The Fertility-Inhibiting Effects of the Intermediate Fertility Variables

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The term intermediate fertility variable was first introduced in the mid-1950s by Davis and Blake.[1] They proposed a set of 11 intermediate fertility variables defined as the factors through which, and only through which, social, economic, and cultural conditions can affect fertility. Although the Davis and Blake framework for analyzing the determinants of fertility has found wide acceptance, it has proven difficult to incorporate into quantitative reproductive models. Since the pioneering work of Henry in the early 1950s, a variety of models that incorporate sociobiological proximate determinants of fertility have been constructed.[2] Model builders now use a set of intermediate fertility variables that is different from, but closely related to, the Davis and Blake set. It is this new set that will be discussed here.

The objective of this paper is to demonstrate that differences in fertility among populations are largely due to variations in only four intermediate variables. In addition, estimates of the fertility effect of these factors and of the levels of general fertility, marital fertility, and natural fertility will be made for populations at various stages in the fertility transition.

Selecting the Important Intermediate Fertility Variables

The following is a complete set of intermediate fertility variables often encountered in reproductive models:

1 proportions married among females
2 contraceptive use and effectiveness
3 prevalence of induced abortion
4 duration of postpartum infecundability
5 fecundability (or frequency of intercourse)
6 spontaneous intrauterine mortality
7 prevalence of permanent sterility

Each of these seven intermediate variables directly influences fertility, and together they determine the level of fertility. The first factor measures the extent to which women are exposed to regular intercourse (marriage is defined broadly to include consensual unions). The second and third factors measure the prevalence of deliberate marital fertility control, and the last four are the determinants of natural marital fertility.[3]

It is generally not necessary to devote the same effort to analyzing and measuring each of these intermediate variables because they are not of equal interest in studies of fertility levels and differentials. Two criteria can be applied to select the intermediate variables that deserve most attention. The first is the sensitivity of fertility to variations in the different intermediate variables. A variable is relatively uninteresting if large variations in it produce only minor changes in fertility. The second criterion is the extent of a factor's variability among populations or over time. A relatively stable intermediate variable can contribute little to explaining fertility differentials and is hence less important.

In Table 1 the seven intermediate variables are given an approximate rating for these two criteria, based on other studies of the relationship between these intermediate variables and fertility.[4] Fertility is least sensitive to variations in the level of intrauterine mortality and most sensitive to changes in the proportions married and the prevalence of contraception. Variability is lowest for the prevalence of sterility and the risk of intrauterine mortality. The overall rating, based on both criteria, indicates that four intermediate fertility variables—proportion mar-

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TABLE 1 Rating of intermediate fertility variables with respect to sensitivity of fertility and variability among populations

Intermediate fertility variables	Sensitivity of fertility to intermediate variables	Variability among populations	Overall rating
Proportions married	+ + +	+ + +	+ + +
Contraceptive use	+ + +	+ + +	+ + +
Prevalence of induced abortion	+ +	+ + +	+ + +
Postpartum infecundability	+ +	+ + +	+ + +
Fecundability	+ +	+ +	+ +
Spontaneous intrauterine mortality	+	+	+
Permanent sterility	+ +	+	+

+ + + = High + + = Medium + = Low or absent

ried, postpartum infecundability, contraception, and induced abortion—are the most important ones in the analysis of fertility levels and trends. This conclusion, which will be confirmed quantitatively later in this paper, does not of course mean that the other factors are never important. For example, a population's fertility may be lower than expected if widespread venereal disease causes a high prevalence of sterility, or if fecundability is reduced substantially by prolonged spousal separations. Although less important than postpartum infecundability, fecundability also explains some of the variance in the natural marital fertility of historical populations.[5]

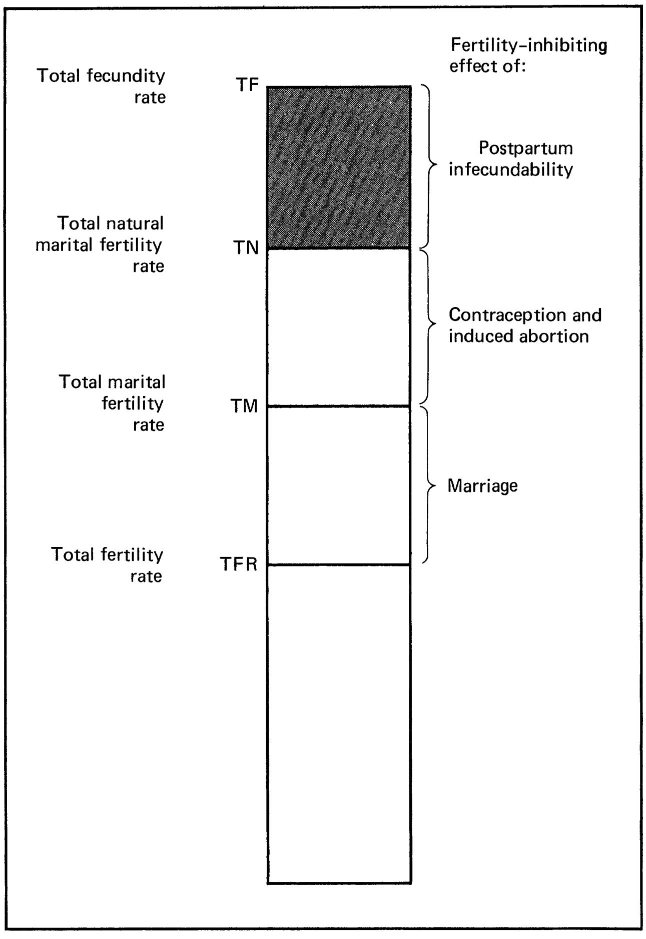
A Model Relating the Intermediate Variables and Fertility

A model relating fertility to the intermediate fertility variables is described in detail elsewhere[6] (a summary of the equations and an example of an application are provided in the Appendix). Only the model's basic concepts and variables will be outlined here.

In this model the four principal intermediate variables are considered inhibitors of fertility, because fertility is lower than its maximum value as a result of delayed marriage (and marital disruption), the use of contraception and induced abortion, and postpartum infecundability induced by breastfeeding (or abstinence). As is illustrated in Figure 1, four different types of fertility levels are identified from which the impact of the intermediate variables can be derived. With the inhibiting effects of all intermediate variables present, a population's actual level of fertility is observed, measured by the total fertility rate, TFR (the total fertility rate and other fertility rates in this paper include only legitimate births). If the fertility-inhibiting effect of celibacy is removed, fertility will increase to a level TM, the total marital fertility rate. If all practice of contraception and induced abortion is also eliminated, fertility will rise further to a level TN, the total natural marital fertility rate. Removing, in addition, the practice of lactation and postpartum abstinence further increases fertility to the total fecundity rate, TF. The total fecundity rate measures the combined effect of the remaining intermediate variables: fecundability, spontaneous intrauterine mortality, and permanent sterility. While the fertility rates TFR, TM, and TN vary widely among populations, the total fecundity rate is rather stable. The TF values of most populations fall within the range of 13 to 17 births per woman, with an average of about 15.3.[7] Lower values are found only in special circumstances—for example, if there is a high prevalence of diseases causing sterility or if prolonged spousal separations are common.[8]

The fertility effects of the four most important intermediate variables are measured in the model by

FIGURE 1 Relationships between the fertility-inhibiting effects of the intermediate variables and various measures of fertility



four indexes. The indexes can only take values between 0 and 1. When there is no fertility-inhibiting effect of a given intermediate variable, the corresponding index equals one; if the fertility inhibition is complete, the index equals zero.

The four indexes are defined as follows:

C_m = index of marriage (equals 1 if all women of reproductive age are married and 0 in the absence of marriage)

C_c = index of contraception (equals 1 in the absence of contraception and 0 if all fecund women use 100 percent effective contraception)

C_a = index of induced abortion (equals 1 in the absence of induced abortion and 0 if all pregnancies are aborted)

C_i = index of postpartum infecundability (equals 1 in the absence of lactation and postpartum abstinence and 0 if the duration of infecundability is infinite)

Each index (or set of indexes) by definition equals the ratio of the fertility levels in the presence and in the absence of the inhibition caused by the corresponding intermediate fertility variable(s):

$$C_m = \frac{\mathrm{TFR}}{\mathrm{TM}} \tag{1}$$

$$C_c \times C_a = \frac{\mathrm{TM}}{\mathrm{TN}} \tag{2}$$

$$C_i = \frac{\mathrm{TN}}{\mathrm{TF}} \tag{3}$$

It follows from these equations that:

$$\mathrm{TFR} = C_m \times C_c \times C_a \times C_i \times \mathrm{TF} \tag{4}$$

This simple equation summarizes the relationship between the total fertility rate and the intermediate fertility variables.

The indexes C_m, C_c, C_a, and C_i can be calculated with equations (1), (2), and (3) if measures of the fertility rates TFR, TM, TN, and TF are available (which is rarely the case). In most applications, the indexes are estimated directly from the following measures of the intermediate fertility variables:

$m(a)$ = age-specific proportions of women currently married

u = proportion of married women currently using contraception

e = average use-effectiveness of contraception[9]

TA = total induced abortion rate (abortions per woman)

i = mean duration of postpartum infecundability (in months)

The equations for calculating the indexes from these variables are given in Appendix 1 (note the minor change in the equation for C_c compared with the earlier version of the model).

Testing the Validity of the Model

It was concluded earlier that variations in fertility are usually due to variations in only four factors: the proportions married, contraceptive prevalence and effectiveness, the incidence of induced abortion, and the duration of postpartum infecundability. The remaining intermediate variables, generally much less important, were represented in the model by the total fecundity rate, which has values around 15.3 births per woman. The validity of these findings will now be tested by comparing the observed total fertility rates of different populations with the model estimates of total fertility rates obtained from the following equation (from equation (4), assuming TF = 15.3):

$$\mathrm{TFR} = C_m \times C_c \times C_a \times C_i \times 15.3 \tag{5}$$

The testing procedure will be applied in 41 developing, developed, and historical populations, and involves four successive steps: estimation of the intermediate fertility variables; calculation of the indexes; estimation of the total fertility rates using equation (5); and a comparison of the model estimates of TFR with the observed TFRs to determine how well the four principal intermediate variables predict the fertility level of a population.

Table 2 presents the estimates of the intermediate variables; rather than including the entire $m(a)$ distribution, the values for TFR and TM are given, from which C_m is calculated with equation (1). The data are obtained from a variety of sources, including WFS surveys.[10] Estimates of the duration of postpartum infecundability were the most difficult to obtain, and indirect estimation procedures had to be applied in nearly all populations. For WFS countries, information about the average duration of breastfeeding was available[11] from which the infecundable interval was obtained with an equation presented elsewhere.[12] For the historical populations the infecundable interval was derived from the average difference between the interval from marriage to first birth and subsequent birth intervals.

From the data in Table 2, one can calculate the indexes C_m, C_c, C_a, and C_i with equations summarized in Appendix 1. The results are presented in Table 3. The total fertility rates can now be estimated

TABLE 2 Estimates of total fertility rate, total marital fertility rate, and intermediate fertility variables for selected populations

Populations	Total fertility rate	Total marital fertility rate	Prevalence of contraceptive use	Use-effectiveness	Total induced abortion rate	Duration of postpartum infecundability (in months)
Developing countries						
Bangladesh, 1975	6.34	7.43	0.08	0.82	—	18.61
Colombia, 1976	4.57	7.91	0.39	0.84	—	5.28
Costa Rica, 1976	3.69	6.46	0.64	0.86	—	3.60
Dominican Republic, 1975	5.85	9.74	0.32	0.89	—	4.76
Guatemala, 1972	7.05	9.74	0.03	0.87	—	14.18
Hong Kong, 1978	2.26	4.56	0.72	0.86	—	3.01
Indonesia, 1976	4.69	6.64	0.26	0.87	—	16.16
Jamaica, 1976	4.32	7.99	0.40	0.84	—	4.25
Jordan, 1976	7.41	9.95	0.24	0.84	—	6.50
Kenya, 1976	8.02	10.44	0.03	0.75	—	11.22
Korea, 1970	3.97	6.85	0.24	0.89	1.5	11.90
Lebanon, 1976	4.77	8.28	0.35	0.83	—	7.14
Malaysia, 1974	4.76	7.84	0.33	0.85	—	3.80
Mexico, 1976	5.73	9.40	0.29	0.86	—	5.28
Nepal, 1976	6.37	7.48	0.02	0.94	—	17.86
Pakistan, 1975	7.02	8.94	0.05	0.83	—	12.65
Panama, 1976	4.57	7.14	0.54	0.90	—	4.25
Peru, 1977	5.11	8.92	0.31	0.78	—	7.85
Philippines, 1976	5.01	8.17	0.35	0.78	—	7.85
Sri Lanka, 1975	3.53	6.88	0.32	0.84	—	14.39
Syria, 1973	7.00	9.59	0.22	0.87	—	8.90
Thailand, 1975	4.70	7.48	0.33	0.91	—	11.80
Turkey, 1968	5.60	7.37	0.35	0.80	—	8.90
Developed countries						
Denmark, 1970	1.78	3.21	(0.70)	0.96	0.169	(3.0)
Finland, 1971	1.61	3.13	(0.80)	0.96	0.284	(3.0)
France, 1972	2.21	4.26	(0.67)	0.94	0.093	(3.0)
Hungary, 1966	1.80	2.92	(0.67)	0.93	2.086	(3.0)
Poland, 1972	2.09	4.78	(0.60)	0.91	0.427	(3.0)
United Kingdom, 1967	2.38	3.91	(0.72)	0.95	0.039	(3.0)
United States, 1967	2.34	3.71	0.72	0.96	0.004	(3.0)
Yugoslavia, 1970	2.11	3.69	(0.62)	0.95	1.080	(3.0)
Historical populations						
Bavarian villages 1700–1850	(4.45)	11.89	—	—	—	4.9
Crulai Mar.[a] 1674–1742	5.60	9.89	—	—	—	11.2
Grafenhausen 1700–1850	(4.74)	10.73	—	—	—	11.3
Hutterites Mar. 1921–1930	9.50	12.96	—	—	—	6.0
Ile de France Mar. 1740–1779	6.10	12.08	—	—	—	9.6
Oschelbron 1700–1850	(5.06)	10.60	—	—	—	9.0
Quebec Mar. 1700–1730	8.00	12.72	—	—	—	6.2
Tourouvre au Perche Mar. 1665–1714	6.00	10.15	—	—	—	8.2
Waldeck villages 1700–1850	(4.41)	9.97	—	—	—	11.1
Werdum 1700–1850	(3.78)	9.37	—	—	—	12.7

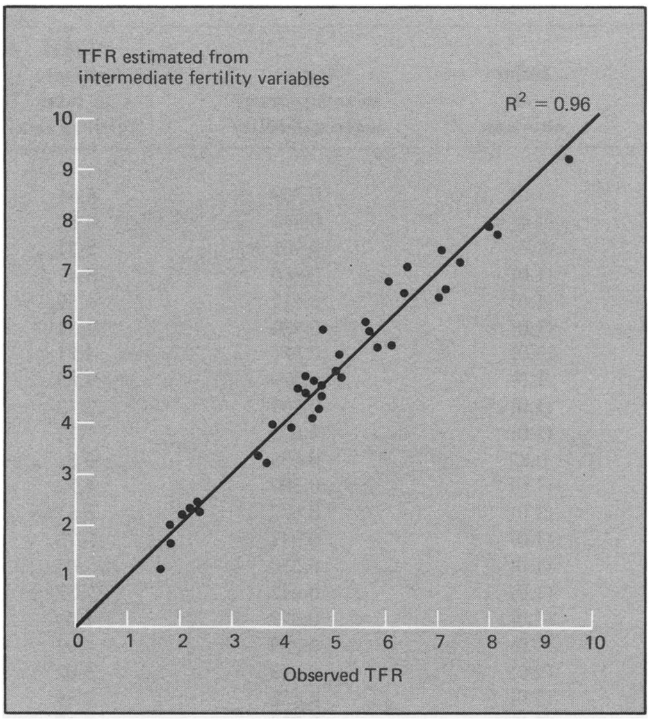
[a]Mar. = marriages. NOTE: Figures in parentheses are approximate. SOURCES: See note 10.

TABLE 3 Estimates of the indexes of the intermediate fertility variables and model estimate of total fertility rates for selected populations

Populations	Index of marriage	Index of contraception	Index of abortion	Index of postpartum infecundability	Model estimate of total fertility rate
Developing countries					
Bangladesh, 1975	0.853	0.929	(1.0)	0.539	6.54
Colombia, 1976	0.578	0.646	(1.0)	0.841	4.80
Costa Rica, 1976	0.571	0.406	(1.0)	0.905	3.21
Dominican Republic, 1975	0.601	0.692	(1.0)	0.860	5.47
Guatemala, 1972	0.724	0.972	(1.0)	0.612	6.59
Hong Kong, 1978	0.496	0.331	(1.0)	0.930	2.34
Indonesia, 1976	0.706	0.756	(1.0)	0.577	4.71
Jamaica, 1976	0.541	0.637	(1.0)	0.879	4.63
Jordan, 1976	0.745	0.782	(1.0)	0.800	7.13
Kenya, 1976	0.768	0.976	(1.0)	0.673	7.72
Korea, 1970	0.580	0.769	0.82	0.658	3.81
Lebanon, 1976	0.576	0.686	(1.0)	0.780	4.72
Malaysia, 1974	0.607	0.697	(1.0)	0.897	5.81
Mexico, 1976	0.610	0.731	(1.0)	0.841	5.73
Nepal, 1976	0.852	0.980	(1.0)	0.550	7.02
Pakistan, 1975	0.785	0.955	(1.0)	0.642	7.37
Panama, 1976	0.640	0.475	(1.0)	0.879	4.09
Peru, 1977	0.573	0.739	(1.0)	0.759	4.92
Philippines, 1976	0.613	0.705	(1.0)	0.759	5.02
Sri Lanka, 1975	0.513	0.710	(1.0)	0.608	3.39
Syria, 1973	0.730	0.793	(1.0)	0.730	6.47
Thailand, 1975	0.628	0.676	(1.0)	0.660	4.29
Turkey, 1968	0.760	0.698	(1.0)	0.730	5.92
Developed countries					
Denmark, 1970	0.555	(0.274)	0.939	(0.930)	2.03
Finland, 1971	0.514	(0.171)	0.887	(0.930)	1.11
France, 1972	0.519	(0.320)	0.973	(0.930)	2.30
Hungary, 1966	0.617	(0.327)	0.564	(0.930)	1.62
Poland, 1972	0.437	(0.410)	0.884	(0.930)	2.26
United Kingdom, 1967	0.609	(0.261)	0.989	(0.930)	2.24
United States, 1967	0.631	0.254	0.999	(0.930)	2.27
Yugoslavia, 1970	0.572	(0.364)	0.751	(0.930)	2.22
Historical populations					
Bavarian villages 1700–1850	(0.374)	(1.0)	(1.0)	0.856	4.89
Crulai Mar.[a] 1674–1742	0.566	(1.0)	(1.0)	0.673	5.83
Grafenhausen 1700–1850	(0.442)	(1.0)	(1.0)	0.671	4.54
Hutterites Mar. 1921–1930	0.733	(1.0)	(1.0)	0.816	9.15
Ile de France Mar. 1740–1778	0.505	(1.0)	(1.0)	0.712	5.50
Oschelbron 1700–1850	(0.477)	(1.0)	(1.0)	0.727	5.31
Quebec Mar. 1700–1730	0.629	(1.0)	(1.0)	0.810	7.80
Tourouvre au Perche Mar. 1664–1714	0.591	(1.0)	(1.0)	0.749	6.77
Waldeck villages 1700–1850	(0.442)	(1.0)	(1.0)	0.676	4.57
Werdum 1700–1850	0.403	(1.0)	(1.0)	0.640	3.95

[a]Mar. = marriages. NOTE: Figures in parentheses are approximate. SOURCE: Equations in Appendix.

FIGURE 2 Observed and model estimates of the total fertility rates (TFR) of 41 populations



from the indexes using equation (5). These model estimates of TFR are given in the last column of Table 3.

A comparison of the model estimates with the observed TFRs reveals that there is good agreement between these two fertility levels (see Figure 2). In fact, the model estimates of TFR, and therefore the four principal intermediate fertility variables, explain 96 percent of the variation in the observed fertility rate. The standard error of the model estimate is 0.36, and in only two populations (Tourouvre au Perche and Malaysia) are the differences more than twice this standard error. Clearly, the earlier conclusion that proportions married, contraception, induced abortion, and postpartum infecundability are the most important intermediate fertility variables is supported by this finding. These results also confirm the general validity of the model.

The variance in fertility that is not explained by the four principal intermediate variables is due to several factors, including:

1 Errors in the measurement of the intermediate variables in Table 2.
2 Errors in the specification of the model. To arrive at a simple analytic model for the relationship between fertility and the intermediate variables, a number of simplifying assumptions had to be made. These assumptions make the model less than fully accurate.
3 Deviations from the total fecundity value of 15.3. The total fecundity rate is a function of the three intermediate variables not explicitly included in the model (i.e., natural fecundability, intrauterine mortality, and the prevalence of permanent sterility). As a consequence, the assumption that TF = 15.3 is only an approximation. As already noted, the normal range of TF is from 13 to 17 births per woman.
4 Errors in the observed total fertility rates. Since existing methods for measuring fertility are not perfect, it follows that the best available fertility estimates differ somewhat from the true rates.
5 Induced abortion is assumed absent except in the developed countries and in Korea (a low level of induced abortion common to all populations is allowed for in the estimate of TF = 15.3). If incorrect, this assumption results in an upward bias in the model estimates of TFR.
6 All births are assumed to be legitimate except in the developed countries, where the total fertility rates given in Table 2 are corrected to exclude illegitimate births. In the developing countries in which this assumption is incorrect, the observed TFRs are overestimated.

Although the overall fit of the model is quite good, the combined effect of these error components is sufficiently large to make equation (5) unsuitable for the accurate estimation of fertility levels. Errors exceeding 0.5 births per woman in the total fertility rate are not unusual, and other existing methods for estimating fertility are therefore preferable. The purpose of this equation is not to provide a new estimation method; instead, it gives an approximate breakdown of the contributions made by different intermediate variables to levels and trends in fertility.

The Transition in the Intermediate Fertility Variables

As a population moves through the transition from natural to controlled fertility there is, by definition, an increase in deliberate marital fertility control. This control is exerted primarily through a rise in contraceptive use, but in a number of populations the practice of induced abortion plays a major role. Accompanying the transition in the deliberate control of marital fertility are transitions in the other principal intermediate variables—marriage and postpartum infecundability. As a consequence of these trends in the intermediate variables, important changes take place in the levels of natural marital fertility, marital fertility, and overall fertility.

In examining changes in these fertility measures over the course of the transition, it is unfortunately not possible to rely on time trends in individual populations because the necessary data are lacking. Instead a comparative analysis will be made here of contemporary populations at different points in the transition. The result will be an outline of a typical "synthetic" transition from the fertility behavior found in contemporary developing countries to that currently observed in developed countries. To provide a clearer picture of the trends in the intermediate variables, populations are divided into four transition phases according to the level of fertility:

I TFR over 6.0
II TFR 4.5–6.0
III TFR 3.0–4.5
IV TFR less than 3.0

The fertility of most populations in phase I is close to natural, while populations in phase IV have completed most or all of the fertility transition.

Estimates of the intermediate variables—the indexes C_m, C_c, C_a, and C_i—and of the total natural marital fertility rate, the total marital fertility rate, and the total fertility rate of groups of populations in each of the four transition phases are obtained by averaging the data of 31 developing and developed countries in Tables 2 and 3. The results are presented in Table 4 and Figure 3. (All estimates in Table 4 are sub-

FIGURE 3 Estimated average total natural marital fertility rates, total marital fertility rates, and total fertility rates of countries in different phases of the fertility transition

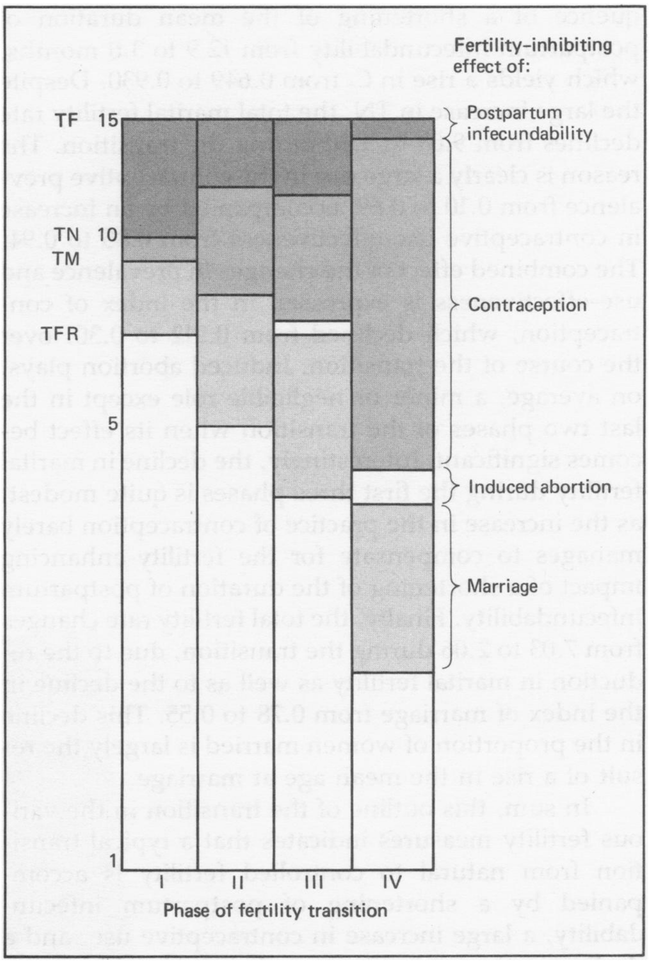


TABLE 4 Averages of measures of the intermediate fertility variables, the indexes, and the total, marital, and natural marital fertility rates for groups of populations in different phases of a synthetic transition

	Phase of fertility transition			
	I	II	III	IV
Prevalence of contraceptive use	0.10	0.35	0.40	0.69
Use-effectiveness of contraception	0.85	0.85	0.86	0.94
Total induced abortion rate	0.0	0.0	0.38	0.46
Postpartum infecundability	12.9	7.6	8.5	3.0
Index of marriage	0.780	0.627	0.551	0.550
Index of contraception	0.912	0.682	0.630	0.301
Index of induced abortion	1.000	1.000	0.961	0.887
Index of postpartum infecundability	0.649	0.780	0.763	0.930
Total fertility rate	7.03	5.03	3.88	2.06
Total marital fertility rate	9.08	8.08	7.05	3.80
Total natural marital fertility rate[a]	9.93	11.93	11.67	14.23
Number of countries included	7	11	4	9

[a]Estimated as 15.3 times index of postpartum infecundability. SOURCE: Tables 2 and 3.

ject to large sampling errors because of small numbers of populations included in each transition phase.) The total natural marital fertility rate (TN) rises from 9.93 to 14.23 births per woman between the first and last phase of the transition. This is the consequence of a shortening of the mean duration of postpartum infecundability from 12.9 to 3.0 months, which yields a rise in C_i from 0.649 to 0.930. Despite the large increase in TN, the total marital fertility rate declines from 9.08 to 3.80 during the transition. The reason is clearly a large rise in the contraceptive prevalence from 0.10 to 0.69, accompanied by an increase in contraceptive use-effectiveness from 0.85 to 0.94. The combined effect of the changes in prevalence and use-effectiveness is expressed in the index of contraception, which declined from 0.912 to 0.301 over the course of the transition. Induced abortion plays, on average, a minor or negligible role except in the last two phases of the transition when its effect becomes significant. Interestingly, the decline in marital fertility during the first three phases is quite modest, as the increase in the practice of contraception barely manages to compensate for the fertility-enhancing impact of a shortening of the duration of postpartum infecundability. Finally, the total fertility rate changes from 7.03 to 2.06 during the transition, due to the reduction in marital fertility as well as to the decline in the index of marriage from 0.78 to 0.55. This decline in the proportion of women married is largely the result of a rise in the mean age at marriage.

In sum, this outline of the transition in the various fertility measures indicates that a typical transition from natural to controlled fertility is accompanied by a shortening of postpartum infecundability, a large increase in contraceptive use, and a decline in the proportion married. It should be emphasized that this pattern is based on a comparison of contemporary populations at different stages in the transition. Actual transitions over time in developing countries probably resemble this pattern quite closely, but the transitions in historical European populations are different in one respect. Instead of a reduction in the proportion married, these historical populations typically experienced a decline in the mean age at marriage and a rise in the proportion of women married.[13]

Conclusion

The principal finding of this study is that a small number of intermediate fertility variables are responsible for most of the variation in fertility levels of populations. Four intermediate factors—proportion married, contraception, induced abortion, and postpartum infecundability—are the most important determinants of fertility. These four factors explain 96 percent of the variance in the total fertility rate in a sample of 41 populations that included developing and developed countries as well as historical populations. The remaining intermediate variables—natural fecundability (or frequency of intercourse), spontaneous intrauterine mortality, and permanent sterility—are generally much less important although they may substantially affect fertility in some populations.

In the last section of the paper the average fertility effect of the intermediate fertility variables, as measured by the corresponding indexes, was estimated for groups of contemporary populations with different total fertility rates. Postpartum infecundability resulting from breastfeeding has a strong fertility-inhibiting effect in countries with high total fertility rates. As a result, natural marital fertility in these countries is much lower than in the developed countries. Although natural marital fertility is very high in the developed world, marital fertility is relatively low because of high contraceptive prevalence: around 1970 about two-thirds of married women of reproductive age were using contraception (this level increased further during the 1970s). This high prevalence of contraceptive use is the primary reason for the low total fertility rates in the developed countries, but late marriage and a high rate of marital disruption, as well as significant use of induced abortion, also contribute to lowering the total fertility rate.

Appendix: A Summary of the Model

Several equations relate the fertility rates TFR, TM, TN, and TF to the indexes C_m, C_c, C_a, and C_i (see text or reference in note 6 for a definition of these variables):

$$
\begin{aligned}
\text{TFR} &= C_m \times C_c \times C_a \times C_i \times \text{TF} \\
&= C_m \times C_c \times C_a \times \text{TN} \\
&= C_m \times \text{TM} \\
\text{TM} &= \text{TFR} \,/\, C_m \\
&= C_c \times C_a \times C_i \times \text{TF} \\
&= C_c \times C_a \times \text{TN} \\
\text{TN} &= \text{TFR} \,/\, (C_m \times C_c \times C_a) \\
&= \text{TM} \,/\, (C_c \times C_a) \\
&= C_i \times \text{TF} \\
\text{TF} &= \text{TFR} \,/\, (C_m \times C_c \times C_a \times C_i) \\
&= \text{TM} \,/\, (C_c \times C_a \times C_i) \\
&= \text{TN} \,/\, C_i
\end{aligned}
$$

Each of the indexes can be calculated from measurements of the intermediate fertility variables, as is illustrated below for Sri Lanka, 1975.

Index of Marriage

$$C_m = \frac{\text{TFR}}{\text{TM}} = \frac{\Sigma f(a)}{\Sigma f(a)/m(a)}$$

where *m(a)* equals the proportion currently married among females, by age, and *f(a)* is a schedule of age-specific fertility rates [$m(a)$ should include consensual unions, but visiting unions are given a weight of 0.5]. Only births to married women should be included in *f(a)*.

For Sri Lanka, 1975, the estimated values for *f(a)* and *m(a)* are:

Age group	$f(a)$	$m(a)$	$g(a) = f(a)/m(a)$
15–19	35.9	0.065	(293.5)
20–24	148.7	0.380	391.3
25–29	192.1	0.650	295.5
30–34	170.0	0.822	206.8
35–39	117.2	0.856	136.9
40–44	36.2	0.814	44.5
45–49	5.6	0.817	6.9
	TFR = 3.528		TM = 6.877

and therefore: $C_m = \dfrac{3.528}{6.877} = 0.513$

The value of the age-specific marital fertility rate $g(a)$ for the age group 15–19 is estimated as $g(15\text{–}19) = 0.75 \times g(20\text{–}24)$, because the direct estimate $f(15\text{–}19)/m(15\text{–}19)$ tends to be unreliable, especially in populations with low values for $m(15\text{–}19)$.

Index of Contraception

$$C_c = 1 - 1.08 \times e \times u$$

where u is the prevalence of current contraceptive use (including male methods and sterilizing operations) among married women of reproductive age (15–49), e is the average use-effectiveness of contraception, and 1.08 is a sterility correction factor. Since estimates of contraceptive effectiveness are difficult to obtain and therefore rarely available, the following standard method-specific values (adapted from data from the Philippines[14]) are used in the calculation of average effectiveness levels in developing countries.

Method	Estimated use-effectiveness
Sterilization	1.0
IUD	0.95
Pill	0.90
Other	0.70

Effectiveness levels for the developed countries are based on US data[15]:

Method	Estimated use-effectiveness
Sterilization	1.00
Pill	0.99
IUD	0.97
Condom	0.94
Diaphragm	0.92
Foam/cream/jelly	0.91
Rhythm	0.87
Other	0.93

The sterility correction factor is estimated to be 1.08. In the version of the model published earlier (see note 6), this coefficient was estimated to equal 1.18 on the not quite accurate assumption that all contraceptive users are nonsterile. The new coefficient is calculated from the reported age-specific prevalence of sterility from a number of WFS surveys.[16]

For Sri Lanka, 1975, $u = 0.32$ and $e = 0.84$, so that $C_c = 1 - 1.08 \times 0.32 \times 0.84 = 0.710$.

Average use-effectiveness, e, is estimated as the weighted average of the method-specific use-effectiveness levels, $e(m)$, with the weights equal to the proportion of women using a given method, $u(m)$: $e = \Sigma\, e(m)\, u(m)/u$. For Sri Lanka, 1975:

Method	$u(m)$	$e(m)$
Pill	0.019	0.90
IUD	0.048	0.95
Sterilization	0.099	1.00
Other	0.154	(0.70)
	0.32	

so that $e = (0.019 \times 0.9 + 0.048 \times 0.95 + 0.099 \times 1.0 + 0.154 \times 0.7)/0.32 = 0.84$.

Index of Induced Abortion

$$C_a = \frac{\text{TFR}}{\text{TFR} + 0.4 \times (1+u) \times \text{TA}}$$

where TA equals the total abortion rate (including only abortions among married women).

Reliable statistics for induced abortions are not available in Sri Lanka. If induced abortion is assumed to be absent, $C_a = 1.0$.

Index of Postpartum Infecundability

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

where i is the mean duration of postpartum infecundability.

If a direct estimate of i is not available, it is possible to obtain an approximate value from the duration of breastfeeding, B, with the following equation[17]:

$$i = 1.753 \exp (0.1396 \times B - 0.001872 \times B^2)$$

In Sri Lanka the mean duration of breastfeeding was 21 months, yielding $i = 14.4$ months and

$$C_i = \frac{20}{18.5 + 14} = 0.608$$

References and Notes

This is a revised version of a paper originally prepared for the IUSSP and WFS Seminar on the Analysis of Maternity Histories, London, April 1980 (Proceedings forthcoming).

1 K. Davis and J. Blake, "Social structure and fertility: An analytic framework," *Economic Development and Cultural Change* 4, no. 4 (1956): 211.

2 *On the Measurement of Human Fertility: Selected Writings of Louis Henry*, translated by M. C. Sheps and E. Lapierre-Adamcyk (Amsterdam: Elsevier Publishing Company, 1972); M. C. Sheps and J. A. Menken, *Mathematical Models of Conception and Birth* (Chicago: University of Chicago Press, 1973); M. C. Sheps, "A review of models for population change," *Review of the International Statistical Institute* 39 (1971): 185; J. A. Menken, "Biometric models of fertility," *Social Forces* 54 (1975): 52; J. Bongaarts, "Intermediate fertility variables and marital fertility," *Population Studies* 30, no. 2 (1976): 227; J. Bongaarts, "A dynamic model of the reproductive process," *Population Studies* 31, no. 1 (1977): 59.

3 The term natural fertility is defined as fertility in the absence of deliberate parity-dependent birth control; see Louis Henry, "Some data on natural fertility," *Eugenics Quarterly* 8, no. 1 (1961): 81.

4 Bongaarts (1976), cited in note 2; J. Bongaarts and J. A. Menken, "The supply of children," in *Determinants of Fertility in Developing Countries: A Summary of Knowledge* (Washington, D.C.: National Academy of Sciences, forthcoming, 1982); J. Bongaarts, "Does malnutrition affect fecundity? A summary of evidence," *Science* 208 (9 May 1980): 564–569.

5 C. Wilson, "The components of natural fertility in historical Europe," paper prepared for the IUSSP and WFS Seminar on the Analysis of Maternity Histories, London, April 1980.

6 J. Bongaarts, "A framework for analyzing the proximate determinants of fertility," *Population and Development Review* 4, no. 1 (1978): 105–132. See also J. Bongaarts and R. G. Potter, *Behavior, Biology and Fertility Behavior: An Analysis of the Proximate Determinants* (New York: Academic Press, forthcoming).

7 See note 6.

8 An index of spousal separation has been proposed to quantify the effect of separation; see A. Hill and F. Shorter, "Intermediate variables in fertility analysis: A practical guide," Regional Paper of the Population Council in West Asia and North Africa, 1979.

9 This variable measures the reduction in the monthly probability of conception due to the use of contraception.

10 Sources of data for Table 2 are as follows.

For developing countries: estimates are taken from J. Bongaarts and S. Kirmeyer, "Estimating the impact of contraceptive prevalence on fertility: Aggregate and age specific versions of a model," in *The Role of Surveys in the Analysis of Family Planning Programs*, ed. A. Hermalin and B. Entwisle (Liège: Ordina, 1981), except Korea, which is based on Bongaarts, cited in note 6, with fertility estimates updated from L. Cho, "The demographic situation in the Republic of Korea," Papers of the East-West Population Institute, no. 29.

For developed countries: *Demographic Yearbook* 1969 and 1975 (New York: United Nations, Department of Economic and Social Affairs, 1970 and 1976); *Fertility and Family Planning in Europe around 1970*, Population Studies no. 58 (New York: United Nations, Department of Economic and Social Affairs, 1976) (total fertility rates do not include illegitimate births); C. Tietze, *Induced Abortion: 1979* (New York: The Population Council, 1979). Contraceptive prevalence data were inflated to include sterilizing operations for noncontraceptive reasons (in the European countries 3 percent was added for lack of direct estimates of the incidence of such operations).

For historical populations: German populations—J. Knodel, "Natural fertility in pre-industrial Germany," *Population Studies* 32, no. 3 (1978): 481; "Demographic transitions in German villages," paper prepared for the Summary Conference on European Fertility, Princeton, N. J., July 1979; "From natural fertility to family limitation: The onset of fertility transition in a sample of German villages," *Demography* 16, no. 4 (1979): 493; C. Wilson, cited in note 5. Mean duration of postpartum infecundability was estimated by subtracting the mean interval between marriage and first birth from the average birth interval among married women with two or more legitimate births; total fertility rates were estimated by multiplying the average number of children ever born per married woman in completed unions by 0.88, the approximate value of the proportion ever marrying among women. Other populations—H. Leridon, *Human Fertility: The Basic Components* (Chicago: University of Chicago Press, 1977). Mean duration of postpartum infecundability was estimated by subtracting the mean interval between marriage and first birth from the interval between the first and second birth, adding one month to correct for increasing durations of birth intervals with age. The estimate of postpartum infecundability among the Hutterites was taken from M. Sheps, "An analysis of reproductive patterns in an American isolate," *Population Studies* 19, no. 1 (1965): 65.

11 B. Ferry, "Breastfeeding," WFS Comparative Studies, no. 13, May 1980.

12 J. Bongaarts, "The proximate determinants of natural marital fertility," in *Determinants of Fertility in Developing Countries*, cited in note 4.

13 S. Watkins, "Regional patterns of nuptiality in Europe 1870–1960," *Population Studies* 35, no. 2 (1981): 199–216.

14 J. Laing, "Estimating the effects of contraceptive use on fertility," *Studies in Family Planning* 9, no. 6 (1978): 150. Laing gives the following effectiveness estimates for four methods in the Philippines: the pill, 0.949; the IUD, 0.963; rhythm, 0.798; and the condom, 0.616. Preliminary evidence from as yet unpublished studies in other developing countries indicates that the use-effectiveness of the pill is lower than in the Philippines. A possible explanation for this finding is that literacy levels in the Philippines are among the highest in the developing world. The average effectiveness levels in the developing world used in Appendix 1 are therefore estimated to be slightly lower than in the Philippines.

15 Bongaarts and Potter, cited in note 6.

16 D. Nortman, "Voluntary sterilization: Its demographic impact in relation to other contraceptive methods," Papers of the East-West Population Institute, no. 65, 1980.

17 See note 12.