isoquants on which the total marital fertility rate is at a fixed level. The total natural marital fertility rate ranges from 15.9 to 7.4 births per woman. The index of noncontraception reaches a maximum of 0.98 in Nepal and a minimum

Table 1
Average Use-Effectiveness of Contraceptive Methods, United States, 1970

Method	Contraceptive Effectiveness (e)
Abstention	1.00
Sterilization	1.00
Pill	0.98
IUD	0.96
Condom	0.91
Diaphragm	0.88
Foam/cream/jelly	0.87
Rhythm	0.82
Other	0.90

SOURCE: See note 9.

of 0.28 in the United States. Interestingly, the countries fall into a linear pattern around the regression line $TNM = 17.2 - 8.7\ C_c$ ($R^2 = 0.8$). The highest natural fertility levels are found in the developed countries, where the index of noncontraception is lowest. Contraception clearly reduces marital fertility, but in the countries where the prevalence of contraception is highest (lowest C_c), natural fertility levels tend to be highest, thus partly offsetting the fertility-inhibiting influence of contraception.

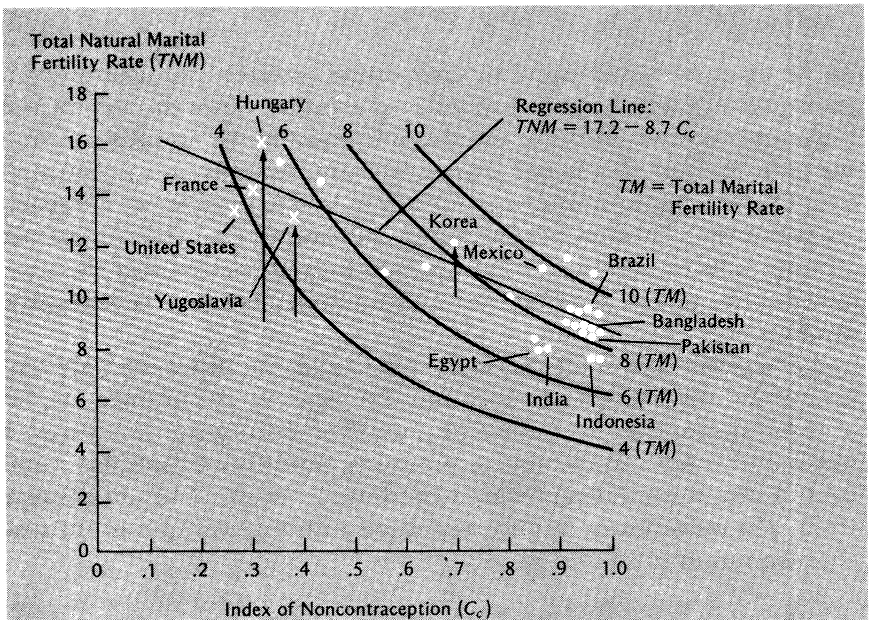
Up to this point, the discussion has focused on the effect of contraception on marital fertility. To relate the index of noncontraception to the total fertility rate, equation (3) is substituted in equation (2), yielding

$$TFR = C_m \times C_c \times TNM \qquad (5)$$

This equation calculates the total fertility rate from the natural marital fertility rate by taking into account the fertility-reducing impact of contraception and nonmarriage measured by the indexes C_c and C_m, respectively.

Induced Abortion Although reliable measurements of the prevalence of induced abortion are often lacking, it is well known that induced abortion is practiced in many societies. Even in cases where good estimates are available, it has proven difficult to determine the reduction in fertility that is associated with the practice of induced abortion. Estimates of the number of births averted by induced abortion are largely based on numerical exercises using mathematical reproductive models. The most detailed studies of this topic have been made by Robert Potter,[11] whose work has demonstrated that:

Figure 2
Total Natural Marital Fertility Rate and Index of Noncontraception for Developed Countries (x) Around 1970 and for Developing Countries (•) for 1970–75



NOTE: Arrows indicate corrections for the fertility effect of induced abortion (see text). Only countries with this correction and countries with populations of over 25 million are labeled.

SOURCE: See note 10.

1. An induced abortion always averts less than one birth. There are two principal explanations for this finding. First, an induced abortion may be unnecessary because a spontaneous abortion or stillbirth would have prevented the pregnancy from ending in a live birth. Second, and more importantly, after an induced abortion a woman resumes ovulation much sooner than would have been the case if she had carried the pregnancy to term, especially if pregnancy is followed by a period of lactation. The net fertility effect of an induced abortion has to take into account the probability of another conception during the period in which the woman would have been unable to conceive if she had had no induced abortion.

2. The number of births averted per induced abortion is largely independent of the age of the woman.

3. The number of births averted per induced abortion is strongly influenced by the practice of contraception following the induced abortion. In the absence

of contraception, an induced abortion averts about 0.4 births, while about 0.8 births are averted when moderately effective contraception is practiced.

To generalize from this last finding, the births averted per induced abortion, b, may be estimated with the equation

$$b = 0.4\ (1 + u) \tag{6}$$

To be exact, u should equal the proportion protected by contraception among women who have had an induced abortion. Since this information is almost never available, the variable u in equation (6) is taken to equal the proportion of all married women who are currently using contraception. That this approximation is not likely to lead to gross errors is strongly suggested by a detailed comparison of contraceptive practice before and after an induced abortion in Taiwan, which demonstrated that the experience of an induced abortion does not lead to an increase in contraceptive practice.[12]

A convenient overall measure of the incidence of induced abortion is provided by the total abortion rate, TA, equal to the average number of induced abortions per woman at the end of the reproductive period if induced abortion rates remain at prevailing levels throughout the reproductive period (excluding induced abortions to women who are not married). The reduction in fertility associated with a given level of the total abortion rate is calculated as

$$A = b \times TA = 0.4\ (1 + u) \times TA \tag{7}$$

where A equals the average number of births averted per woman by the end of the reproductive years. The observed total fertility rate in a population is A births less than would be the case without induced abortion. The index of induced abortion is defined as the ratio of the observed total fertility rate, TFR, to the estimated total fertility rate without induced abortion, $TFR + A$,

$$C_a = \frac{TFR}{TFR + A} \tag{8}$$

The index C_a equals the proportion by which fertility is reduced as the consequence of the practice of induced abortion. (Note that C_a declines with increasing incidence of induced abortion.) Modifying equation (5) accordingly, the relationship between TFR and TNM now becomes[13]

$$TFR = C_m \times C_c \times C_a \times TNM \tag{9}$$

In the estimates of the total marital fertility rate presented in Figure 2, corrections for induced abortions have been ignored except for three countries (Hungary, Yugoslavia, and Korea) where the level of induced abortion is high and the data are relatively reliable. The beginning and end points of the arrows in Figure 2 represent the uncorrected $[TNM = TM/C_c]$ and corrected $[TNM = TM/(C_c \times C_a)]$ natural marital fertility levels for the three countries. The corrections make these countries conform more closely to the expected linear regression pattern, thus providing some indication of the validity of equations (7) and (8).[14]

Lactational Infecundability The data summarized in Figure 2 indicate that natural marital fertility is highest in the developed countries. It will now be demonstrated that this finding is largely explained by the differences in lactation practices among countries at various levels of development. In modern Western populations lactation is generally short, and many women do not lactate at all. In traditional societies in Africa, Latin America, and Asia, lactation is usually long and often lasts until the next pregnancy occurs.

Lactation has an inhibitory effect on ovulation and thus increases the birth interval and reduces natural fertility. Quantitative estimation of the fertility-reducing effect of lactational infecundability is most easily accomplished by comparing average birth-interval lengths in the presence and absence of lactation. A birth interval can be divided into four components[15]:

1. An infecundable interval immediately following a birth. In the absence of lactation, this segment averages about 1.5 months, while prolonged lactation results in infecundable periods of up to two years. The duration of this birth-interval segment is usually measured from birth to the first postpartum menses, because the return of menses closely coincides with the return of ovulation.
2. Waiting time to conception, which starts at the first ovulation following birth and ends with a conception. Although few measurements are available, existing observations indicate that population averages for this interval range from a low of about 5 months to high values that only rarely exceed 10 months, with typical values around 7.5 months.[16]
3. Time added by spontaneous intrauterine mortality. In cases where a conception does not end in a live birth, the duration of a shortened pregnancy and another waiting time to conception are added to the birth interval. On average the time added by intrauterine mortality equals about 2 months per birth interval.
4. A nine-months gestation period ending in a live birth.

Without lactation, a typical average birth interval can therefore be estimated to equal $1.5 + 7.5 + 2 + 9 = 20$ months, and with lactation it equals the average total duration of the infecundable period plus 18.5

months (7.5 + 2 + 9). The ratio of the average birth intervals without and with lactation will be called the index of lactational infecundability:

$$C_i = \frac{20}{18.5 + i} \tag{10}$$

where

C_i = index of lactational infecundability;

i = average duration (in months) of infecundability from birth to the first postpartum ovulation (menses).

The relationship between lactation and the total natural marital fertility rate, TNM, is summarized by the equation

$$TNM = C_i \times TF \tag{11}$$

where

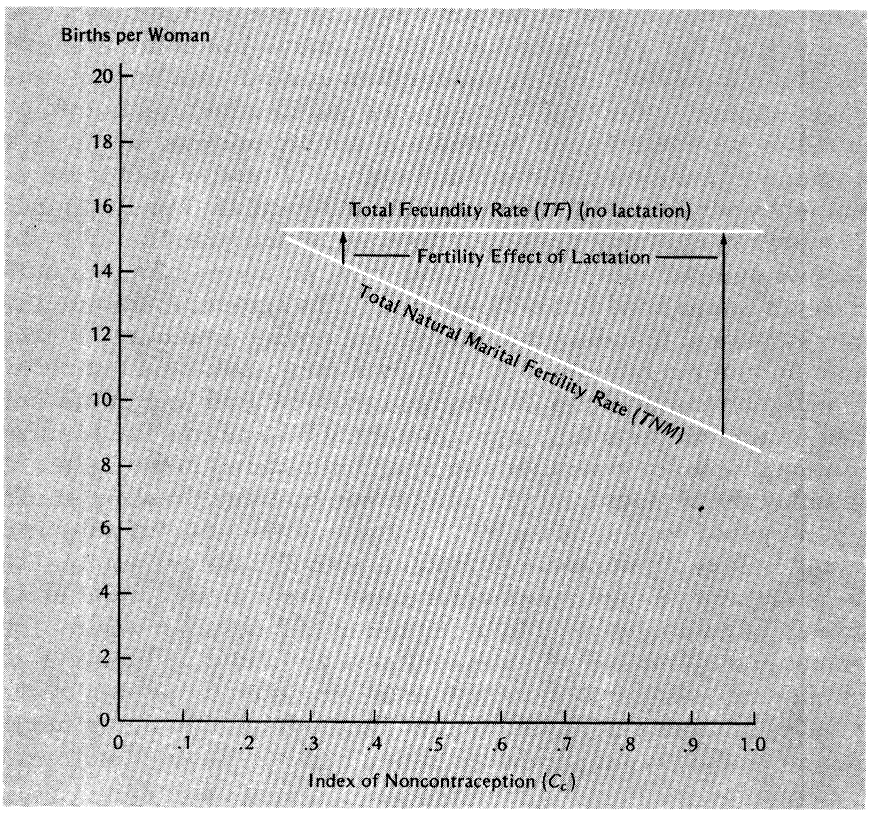
TF = total fecundity rate equal to the total natural marital fertility rate in the absence of lactation.[17]

From equations (10) and (11) it follows that without lactation, $C_i = 1$ and $TNM = TF$, because $i = 1.5$ months. As lactation lengthens, C_i declines. One of the longest periods of infecundability on record is 18.9 months observed in Bangladesh.[18] In that case $i = 18.9$, $C_i = 0.53$, and $TNM = 0.53 \times TF$. In effect, natural fertility in Bangladesh is about half the level it would be in the absence of lactation. Most populations are likely to have C_i values between 0.5 and 1.0. Unfortunately, nationally representative estimates of i are virtually nonexistent, and as a consequence it is not possible to calculate C_i and TF for different countries. One can make a crude estimate of the average levels of the total fecundity rate, however, if one relies on the fact that in the least developed nations, where contraception is very low, lactation is longest, while in the developed nations, where contraception is widespread, lactation is shortest. Estimates of the mean duration of infecundable periods reported in subgroups in five populations with low levels of contraceptive practice (C_c near 0.95) are as follows[19]:

Country	Mean Duration of Lactational Infecundability (in Months)
Bangladesh	18.9
Indonesia	18.7
Senegal	17.3
Guatemala	14.3
India (Punjab)	10.9

An average of 16 months may be considered representative of this group of populations. At the other extreme, in contemporary Western populations with C_c values around 0.35, the average length of the period of infecundability is usually short, say about 3 months. With these typical values of i and with the assumption that i decreases linearly with decreasing values of C_c, an estimate can be made of the effect of the removal of lactation on the relationship between TMN and C_c in Figure 2. The results of this exercise are given in Figure 3. If one takes the values of $i = 16$ and $i = 3$ to correspond with $C_c = 0.95$ and $C_c = 0.35$, respectively, then—according to equations (10) and (11)—$C_i = 0.58$ and $TF = 15.4$ for the high level of C_c, where $TNM = 8.93$; and $C_i = 0.93$ and $TFR = 15.2$ at the low level of C_c, where $TNM = 14.16$. These calculations, the results of which are shown in Figure 3, indicate that developed and developing countries have more or less the same level of total fecundity rate: about 15.3 births per woman. This value of the total fecundity rate will be confirmed by a quite different derivation in the next section.

Figure 3
Estimated Total Fecundity Rate and Total Natural Marital Fertility Rate for Different Levels of the Index of Noncontraception



The figure also shows the strong fertility-limiting impact of prolonged lactation. This finding has particular significance, given recent trends in a number of developing countries toward a reduction in lactation.

To complete this analysis of the fertility effect of lactation, the index of lactational infecundability is related to the total fertility rate by substituting equation (11) in equation (9):

$$TFR = C_m \times C_c \times C_a \times C_i \times TF \tag{12}$$

This equation summarizes the entire model for the relationships between the four intermediate fertility variables discussed up to this point and fertility.

Frequency of Intercourse The level of the total fecundity rate is influenced by coital frequency, but it is easily demonstrated that coital frequency is not a very important determinant of fertility differences among populations. Because reliable coital frequency data exist for very few countries, it is difficult to analyze this relationship by comparing individual populations. It is possible, however, to estimate a plausible range of values for the total fecundity rate by relying on observations of the mean waiting time to conception, which is determined by coital frequency.

The average of 15.3 births per woman for the total fecundity rate was obtained from the observed total fertility rates by successively removing the influence of different intermediate fertility variables. A more direct estimate of the total fecundity rate can be calculated as follows. Based on the values for the incidence of sterility proposed by Henry,[20] women (couples) are sterile for an average of 17 percent of their potential reproductive years between the ages of 15 and 45. This leaves only 25 years for actual reproduction. If the typical mean birth interval in the absence of lactation equals 20 months, then, on average, 15 such birth intervals can be fitted into a 25-year span. The agreement between this new estimate of 15 births per woman for the average total fecundity rate, and the previous estimate of 15.3, is close, thus providing a test of the internal consistency of the analytic framework outlined here. If one further accepts the previously proposed range of 5–10 months for the mean waiting time to conception, then the mean birth interval in the absence of lactation would range from 17.5 to 22.5 months. Using the above simple direct method for calculating *TF*, the range of the total fecundity rate would be from slightly below 13 to a little over 17 births per woman. The large majority of populations are therefore likely to fall within about 2 births of the average total fecundity rate of 15.3 births per woman. The relatively small range for *TF* and the lack of correlation with the level of development suggest that average coital frequency is not one of the principal determinants of variations in fertility levels. The exceptions to this generalization are populations with a high prevalence of prolonged spousal separations, which cause a reduction in the total fecundity rate. A convenient way to analyze the fertility effect of prolonged separation is to classify women whose husbands are absent for long periods as not currently married. In that case, the index C_m will be reduced while the total fecundity rate should be in the normal range.

Intrauterine Mortality, Sterility, and the Duration of the Fertile Period The three remaining intermediate fertility variables, sterility, intrauterine mortality, and the duration of the fertile period, are discussed together because they are physiological factors that are assumed not to be under the control of individuals. Any variations in these variables among populations are likely to be due to genetic or environmental influences. Little is known about the genetic factors, but two environmental factors, health and nutrition, are often considered significant determinants of fertility. Recent studies of the biological effect of nutrition and health on the human reproductive process, however, indicate that this biological link is generally of little importance. For example, one recent review of existing evidence concludes that "the reproductive function is well protected from nutritional insults and poor health."[21] This conclusion is supported by detailed investigations of the effects of the nutritional status of women on fecundity in Bangladesh and Guatemala, two countries in which a large proportion of the population is malnourished.[22] There are three exceptions to this generalization. First, venereal disease can lead to sterility and an increase in spontaneous intrauterine mortality so that in populations where venereal disease is widespread, fertility may be less than expected.[23] Second, age at menarche is partly determined by nutrition,[24] but this finding is of little demographic significance because childbearing usually starts several years after menarche.[25] Third, and also of little significance demographically, is the influence of prenatal health care on the stillbirth rate. Accordingly, we may assume that sterility, intrauterine mortality, and the duration of the fertile period are not of importance for explaining differences in fertility among populations unless venereal disease is present. The validity of this assumption is supported by the earlier finding of a lack of correlation between the level of development and the total fecundity rate.

It should be noted that the above assumption regarding physiological intermediate fertility variables does not imply that nutrition and health have no effect on the other intermediate fertility variables. In fact, several indirect links have been identified:

1. Nutrition and health may affect infant mortality, which is considered one of the determinants of desired family size. After reaching their desired family size, couples presumably will attempt to reduce fertility by practicing contraception or induced abortion. Changes in infant mortality can also modify

the duration of lactational infecundability, because the death of an infant will end lactation for its mother.

2. Nutrition and health can affect adult mortality and therefore the risk of widowhood. The risk of widowhood in turn influences the proportion married.

3. Well-nourished women have periods of lactational infecundability that are slightly shorter than those of poorly nourished women.[26] It is not clear whether this is due to difference in lactation behavior, ability to lactate, or other physiological characteristics influencing lactational infecundability.

Data Requirements for Application of the Model

We now have a model for the intermediate fertility variables as summarized in equation (12). Estimation of all the indexes of the intermediate fertility variables in this model requires the following sets of data.

C_m: Age-specific proportions married, $m(a)$, and age-specific marital fertility rates $g(a)$. Since the rates $g(a)$ appear in both the numerator and denominator of equation (1), the value of C_m calculated from equation (1) is not very sensitive to proportional errors in the magnitude of the age-specific marital fertility rates. Even substitution of values for $g(a)$ that are taken from another population with similar fertility levels can provide a satisfactory approximation for C_m. If TFR and TM are known, C_m can be calculated directly as $C_m = TFR/TM$.

C_c: Age- and method-specific proportions currently contracepting among married women, and age- and method-specific effectiveness levels of contraception. If not available, the proportion currently contracepting among all married women (aged 15–45) and the method-specific effectiveness levels from the US (Table 1) may be used as approximations.

C_a: Total induced abortion rate, TA, and total fertility rate, TFR (excluding abortions and births to women who are not married). A crude estimate of the total induced abortion rate can be obtained by multiplying the number of induced abortions per woman aged 15–44 by 30 (with 30 years being the duration of the reproductive span from 15 to 44). Since the total fertility rate appears in both the numerator and denominator of equation (8), any rough estimate for TFR will be acceptable.

C_i: Average duration of lactational infecundability, i. In the absence of direct information on the timing of the return of menses or ovulation after birth, i can be estimated from the mean duration (in months) of lactation, L, with the following equation: $i = 1.5 + 0.56L$.[27] The mean duration of lactation is easily calculated if the proportion of women that are currently lactating, by duration since last birth, is known.[28]

With the possible exception of the total abortion rate, these required data are readily available from standard sources. Censuses or household surveys usually produce estimates of age-specific proportions married. The total fertility rate, age-specific marital fertility rates, and proportions currently contracepting and lactating are obtained through fertility surveys or surveys of knowledge, attitude, and practice of contraception. Perhaps most difficult is the accurate measurement of the incidence of induced abortion, because one has to rely on official statistics of legal abortions or special surveys, both of which are believed to provide incomplete estimates in many countries.[29]

Formulas for estimating the indexes of the intermediate fertility variables from the basic input data are summarized in Table 2. This table also gives the equations for calculating the fertility measures, *TFR*, *TM*, *TNM*, and *TF*. It is important to note that partial application of the model is possible. For example, if data on lactational infecundability or lactation are lacking, it is still possible to calculate the indexes C_m, C_c, and C_a, and the fertility measures *TFR*, *TM*, and *TMN*.

Table 2
Summary of Methods of Estimation of Indexes of Intermediate Fertility Variables, Fertility Measures, and Required Input Measures

Variable	Approximate Observed Range: Countries with high fertility (*TFR* greater than 5)	Approximate Observed Range: Countries with low fertility (*TFR* less than 3)	Method of Estimation
Indexes of Intermediate Fertility Variables			
C_m = index of proportion married	0.65–0.9	0.4–0.65	$C_m = \dfrac{\Sigma\, m(a)\, g(a)}{\Sigma g(a)} = \dfrac{TFR}{TM}$
C_c = index of noncontraception	0.8–1.0	0.22–0.45	$C_c = 1 - 1.18ue$
C_a = index of induced abortion	1.0–n.a.	1.0–0.5	$C_a = TFR/(TFR + b \times TA)$

Table 2 (continued)

Variable	Approximate Observed Range: Countries with high fertility (*TFR* greater than 5)	Approximate Observed Range: Countries with low fertility (*TFR* less than 3)	Method of Estimation
C_i = index of lactational infecundability	0.5–0.7	0.9–1.0	$C_i = \frac{20}{18.5 + i}$
Fertility Measures			
TFR = total fertility rate	5.0–7.2	1.5–3.0	Sum of observed age-specific fertility rates, excluding illegitimate birth. $TFR = C_m \times C_c \times C_a \times C_i \times TF = C_m \times C_c \times C_a \times TNM = C_m \times TM$
TM = total marital fertility rate	6.5–11.0	3.0–5.5	Sum of observed age-specific marital fertility rates. $TM = TFR/C_m = C_c \times C_a \times C_i \times TF = C_c \times C_a \times TNM$
TNM = total natural marital fertility rate	7.0–11.0	13.0–15.0	$TNM = TFR/(C_m \times C_c \times C_a) = TM/(C_c \times C_a) = C_i \times TF$
TF = total fecundity rate	13.5–17.0	13.5–17.0	$TF = TFR/(C_m \times C_c \times C_a \times C_i) = TM/(C_c \times C_a \times C_i) = TNM/C_i$
Required Input Measures			
$m(a)$ = age-specific proportions married			As observed
$g(a)$ = age-specific marital fertility rates			As observed (may be approximate)
u = average proportion of married women currently using contraception	0–0.2	0.5–0.75	As observed
e = average effectiveness of contraception	n.a.	0.85–0.95	As observed
b = births averted per induced abortion	0.4–0.5	0.6–0.7	$b = 0.4\ (1 + u)$
TA = total induced abortion rate	n.a.	0–7.5	As observed (excluding extra-marital induced abortions)
i = average duration of lactational infecundability (months)	10–20	2–6	As observed

n.a. = not available.

Numerical Illustrations

The Korean Fertility Decline Between 1960 and 1970 South Korea is one of the few developing countries where measurements of reproductive variables are sufficiently detailed to allow the calculation of the indexes of the intermediate fertility variables at different points in time. Table 3 summarizes the necessary reproductive measures for 1960 and 1970 and the indexes of the behavioral intermediate fertility variables calculated from the data on reproduction.[30] During the 1960s, the indexes of noncontraception, induced abortion, and proportions married decreased, but the index of lactational infecundability increased. The contribution made by each of the intermediate fertility variables to fertility change during the 1960s is summarized in Figure 4, where the fertility measures *TFR*, *TM*, *TNM*, and *TF* are plotted. The total fecundity rate remained virtually constant between 1960 and 1970, while the total natural fertility rate increased as a result of a decline in lactation. The substantial increases in the use of contraception and induced abortion and a decline in the proportions married counteracted the fertility-promoting effect of the decline in lactation and caused an overall decline in the total fertility rate from 6.1 in 1960 to 4.0 in 1970.

The US Fertility Decline Between 1965 and 1973 The procedures applied to the Korean case were repeated for the United States for the

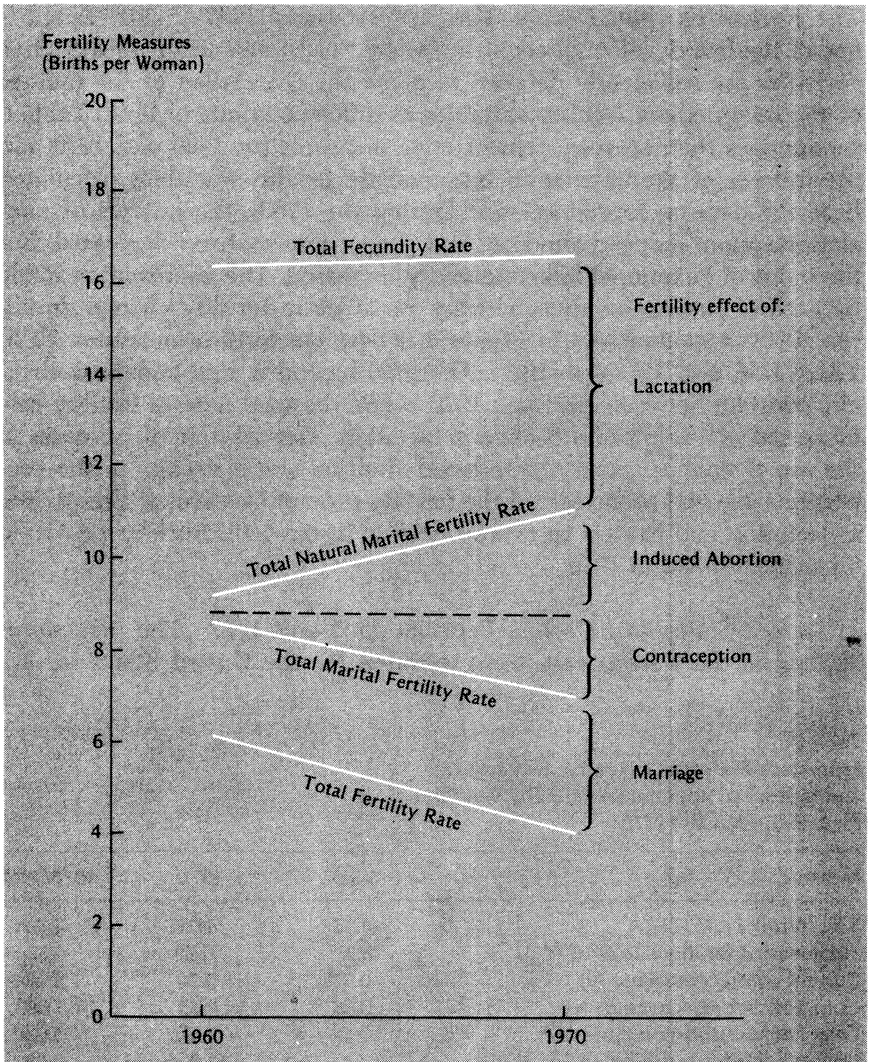
Table 3
Estimates of Selected Reproductive Measures and Indexes of Intermediate Fertility Variables for Korea, 1960 and 1970

Measure	1960	1970	1970/1960
Total fertility rate (*TFR*)[a]	6.13	4.05	0.66
Total marital fertility rate (*TM*)	8.57	7.02	0.82
Current contraceptive use (*u*)	0.03	0.24	8.00
Contraceptive effectiveness (e)	0.85	0.85	1.00
Total induced abortion rate (*TA*)[a]	0.52	1.57	3.02
Lactational infecundability (*i*)	17.4	11.9	0.68
Index			
Index of proportions married (C_m)	0.72	0.58	0.81
Index of noncontraception (C_c)	0.97	0.76	0.78
Index of induced abortion (C_a)	0.97	0.84	0.87
Index of lactational infecundability (C_i)	0.56	0.66	1.18
Combined indexes ($C_m \times C_c \times C_a \times C_i$)	0.38	0.24	0.63

[a] Includes legitimate births and abortions to married women only.

SOURCES: See note 30.

Figure 4
Changes in Measures of Fertility, Korea, 1960–70



SOURCES: Tables 3, 4 and 5.

period 1965–73. The results are given in Table 4 and Figure 5.[31] The decline in the total fertility rate between 1965 and 1973 was caused primarily by an increase in the use and effectiveness of contraception, as is evident from the reduction in the index of noncontraception from 0.31 to 0.22. A decline in the proportion married and an increase in induced

Table 4
Estimates of Selected Reproductive Measures and Indexes of Intermediate Fertility Variables for the US, 1965 and 1973

Measure	1965	1973	1973/1965
Total fertility rate (*TFR*)[a]	2.72	1.67	0.61
Total marital fertility rate (*TM*)	4.49	2.93	0.65
Current contraceptive use (*u*)	0.64	0.70	1.09
Contraceptive effectiveness (e)	0.92	0.95	1.03
Total induced abortion rate (*TA*)[a]	0.0	0.13	
Lactational infecundability (*i*)			
Index			
Index of proportions married (C_m)	0.61	0.57	0.93
Index of noncontraception (C_c)	0.31	0.22	0.71
Index of induced abortion (C_a)	1.00	0.95	0.95
Index of lactational infecundability (C_i)	0.93	0.93	1.00
Combined indexes ($C_m \times C_c \times C_a \times C_i$)	0.18	0.11	0.61

[a] Includes legitimate births and abortions to married women only.
SOURCES: See note 31.

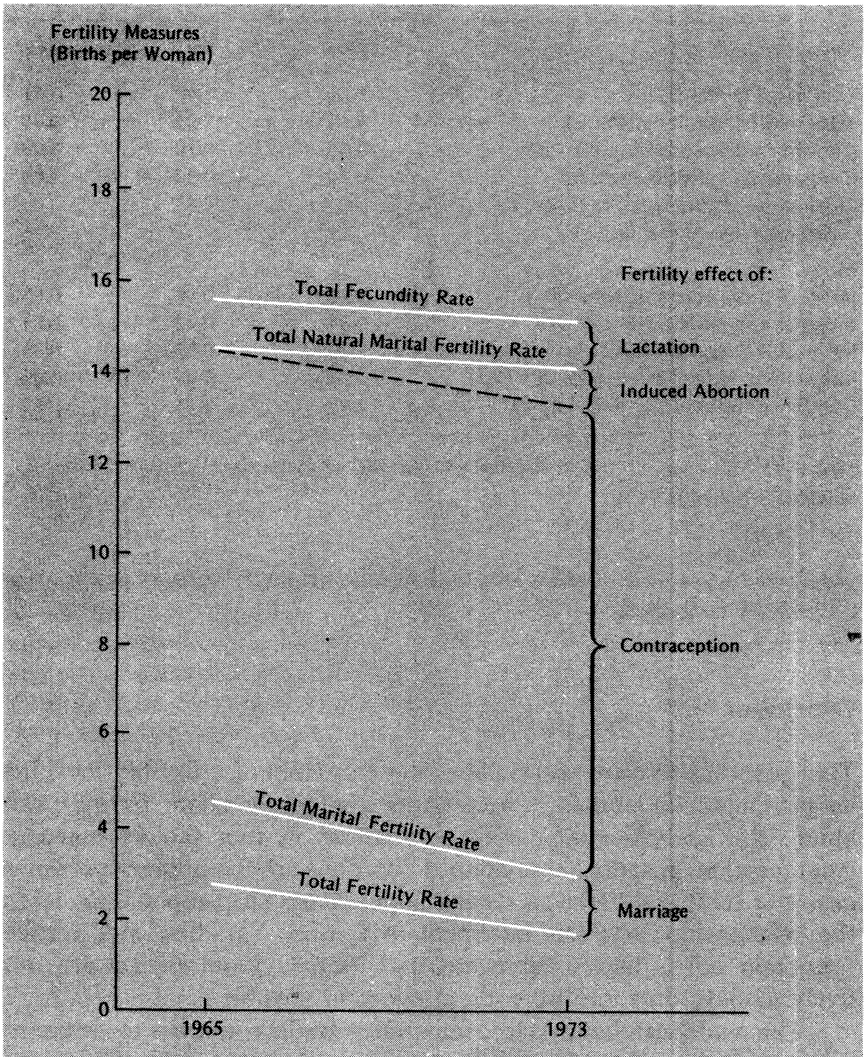
abortion rates made smaller but still significant contributions to the overall fertility reduction.

Conclusion

This quantitative framework allows the dissection of a fertility level into its proximate determining components, the intermediate fertility variables. The analysis indicates that variations in four factors—marriage, contraception, lactation, and induced abortion—are the primary proximate causes of fertility differences among populations. The proposed model for the relationship between intermediate fertility variables and fertility (equation 12) is highly aggregate, and its data requirements are relatively modest, thus making wide application possible.

The model can be used in comparative fertility analysis to determine the intermediate fertility variables responsible for fertility differences among populations or among subgroups within a population. This application can be valuable in analyses of the socioeconomic determinants of fertility, because the intermediate fertility variables allow the identification of the paths through which different socioeconomic variables affect fertility. Of special interest are the cases in which a socioeconomic indicator is only weakly correlated with fertility, while strong but compensating effects on the intermediate fertility variables are found. If, for example, the labor force participation rate of women is weakly related

Figure 5
Changes in Measures of Fertility, United States, 1965–73



SOURCES: Tables 3, 6 and 7.

to fertility, this may be because such participation has a strong positive effect on contraceptive use combined with a strong negative and compensating effect on lactation. An analysis of determinants of fertility that includes the intermediate fertility variables can therefore greatly clarify the relationships between socioeconomic indicators and fertility.

The model can also be used to trace a change in the fertility level of a population to changes in the intermediate fertility variables. This application is illustrated for recent time periods in Korea and the US in Figures 4 and 5. Finally, in projection of future fertility trends, the model can be used to estimate how much one or a combination of several of the intermediate fertility variables would have to be modified to obtain a given reduction in fertility. This projection of alternative paths toward a future fertility decline could be of interest to planners and policymakers.

Technical Note

The relationship between the total marital fertility rate and contraceptive use and effectiveness can be estimated by means of reproductive models. For simplicity, the analysis here is confined to a population of married women for which the following variables are defined:

a = age, in single years.

$f(a)$ = proportion of all women that is fecund (i.e., nonsterile).

$p(a)$ = proportion of fecund women that attempts to prevent pregnancies by contracepting. These women will be called "contraceptors."

$u(a)$ = proportion of all women that is currently using contraception.

$u^1(a)$ = proportion of contraceptors that is currently using contraception, that is, the proportion not pregnant or in postpartum amenorrhea.

$e(a)$ = contraceptive effectiveness.

$N(a)$ = mean duration of the nonsusceptible segment of the birth interval, consisting of pregnancy and infecundable periods.

$C(a)$ = mean duration of the susceptible ovulatory segment of the birth interval in the absence of contraception.

$F(a)$ = fertility rate among all women (births per woman per year).

$F_n(a)$ = natural fertility rate among all women.

$F_c(a)$ = fertility rate among contraceptors.

$F_a(a)$ = fertility rate among fecund noncontraceptors.

If it is assumed that contraceptors are always fecund, the population can be divided into three subpopulations: the contraceptors, the fecund noncontraceptors, and the sterile women. The fertility rate of all women equals the weighted average of the fertility rates of contraceptors and noncontraceptors.

$$F(a) = p(a)\, f(a)\, F_c(a) + [1 - p(a)]\, f(a)\, F_a(a) \tag{1}$$

If one further assumes that fecund women are homogeneous with respect to their fecundity characteristics, then

$$F_a(a) = \frac{1}{N(a) + C(a)} \tag{2}$$

$$F_c(a) = \frac{1}{N(a) + \dfrac{C(a)}{1 - e(a)}} \tag{3}$$

$$F_n(a) = \frac{f(a)}{N(a) + C(a)} \tag{4}$$

The homogeneity assumption can be relaxed by allowing heterogeneity within each of the subgroups of contraceptors and noncontraceptors, but on average the two groups have to be equal in their fecundity characteristics. In either case, the exchange of women between the two groups is allowed if the proportion $p(a)$ is not affected.

Within the subpopulation of contraceptors, a small proportion of women is in the nonsusceptible state because accidental pregnancies occur. If all other contraceptors are using contraception, then the proportion of contraceptors that is currently using equals

$$u^1(a) = \frac{\dfrac{C(a)}{1 - e(a)}}{N(a) + \dfrac{C(a)}{1 - e(a)}} \tag{5}$$

so that

$$u(a) = p(a)\, f(a) \frac{\dfrac{C(a)}{1 - e(a)}}{N(a) + \dfrac{C(a)}{1 - e(a)}} \tag{6}$$

Equation (6) can be rearranged as

$$p(a) = u(a) \frac{N(a) + \dfrac{C(a)}{1 - e(a)}}{f(a) \dfrac{C(a)}{1 - e(a)}} \tag{7}$$

Substitution of equations (2), (3), and (7) in (1) results in:

$$F(a) = F_n(a) \left[1 - \frac{u(a)e(a)}{f(a)} \right] \tag{8}$$

If more than one method of contraception is employed, $u(a)$ equals the total use of all methods and $e(a)$ equals the weighted average effectiveness (weights given by the proportions using different methods).

The total marital fertility rate, TM, is found by summing $F(a)$ over all age groups in the reproductive period (30 years between ages 15 and 45):

$$\begin{aligned} \mathrm{TM} &= \Sigma\, F(a) \\ &= \Sigma\, F_n(a) \left[1 - \frac{u(a)e(a)}{f(a)} \right] \\ &= TNM - \Sigma\, F_a(a)u(a)e(a) \end{aligned} \tag{9}$$

where TNM is the total natural fertility rate and $F_a(a)$ represents the age-specific natural marital fertility rate among fecund women. Equation (9) can be simplified further because the variables $F_a(a)$ and $e(a)$ vary little with age. For example, among the Hutterites $F_a(a)$ declines from 0.571 for the age group 20–24 to 0.509 for the age group 35–39.[32] The effectiveness of contraception can be expected to increase somewhat with age because both motivation and reliance on sterilization are greater among older couples. One might, for example, find that $e(a)$ increases from 0.85 to 0.95 between the early twenties and the late thirties. It should be noted that in addition to the relatively small changes with age, the age trends in the variables $F_a(a)$ and $e(a)$ compensate one another. That is, in the older age groups $F_a(a)$ is slightly below the average for all ages, and $e(a)$ is slightly above average, so that the product $F_a(a)\, e(a)$ is even less age-dependent than either function alone. Consequently, with good approximation,

$$TM = TNM - F_a e \, \Sigma \, u(a) \tag{10}$$

with the averages F_a and e defined as

$$F_a = \frac{1}{30} \Sigma \, F_a(a) \tag{11}$$

$$e = \frac{1}{30} \Sigma \, e(a) \tag{12}$$

If one further defines

$$u = \frac{1}{30} \Sigma \, u(a) \tag{13}$$

and

$$s = \frac{\Sigma \, F_n(a)/f(a)}{\Sigma \, F_n(a)} \tag{14}$$

then equation (10) becomes

$$TM = TNM \, (1 - s \, e \, u) \tag{15}$$

A value of 1.18 was obtained for s by substituting average estimates of $F_n(a)$ and $f(a)$ found by Henry in a group of historical populations.[33] It is unlikely that s varies substantially among populations because the incidence of sterility [the determinant of $f(a)$] presumably differs little among populations, and the value of s is not influenced by the absolute values of $F_n(a)$ as long as the age pattern remains the same. Even if the incidence of sterility is slightly higher in the poorer developing nations, this would be compensated by a higher prevalence of sterilizing operations for reasons other than contraception in the developed countries. On balance, therefore, the value of $s = 1.18$ is likely to provide a good approximation for many countries.

Notes

1. Kingsley Davis and Judith Blake, "Social structure and fertility: An analytic framework," *Economic Development and Cultural Change* 4, no. 4 (July 1956): 211–235. For a discussion of models, see Mindel C. Sheps and Jane A. Menken, *Mathematical Models of Conception and Birth* (University of Chicago Press, 1973); and John Bongaarts, "Intermediate fertility variables and marital fertility," *Population Studies* 30, no. 2 (July 1976): 227–241.

2. Louis Henry, "Some data on natural fertility," *Eugenics Quarterly* 8, no. 1 (March 1961): 81–91.

3. Although postpartum abstinence theoretically should be included in the frequency of intercourse variable, it is much more convenient to analyze the fertility effect of this abstinence by combining it with lactational infecundability into a postpartum infecundability interval. This interval is measured as the time from birth to the first month in which an ovulation combined with intercourse occurs.

4. Ansley Coale, "Factors associated with the development of low fertility: An historic summary," *Proceedings of the World Population Conference, Belgrade 1965* (New York: United Nations, 1967), pp. 205–209.

5. In illustrations presented in this study, the age-specific marital fertility rate $g(a)$ is obtained by dividing the age-specific fertility rate by the proportion of women that is currently married in each age group. This procedure often leads to erratic results for the age group 15–19, because small errors in the proportion married produce large errors in $g(15–19)$, and because the incidence of premarital conception is not negligible. In addition, the married women in the 15–19 age group are mostly 18 or 19 years old, and they are therefore not representative of the entire age group. To avoid these problems in the present paper $g(15–19)$ is set equal to $0.75 \times g(20–24)$ for all populations, when $g(a)$ is used to calculate TM [$TM = \Sigma\, g(a)$]. For the estimation of C_m, this correction of $g(15–19)$ is only made in the denominator of equation (1), in order to assure the validity of equation (2). Births to women under age 15 and over age 44 are included in the age groups 15–19 and 40–44, respectively.

6. The age-specific fertility rates from which TFR and TM are calculated (see note 5) are averages for the period 1970–74. The age-specific proportions married used to estimate C_m refer to various years between 1967 and 1975, depending on availability of data. Sources of data are: United Nations Population Division, "Selected world demographic indicators by countries 1950–2000," Working Paper, no. 55, ST/STAT/SER.R (1975); age-specific fertility rates obtained from a computer tape provided by the UN Population Division; and *Demographic Yearbook* (New York: United Nations, 1971 and 1973). In Figure 1, all births were assumed to be legitimate.

7. Effectiveness of contraception is measured as the proportion by which the monthly probability of conception (i.e., fecundability) is reduced as the result of contraceptive practice.

8. This variable gives an exact estimate for u, if the age-specific use rates do not vary with age or if the number of married women is the same in each age group.

9. The effectiveness levels by method are calculated from one-year failure rates given by Barbara Vaughn et al., "Contraceptive failure among married women in the United States, 1970–1973," *Family Planning Perspectives* 9, no. 6 (November–December 1977): 251–258. The formula used in this calculation was proposed in Norman B. Ryder, "Contraceptive failure in the US," *Family Planning Perspectives* 5, no. 3 (May–June 1973): 133–142. The estimation procedure requires an estimate of the level of fecundability in the United States. Based on the following considerations, average fecundability was assumed to equal 0.1. Two estimates of fecundability in the United States have been published: 0.18 and 0.15 by, respectively, Charles Westoff et al., *Family Growth in Metropolitan America* (Princeton University Press, 1961); and William H. James, "The fecundability of U.S. women," *Population Studies* 27, no. 3 (November 1973): 493–500. Since both estimates apply to newlyweds, the fecundability of all married women is likely to be substantially lower, say 0.1 or slightly higher. The value of 0.1 was chosen to allow for underreporting or spontaneously aborted pregnancies in the calculation of contraceptive failure rates.

10. For each of the four developed countries included in Figure 2, data on use by method were available; therefore average effectiveness levels could be estimated on the basis of the figures in Table 1. The index C_c is estimated with equation

(5) and the total natural marital fertility rate is calculated as $TNM = TM/C_c$. Sources of data on contraceptive use are: Dorothy Nortman and Ellen Hofstatter, "Population and family planning programs: A factbook," *Reports on Population/Family Planning,* no. 2 (October 1975); Walter B. Watson and Robert Lapham, "Family planning programs: World review 1974," *Studies in Family Planning* 6, no. 4 (April 1975): 207–220; and *Fertility and Family Planning in Europe around 1970,* Population Studies, no. 58 (New York: United Nations, Department of Economic and Social Affairs, 1976).

11. Robert G. Potter, "Additional births averted when abortion is added to contraception," *Studies in Family Planning* 7, no. 8 (August 1976): 224–230.

12. I. H. Su and L. P. Chow, "Induced abortion and contraceptive practice: An experience in Taiwan," *Studies in Family Planning* 7, no. 8 (August 1976): 224–230.

13. It should be noted that changes in the incidence of induced abortion will affect the index C_m because it is calculated from the age-specific marital fertility rates, which are influenced by the practice of induced abortion. However, this effect is usually unimportant since proportional changes in the values of these marital fertility rates have an equal effect on the numerator and denominator of equation (1).

14. The regression equation was calculated after the correction for the effect of induced abortion was made.

15. Robert G. Potter et al., "A case study of birth interval dynamics," *Population Studies* 19, no. 1 (July 1965): 81-94.

16. Henry Leridon, *Human Fertility: The Basic Components* (University of Chicago Press, 1977).

17. Fecundity is the capacity to reproduce; fertility, on the other hand, is actual reproductive performance.

18. Lincoln Chen et al., "A prospective study of birth interval dynamics in rural Bangladesh," *Population Studies* 28, no. 2 (July 1974): 277–297.

19. Lincoln Chen, cited in note 18; Masri Singarimbun et al., "Breastfeeding, amenorrhea, and abstinence in a Javanese village: A case study of Mojolama," *Studies in Family Planning* 7, no. 2 (February 1976): 175–179; Pierre Cantrelle and Benoît Ferry, "La mise en évidence de la fécondité naturelle dans les populations contemporaines," *International Population Conference, Mexico City, 1977* (Liege: International Union for the Scientific Study of Population, 1977), Vol. 1; John Bongaarts and Herman Delgado, "Effects of nutritional status on fertility in rural Guatemala," paper presented at the Seminar on Natural Fertility, Paris, March 1977, organized by the International Union for the Scientific Study of Population and the Institut National d'Etudes Démographiques (In press); and Potter, cited in note 15.

20. See note 2.

21. William Butz and Jean-Pierre Habicht, "The effects of nutrition and health on fertility: Hypotheses, evidence and interventions," in *Population and Development: The Search for Selective Interventions,* ed. Ronald G. Ridker (Baltimore: Johns Hopkins University Press, 1976), pp. 210–238.

22. Henry Mosley, "The effects of nutrition on natural fertility," paper presented at the Seminar on Natural Fertility, Paris, March 1977; and Bongaarts and Delgado, cited in note 19.

23. H. Hansluwka, "Health, population and socioeconomic development," in *Population Growth and Economic Development in the Third World,* ed. Leon Tabah (Dolhain, Belgium: Ordina Editions, for International Union for the Scientific Study of Population, 1976), pp. 191–249.

24. Rose Frisch, "Menstrual cycles: Fatness as a determinant of minimum weight for height necessary for their maintenance and onset," *Science* 185, no. 4155 (13 September 1974): 949–951.

25. Jane A. Menken and John Bongaarts, "Reproductive models in the study of nutrition-fertility interrelationships,"

paper presented at the Conference on Nutrition and Reproduction, organized by the Subcommittee on Nutrition and Fertility of NICHD, Washington, February 1977. (Proceedings to be published.)

26. See note 22.

27. Carlo Corsini, "Is the fertility reducing effect of lactation really substantial?," paper presented at the Seminar on Natural Fertility organized by the IUSSP and INED, Paris, March 1977. (Proceedings to be published.)

28. If the proportion of women still lactating in the t^{th} month after birth equals $P(t)$, then $L = \Sigma\ P(t)$. Similarly, if the proportion of women still amenorrheic in the t^{th} month after birth equals $R(t)$, then $i = \Sigma\ R(t)$.

29. Christopher Tietze and Marjorie Murstein, "Induced abortion: 1975 factbook," *Reports on Population/Family Planning*, no. 14 (December 1975).

30. *Population of the Republic of Korea*, Country Monograph Series, no. 2 (Bangkok: United Nations Economic and Social Commission for Asia and the Pacific); *Population and Family Planning in the Republic of Korea* (Seoul: Korean Institute for Family Planning, 1974); *Demographic Yearbook* (New York: United Nations, 1968 and 1973); *1973 National Family Planning and Fertility Survey: A Comprehensive Report* (Seoul: Korean Institute for Family Planning); Christopher Tietze, "Induced abortion: A factbook," *Reports on Population/Family Planning*, no. 14 (December 1973); Kap Suk Koh and David Smith, *The Korean 1968 Fertility and Family Planning Survey* (Seoul: National Family Planning Center, 1970). Values for current contraceptive use and lactational infecundability in 1960 are extrapolated. Five percent of reported induced abortions were assumed to take place outside marriage (personal communication from Christopher Tietze).

31. *Statistical Abstract of the United States* (Washington, D.C.: US Bureau of the Census, 1975); US Bureau of the Census, "Marital status and family status," *Current Population Reports, Population Characteristics*, Series P-20, no. 144 (1965); US Bureau of the Census, "Marital status and living arrangements: March 1975," *Current Population Reports, Population Characteristics*, Series P-20, no. 255 (1975); Charles Westoff, "Trends in contraceptive practice: 1965–1973," *Family Planning Perspectives* 8, no. 2 (March–April 1976): 53–57.

32. Hubert Charbonneaux, "Les Régimes de fecondité naturelle en Amerique du Nord: Bilan des observations," paper presented at the Seminar on Natural Fertility, Paris, March 1977, organized by the International Union for the Scientific Study of Population and the Institut National d'Etudes Démographiques (In press).

33. See note 2.