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AGE, BIOLOGICAL FACTORS, AND SOCIOECONOMIC DETERMINANTS OF FERTILITY: NEW MEASURES OF CUMULATIVE FERTILITY FOR USE IN THE SOCIOECONOMIC ANALYSIS OF FAMILY SIZE

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ABSTRACT

To influence the number of children ever born to a woman, socioeconomic variables must operate through behavioral mechanisms such as the age at marriage, the level of fertility in the absence of deliberate fertility control, and the level of control exerted to reduce fertility within marriage. In this paper, we propose two new measures of cumulative fertility which are standardized for the age-fecundity relationship and for exposure to the risk of conception associated with marriage duration. These measures appear to be superior to children ever born in allowing more precise estimates of socioeconomic fertility relationships. A simple model of fertility behavior which incorporates some of the mechanisms through which socioeconomic factors may affect fertility is developed and applied to data from the Philippines and the United States to demonstrate the properties of these measures.

I. Introduction

To influence the number of children ever born to a women, social and economic variables must operate through behavioral and biological mechanisms such as exposure to intercourse, fecundity, use or nonuse of contraception, and others (Davis and Blake, 1956; Ryder, 1959; Yaukey, 1961; Easterlin, 1975; Freedman, 1975). All too often, however, the constraints on fertility emposed by these biological factors are ignored in both theoretical and empirical investigations of fertility determination. For example, in many economic models the demand for own children of a newly married couple is assumed to be influenced by variables such as education and the price of the woman's time and constrained by the level of potential income (Willis, 1973; DeTray, 1973), but no account is taken of the biological constraints on the supply of own children as part of the theoretical model. Few economic models of family size determination also explicitly integrate decisions regarding marriage. Thus,empirical tests of models of the determinants of marital fertility, which often consist of regressions of children ever born on social and economic variables, are difficult to interpret since the estimated coefficients in these studies reflect the influences of the independent variables on both age at marriage, which affects the length of exposure to the risk of childbearing, and marital fertility. Moreover, as we will show, attempts to control for exposure by including age, age at marriage, duration of marriage, or some combination of these variables in a linear regression with social and economic variables in almost all cases results in biased estimates of socioeconomic effects on the fertility measures often utilized.

The main purpose of this paper is to present two new standardized measures of cumulative marital fertility which incorporate some of these biological mechanisms. These new measures appear to allow sharper and less biased estimates of socioeconomic effects in empirical investigations of marital fertility than does the children ever born variable and are, in addition, relatively simple to compute.

In Section 2 we present a brief discussion of the shortcomings of the methods most often used for incorporating behavioral and biological variables in prior studies of fertility determinants. We define and interpret the new standardized fertility measures and present a preliminary analysis of measurement problems in Section 3. In Section 4, a simple model of fertility behavior is formulated in which social and economic variables affect age at marriage and the timing and level of fertility control within marriage. The model is used to show more precisely the relations between socioeconomic variables, age, marital duration, children ever born, and the new measures of cumulative marital fertility. In Section 5, the model is applied to data sets from two populations, the United States and the rural Philippines, characterized by very different levels of fertility control in order to compare estimates of the impact of various socioeconomic variables on the alternative measures of cumulative fertility. Estimates of the age at which married women begin to control fertility and the level of control in the U.S. population, obtained by non-linear estimation of an equation involving one of the measures, are presented in the final section.

The empirical results suggest that one of the standardized measures of cumulative fertility, which controls for exposure to the risk of childbearing within marriage and age patterns of fecundity, is superior to children ever born as a dependent variable for the statistical investigation of the influence of socioeconomic variables on marital fertility. The comparative analysis also indicates that examining the determinants of age at marriage and one of the standardized marital fertility variables separately would be much more informative than looking at the relationship between socioeconomic characteristics and children ever born.

II. Review of the Literature

A common method of examining the relation between cumulative fertility and social and economic variables is to regress children ever born on variables believed to be relevant to fertility determination. To take account of a woman's exposure to the risks of childbearing, variables such as age at marriage, duration of marriage, age, or some combination of these variables are included in the regression. Thus, for instance, Ben Porath (1973) includes age; Harman (1970) includes duration of marriage; Encarnación (1976) includes age at marriage, marriage duration and the square of marriage duration; and Kelley (1976) includes age but permits the intercept of the regression and the coefficient of age to vary by age group. While a rigorous analysis of the interrelations among these variables must be postponed until after the introduction of an explicit fertility model in Section 4, it is easily shown that the addition of such variables to a linear model is intuitively implausible. Consider, for example, the following linear regression model relating the number of children ever born to a woman (CEB), her education (EDW), and duration of marriage (DM):

(1) $$CEB = \alpha + \beta \ EDW + \gamma \ DM + \varepsilon,$$

where α, β, and γ are parameters to be estimated and ε is an error term. The model implies that an increase in education by one year changes the number of children ever born by the amount β regardless of the duration of marriage--one day, one year, or twenty years. Common sense tells us that the influence of education on children ever born is not independent of the duration of marriage, which affects exposure to the risk of childbearing. Indeed, in the 1965 U.S. National Fertility Survey, the number of children ever born to women aged 35 and over with 9 - 11 years of education exceeded the number of children ever born to women with more than 13 years of education by .36 for marital durations of 15-19 years, by .86 for durations of 20-24 years, and by .97 for durations of 25 or more years (Michael and Willis, 1976).

Another method of adjusting for biological factors is to stratify the sample on the basis of variables such as age or duration of marriage, and then to examine the relations between fertility and social and economic variables within each stratum. (There are, of course, other purposes for stratification, such as investigating the behavior of cohorts which have experienced similar events over their lifetime.) The problems with stratification are that the groups into which women are stratified are generally arbitrary and large samples are needed if the stratification is very fine in order to allow sufficient degrees of freedom. Reductions in sample size induced by stratification often lower greatly the precision of the estimates; hypothesis testing is thus almost impossible (See Harman, 1971 and Snyder, 1974).

A third strategy is to confine the examination to women who have completed childbearing. If the desired number of births were below the number a woman could have had in the absence of attempts to control fertility and if fertility control (i.e., contraception) were perfect, then the number of children-ever-born would be independent of age and duration of marriage. However, since the desired number of births exceeds reproductive capacity for some women and since fertility control is not perfect, there will still be variation in fertility associated with marriage duration. In addition, disadvantages of this procedure are: (1) the values of some of the variables which are important for fertility decisions are different at the survey date than they were at the time fertility decisions were made; (2) the findings of such studies are not always relevant for current fertility practices; and (3) in less developed countries reports of children ever born to women above age 45 are often inaccurate and the degree to which they are inaccurate may be correlated with factors expected to influence fertility (such as education).

III. Measures of Cumulative Marital Fertility

If the focus of theoretical models and empirical investigation is on factors determining cumulative marital fertility, a measure of fertility within marriage is required. Several alternative measures may be constructed which take into account demographic constraints on cumulated births. A simple one is children ever born per year of marriage, computed by dividing children ever born by the duration of marriage (Schultz, 1976). However, since fecundity varies by age, two women who have the same duration of marriage but were married at different ages will have had different numbers of births if neither is controlling fertility or if they are controlling at the same level.

A relatively simple method of adjusting additionally for the age-fecundity relation is to standardize duration of marriage by an age-specific natural fertility schedule. According to Louis Henry (1961), natural fertility is marital fertility in the absence of voluntary control. Voluntary control exists when couples modify their behavior affecting fertility as parity increases. Henry has found that age patterns of marital fertility in populations not practising voluntary control are quite similar, although the levels vary among populations (see also Trussell, 1977). Differences in levels depend upon such factors as the prevalence of breast feeding or social customs regarding the frequency of intercourse (Trussell, 1977). Of course, to the extent that breast feeding behavior and frequency of intercourse vary with parity, they are also methods of voluntary control (Caldwell, 1977; Caldwell and Caldwell, 1977).

One measure of cumulative marital fertility adjusted for both age at marriage and duration of marriage may be computed by dividing the number of children ever born to a woman by the number of children a woman would have had if she had reproduced according to a schedule of natural fertility from her date of marriage to the date of the survey. We call this measure the duration ratio or DRAT. Assuming that a woman was married once, is still married at the date of the survey and is aged a , then letting n(x) be natural fertility at age x, C(a) the number of children ever born, and m her age at marriage,

$$\text{DRAT}(a) = \frac{C(a)}{\int_m^a n(x)\,dx}$$

An alternative measure, which we call the duration difference or DDIF, may be constructed by subtracting the number of children the woman would have borne if she had reproduced at natural fertility rates from the number of children ever born. In terms of the above notation,

$$\text{DDIF}(a) = C(a) - \int_m^a n(x)\,dx.$$

Calculation of DRAT and DDIF requires the selection of a natural fertility schedule for standardizing the duration of marriage.

If the age schedule of natural fertility chosen correctly described the level of fecundity for an individual woman, DRAT would measure accurately the ratio of her actual to "potential" marital fertility and DDIF would measure the difference between actual and potential marital fertility. The schedule can be estimated for the population being studied (Coale and Trussell, 1974) or chosen from schedules which have been constructed for other populations. However, because the selected schedule may be inappropriate for the population being studied, and because there are variations in fecundity among women, the values of DRAT or DDIF calculated for an individual woman will measure imperfectly the ratio of her actual to potential marital fertility or the difference between her actual and potential marital fertility. We discuss the consequences of incorrect schedule choice and stochastic variation in fecundity for the specification and estimation of fertility functions in Sections 4 and 5.

Another reason, however, why the n(x) schedule may not accurately measure fecundity for an individual woman is that the n(x) schedule is estimated for a population. Because newly married women at age a are not representative of the population in terms of their risk of becoming pregnant, the value of $\int_m^a n(x)dx$ will not measure exactly their potential number of children. For example, because newly married women tend to have higher risks of becoming pregnant, $\int_m^a n(x)\,dx$ will be too small and the estimated values of DRAT and DDIF will be too large. As a practical matter, this problem is most serious for women who have been married for only a few years at the time of the survey. Coale, Hill, and Trussell (1975) report that in the absence of premarital conception, cumulated fertility of newly married women by the end of the third year of marriage is "virtually the same as if the average fertility of women long married had prevailed since the day of marriage" (p. 194). For this reason, we recommend that women who have been married, say, less than five years, be excluded from the sample when these standardized measures of cumulative marital fertility are used. Such a procedure, however, may introduce a strong selectivity bias for younger women (women aged 20 would have to have married at 15 to be included in the sample) so that the minimum age for inclusion should probably be set above the mean age at marriage in the population.

IV. A Simple Model of the Socioeconomic Determinants of Fertility

In this section, we present an analysis of the properties of children ever born (CEB), DRAT, and DDIF in the context of a model in which socioeconomic variables influence age at marriage and the level and timing of marital fertility. Although exceedingly simple, the model depicts the fundamental mechanisms through which fertility is affected and helps illustrate the problems of interpreting empirical research in which these cumulative fertility measures are employed. We initially consider the relationship between socioeconomic variables and fertility levels as depicted by the three measures for an individual women with a given n(x) schedule. We then examine these relationships in terms of fertility levels and variances in a population in which fecundity varies stochastically.

The first assumption of the model is that, in the absence of deliberate fertility control, a married woman would reproduce at each age at a rate of childbearing given by an appropriate natural fertility schedule $n(x)$. Second, the age at which a woman marries, m, is a function $m(X)$ of a set of social and economic variables X. Third, a woman can choose the date after marriage at which fertility control begins and the level at which fertility is controlled, where d is the duration of marriage after which fertility is reduced below natural fertility and ρ is the level of control (i.e., after control begins the annual fertility rate equals $(1-\rho) \cdot n(x)$). Both d and ρ are assumed to be functions $d(X)$ and $\rho(X)$ of a set of social and economic variables. For simplicity, we will assume that the vector of X's are identical in all functions, though this need not be the case. Finally, we assume that fecundity varies only with age and is not influenced by previous child-bearing experience or by the values of the X's. If fecundity is influenced by socioeconomic variables, then additional functions involving the X's need to be added to the model.

It should be noted that the model can be formulated in more conventional terms. Suppose that a woman does not control fertility immediately after marriage, that she desires a given number of children and that she begins controlling fertility as soon as the desired number of children is attained. If the age schedule of childbearing is relatively flat from the age at marriage until the age at which the desired number of children is attained, then there is a close correspondence between the desired number of children and the length of the period over which the woman does not practice fertility control. Factors affecting the desired number of children will influence the duration of the period without control, d. Likewise, the degree to which a woman controls fertility after this duration would be a function of, say, the factors which affect the costs and benefits of avoiding additional births; where methods of control might include contraception, abortion, or prolonged lactation. (See Barrett and Brass (1974) for an alternative model in which fertility control varies explicity with fertility experience but which does not incorporate socioeconomic variables).

In terms of the symbols defined above, the number of children ever born to a woman age a, C(a), can be written

(2) $$C(a) \text{ or } CEB(a) = \int_{m}^{m+d} n(x)dx + \int_{m+d}^{a} (1-\rho)\, n(x)dx$$

Letting N(a) be the cumulative of the natural fertility schedule to age a and carrying out the integration, we have

(3) $$CEB(a) = N(m+d) - N(m) + (1-\rho)\,[N(a) - N(m+d)]$$

This equation can be simplified to yield

(4) $$CEB(a) = N(a) - N(m) - \rho\,[N(a) - N(m+d)]$$

In this model, the relation between children ever born and the set of social and economic variables X is non-linear since N(m) and N(m+d), which are functions of X, are non-linear and the difference between N(a) and N(m+d) is multiplied by ρ, which is also a function of X.

Partial differentiation of (4) with respect to age,

$$(5) \quad \frac{\delta CEB(a)}{\delta a} = \frac{\delta N(a)}{\delta a} - \rho(X) \frac{\delta N(a)}{\delta a},$$

shows that age and children ever born are associated in a non-linear way, as is depicted in some studies of fertility using CEB as the fertility measure (Kelley, 1976). Equation (5), however, also indicates that the relationsh: between age and CEB depends on the level of fertility control, $\rho(X)$. Moreover, in contrast to the children ever born equations most often estimated, which are linear with respect to socioeconomic variables and which thereby constrain the partial derivatives of children ever born with respect to social or economic variables X to be constant, the partial derivatives of (4) with respect to X, given by (6), are highly non-linear in this simple model even if the socioeconomic variables influence behavioral and biological factors linearly:

$$(6) \quad \frac{\delta CEB(a)}{\delta X} = [\rho(X)-1] \frac{\delta N}{\delta m} m'(X) - [N(a)-N(m+d)] \rho'(X) + \rho(X) \frac{\delta N(m+d)}{\delta d} d'(X),$$

where $m'(X)$, $\rho'(X)$ and $d'(X)$ are the partial derivatives of $m(X)$, $\rho(X)$, and $d(X)$ with respect to a variable X, respectively. Indeed, expression (6) highlights not only the fact that the relations between socioeconomic variables and children ever born are age and duration-dependent, but also that these variables affect children ever born through their effects on age at marriage as well as through their effects on marital fertility.

In terms of the simple model of fertility, the relation between DDIF and the socioeconomic variables is given by

$$(7) \quad DDIF(a) = C(a) - [N(a)-N(m)] = -\rho \; [N(a) - N(m+d)]$$

The partial derivative of DDIF with respect to X,

$$(8) \qquad \frac{\delta DDIF(a)}{\delta X} = -\rho'(X)\ [N(a)-N(m+d)] + d'(X)\ \frac{\delta N(m+d)}{\delta d} + m'(X)\ \frac{\delta N(m)}{\delta m}\ \rho(X)$$

shows that, as for the CEB variable, the effects of the socioeconomic variables are influenced by age and duration and operate both through age at marriage and through the fertility control variables. However, in principle, equation (7) can be estimated if a suitable approximation to N(m+d) can be found and has the advantage of allowing direct estimates of the timing (m+d) as well as the level (ρ) of fertility control. Derivation and estimation of a DDIF equation is performed in Section 6.

Finally, to obtain the relation between DRAT and the socioeconomic variables, expression (4) can be rewritten to form

$$(9) \qquad DRAT(a) = \frac{C(a)}{N(a)-N(m)} = 1-\rho \left[\frac{N(a) - N(m+d)}{N(a)-N(m)}\right]$$

The partial derivative of (9) with respect to X,

$$(10) \qquad \frac{\delta DRAT}{\delta X}(a) = -\rho'(X) \left[\frac{N(a) - N(m+d)}{N(a)-N(m)}\right]$$

$$-\rho\ (X) \left[\frac{[N(a)-N(m+d)]m'(X) - [N(a)-N(m)][m'(X)+d'(X)]}{(N(a)-N(m))^2}\right],$$

shows that the relation between DRAT(a) and the socioeconomic variables is also age-dependent. However, in the special case in which women begin controlling fertility immediately after marriage, i.e., $d = o$, the bracketed expression in (9) and the first bracketed term in (10) equal one, while the second term in (10) vanishes, so that

$$(11) \qquad DRAT(a) = 1-\rho,$$

and

$$(12) \quad \frac{\delta DRAT(a)}{\delta X} = -\rho'(X)$$

Equation (12) shows that if fertility control is initiated soon after marriage begins DRAT can be used as a dependent variable representing cumulative marital fertility in a statistical analysis of the determinants family size without the need to approximate biological effects correlated with age by non-linear specifications or sample stratification. Moreover, the functional form of the DRAT equation will be identical to that determining the level of fertility control within marriage.

We have thus shown that even under the most simplifying assumptions regarding fertility control, the effects of socioeconomic variables on CEB are age-or duration-dependent while the use of DRAT minimizes the interactions between age and the set of X variables due to biological factors. However, it should be noted that because the age of a woman also identifies her birth cohort and her life-cycle stage, age may still play a role as a determinant of DRAT (as one of the X variables). The use of the standardized measures thus may also enable the separation of cohort and life-cycle from biological effects.

Consider now a population in which n(x) varies stochastically such that the natural fertility rate of a women i aged x is $\mu_i n(x)$, where μ_i is a random variable which is invariant with respect to age. If it can be assumed that the X's do not affect (are independent of) the μ_i, then all the relationships depicted in equations (5) through (12) will also hold on average for a population. However, the stochastic variation in all the fertility measures will depend on the levels of the socioeconomic variables. **The variance in the children ever born measure will in** addition be a function of marriage duration. To see this, note that, with d = o, for women aged a, married a-m years and controlling fertility at level $\bar{\rho}$ the variance in CEB is given by:

(13) $$\text{var (CEB)} = \sigma^2(\bar{\mu})\ (1-\bar{\rho})^2[N(a)-N(m)]^2$$

where $\sigma^2(\mu)$ is the stochastic variance in natural fertility

The variance in DRAT for the same group of women is:

(14) $$\text{var (DRAT)} = \sigma^2(\mu)\ (1-\bar{\rho})^2$$

As can be seen, the variances in both measures are negatively related to the degree of fertility control while the stochastic variance in children ever born, given the level of control, is in addition a positive function of the number of years of exposure to the risk of childbearing (marital duration). The relation between stochastic variation and duration is obviously not eliminated by age stratification when using the CEB measure. The consequences of the association between the magnitude of the stochastic variance and the values of socioeconomic variables, i.e., heteroscedasticity, for the estimation of fertility models and a method for their elimination using the DRAT measure are discussed in the next section.

V. Estimation of Socioeconomic Effects with DRAT

a. Some Econometric Issues

As was shown above, the use of DRAT as a measure of cumulative fertility results in a parsimonious specification of the relation between marital fertility and socioeconomic variables and minimizes (but does not eliminate) heteroscedasticity if it can be assumed that d=0 in the sample population. The exact specification of DRAT as a function of a set of socioeconomic variables to be applied to data, however, depends on the assumptions made concerning the level of the natural fertility schedule chosen, the nature of the stochastic variation in the specified parameters (including fecundity), and the hypothesized characteristics of the ρ (X) function. To clarify these issues and to provide empirical examples of the use and advantages of the DRAT measure, we derive and apply some estimable functions of DRAT based on the model formulated in Section 4.

Suppose that n(x) is the natural fertility schedule chosen to construct the standardized measures but that the true schedule is $k \cdot n(x)$, a constant proportion of the chosen schedule at each age. If we let $DRAT_{ti}$ be the true value of the duration ratio for the ith woman and $DRAT_{ei}$ be the measured value, then $DRAT_{ei} = k \cdot DRAT_{ti}$. If we then assume that (i) ρ is a linear function of a vector of X_j exogenous socioeconomic variables such that

$$(15) \quad \rho_i = \gamma_o + \sum_j \gamma_j X_{ij} + v_i$$

where v_i is an error term, (ii) k is the (unknown) multiplicative correction factor for the level of natural fertility in the population, (iii) DRAT varies stochastically in the population according to an <u>additive</u> error term ε_i which is uncorrelated with the X_{ij} variables; then, if d=o, from (11):

$$(16) \qquad DRAT_{ei} = k\cdot(1-\rho_i) + k\varepsilon_{ji} = k(1-\gamma_o) - k\sum_j \gamma_j X_{ij} + (v_i k + k\varepsilon_i)$$

DRAT is thus a linear function of the X variables, and can be estimated for a population of married women of all ages. While the unknown k is imbedded in all the coefficients, so that they reflect both the true behavioral responses to changes in the values of the X_i's, and k, the correlations between the set of X_i variables and DRAT are unaffected since k is a constant. Thus, for tests of most hypotheses regarding fertility determinants, the confounding of k with the behavioral responses to the socioeconomic variables is irrelevant. Only if the hypotheses relate to specific magnitudes of the coefficients or if comparisons of coefficients across populations having (unmeasured) differences in the level of natural fertility are to be made is the precise estimate of k important.

Alternatively, if it is assumed as in section 4 that the level of fecundity (n(x)), rather than DRAT, varies stochastically in the population according to a multiplicative random error term μ_i, which implies an age-independent random error for the age-specific rates, then with the above assumptions

$$(17) \qquad DRAT_{ei} = k\cdot\mu_i(1-\rho_i) = k\mu_i(1-\gamma_o) - \mu_i \Sigma k\gamma_j X_{ij} - v_i k\mu_i \,.$$

It can be shown that OLS estimation of (17) would result in consistent, although not efficient, estimates of the $k\gamma_j$. Equation (17) would also be characterized by heteroscedasticity, as shown in (14), so that the estimated standard errors of the coefficients would be biased. Some generalized least squares estimation procedure may thus be required to estimate such a relation (as would also be true for equations with CEB). However, if $1-\rho$ is written as an exponential function of the X_j, i.e.,

(18) $$1-\rho_i = e^{\gamma_o + \sum_j \gamma_j X_{ij} + v_i}$$

then

(19) $$DRAT_{ei} = k\mu_i \left(e^{\gamma_o + \sum_j \gamma_j X_{ij} + v_i} \right)$$

which is intrinsically linear, since

(20) $$\ln DRAT_{ei} = (\ln k + \gamma_o) + \Sigma\gamma_j X_{ij} + (\ln \mu_i + v_i)$$

Equation (20) is not only linear and thus easy to estimate, but purges the parameter representing the unknown population level of natural fertility from the estimated γ coefficients and impounds the stochastic variation in fecundity in the additive error term. Thus (20) is homoscedastic and provides unbiased estimates of the effects of socioeconomic characteristics on fertility control within marriage for a population heterogeneous with respect to fecundity and age which are also comparable across populations with different overall levels of natural fertility.

Ordinary least squares estimation of equations such as (17) or (20) may not be desirable, however, even if heteroscedasticity were not a problem. Structural equation estimation techniques, for example, would be required to obtain consistent estimates of the γ_j if any one X_j is correlated with either μ_i or v_i or both. For instance, it has been suggested that in populations characterized by pre-marital sexual activity, more fecund women will tend to marry earlier and thus curtail their schooling. In such a biologically heterogeneous population, due to this selectivity, more educated women will also be less fecund on average, i.e. female education and μ will be negatively correlated resulting in a negative correlation between DRAT (or CEB) and female educational attainment even if education does not affect any individual's fecundity. Moreover, if women who want large families obtain less schooling, female education and v will be negatively correlated and inconsistent estimates of the γ_j will be obtained using ordinary least squares, even if fecundity does not vary in the population. Such considerations, involving the effects of unmeasured behavioral and biological factors, are of course relevant to all studies of the determinants of fertility, no matter what measure is employed. For the purpose here, therefore, we do not explore these important aspects of estimation.

b. Estimates

To assess the usefulness of DRAT in comparison to CEB as a cumulative fertility measure for use in studies of the determinants of family size and to evaluate the sensitivity of empirical estimates to the violation of the assumptions underlying the use of DRAT, we apply these models to micro data sets from two countries--the United States and the Philippines--which are comparable in sample size and the scope of information on socioeconomic variables and fertility. Specifically, we test three hypotheses. The first hypothesis is that the effects of the socioeconomic variables on children ever born are significantly age-dependent while these interactions are absent when the duration ratio is used in place of CEB as the dependent variable. Formally, we estimate the coefficients of equations (21), (22), and (23)

$$(21) \qquad F = \alpha_o + \alpha_a AGEW + \sum_j \alpha_j X_j + e_i$$

$$(22) \qquad F = \alpha_o + \alpha_a AGEW + \sum_j \alpha_j X_j + \sum_{t=1}^{2} [\gamma_t \cdot D_t + \gamma_{at}(AGEW \cdot D_t)] + e_i$$

$$(23) \qquad F = \alpha_o + \alpha_a AGEW + \sum_j \alpha_j X_j + \sum_{t=1}^{2} [\gamma_t \cdot D_t + (\gamma_{at} AGEW + \sum_j \gamma_{jt} X_j) \cdot D_t] + e_i ,$$

where F = CEB, DRAT, ln#DRAT, AGEW is the age of the woman; and

$D_1 = 1$ if $28 \le AGEW < 35$ $\qquad D_2 = 0$ if $28 \le AGEW < 35$

$D_1 = 0$ if $35 \le AGEW < 45$ $\qquad D_2 = 1$ if $35 \le AGEW < 45$

and test the hypothesis, using all measures, that $\gamma_t = \gamma_{at} = \gamma_{jt} = 0$. With F = CEB we would expect to reject this hypothesis; with F = DRAT we should not be able to reject the hypothesis. Testing the significance of the intercept and slope dummies is equivalent to examining the hypothesis that stratification of the sample into three age groups is warranted; i.e., that the functions differ by age. Such stratification should not be necessary for DRAT.

The wife's age coefficient in the children ever born equation, as we have noted, represents not only the accumulation of children with age (or marital duration) but cohort effects and age patterns of fertility control. Because of the overwhelming importance of the first (positive) biological relationship, we would expect that the coefficient of AGEW in the CEB equation would be positive. However, in the equation in which DRAT, which is standardized for the biological age pattern of fertility is the dependent variable, the coefficient of AGEW will reflect cohort and life cycle patterns.

The second hypothesis we test is that the violation of the assumption that $d = o$ does not appreciably alter the results of the tests formulated above. We thus estimate equations (21), (22), and (23) on the two populations, each characterized by very different average levels of d.

The third hypothesis examined concerns the sensitivity of the DRAT results to the assumptions concerning the error pattern characterizing the level of fecundity within a population and the possible presence of heteroscedasticity. This is accomplished by comparing the results obtained with DRAT and those with ln DRAT as the dependent variable.

i. Results - DRAT, U.S.

We first apply the three CEB and DRAT specifications to a sample of white, spouse present, non-farm women in their first marriage, married for at least five years and aged 20 to 45, taken from the 1970 National Fertility Survey, fully described in Ryder and Westoff, (1977). This population is characterized by a high degree of fertility control and early initiation of contraception: Rindfuss and Westoff (1974) report that of all women 20-24 in the survey who had had a first pregnancy, 67 percent had used contraceptives prior to that first pregnancy (71 percent of non-Catholics). Moreover, of those 20-29 and married from 5 to 9 years, only 11 percent had never used contraceptives. Our sub-sample of non-farm white women is likely to be characterized by even earlier use of fertility control than is true of the sample as a whole. In Section 6 we present estimates of the mean age of contraceptive initiation which also indicate early control.

The DRAT measure was computed using the cumulated single-year natural fertility schedule constructed by Coale and Trussell (1974) from 13 non-controlling populations. On average the duration ratio for the U.S. sample women is .53. The exogenous X variables chosen as determinants of the level of contraception, equation (15), listed in Table 1, are not based on any particular theoretical model of behavior but are instead meant to be representative of the principal explanatory variables used in prior studies of fertility. Included are the educational attainment and the educational attainment squared of the wife (EDW, EDWSQ), the educational attainment of the husband (EDH), and the natural log of the husband's permanent income (LNINCH), obtained from an auxiliary regression equation in which the log of the husband's earnings was regressed against his schooling level, age, age squared, the Duncan occupational index corresponding to the husband's occupation, community size, and farm background. Because of the variation in the age of the husbands in the sample, the predicted value of LNINCH was computed with AGEH set at 40 to make the permanent (or expected) income variable comparable for all women. In addition to these regressors there is a dummy variable taking on the value of 1 if the wife is Catholic and 0 if she is not. The first two columns in Table 1 provide the means and standard deviations for all the variables in the U.S. sample.

Table 2 reports the coefficients and associated standard errors obtained for each of the three regression specifications using CEB and DRAT as dependent variables. The first column contains the most naive linear specification for children ever born in which neither the non-linear relationships between age and CEB nor the age interactions are represented. Not surprisingly, the regressor with the most explanatory power is the wife's age, although expected income, husband's education and religion have significant effects. In the second CEB specification, which takes into account direct non-linear age effects, only the age variable coefficients and the coefficient of the dummy variable for religion are statistically significant. This equation would thus lead researchers unaware of the full complexity of the interactions between biological and behavioral factors to accept the hypothesis that socioeconomic variables other than religion do not have any effect on cumulative fertility. The third interactive specification, however, not only reveals that the predicted age-interactions are significant--the set of interaction terms add significantly to the explanatory power of the equation (F-test, 5 percent level)--but indicates that the husband's schooling attainment is at least one significant 'socioeconomic' determinant of children ever born. The third specification, which most closely approximates biological-behavioral interactions, also illustrates the problems engendered by the inherent non-linearity of the CEB specification. Because of the high degree of collinearity between the interaction variables, the statistical significance and the quantitative impact of the individual socioeconomic variables cannot be ascertained.

Table 1. Means and Standard Deviations, Married Women Aged 20-44 with Marital Duration Greater than 5 Years.

	United States - White (1970)[a]		Philippines - Rural (1973)[b]	
	Mean	Standard Deviation	Mean	Standard Deviation
CEB	2.74	1.56	5.43	2.70
DRAT	.53	.30	.91	.33
EDW	12.28	2.15	4.45	2.88
EDH	12.75	2.81	4.45	3.04
AGEW	33.93	6.24	33.80	6.44
AGEH	--	--	37.61	7.95
LNINCH	9.07	.18	-.09	.21
SURV5	--	--	.93	.10
CATH	.26	.44	--	--
n	2623		1632	

[a]Source: 1970 National Fertility Survey

[b]Source: 1973 National Demographic Survey of the Philippines

Table 2. Coefficients of CEB and DRAT Regressions: United States, 1970[a]

Dependent Variable = / Independent Variables	CEB	CEB	CEB	DRAT	DRAT	DRAT
Constant	-4.343	.557	2.475	2.784	2.618	3.116
AGEW	0.050*	.149*	.174*	-.014*	-.011*	-.005
	(.006)	(.028)	(.031)	(.001)	(.005)	(.006)
EDW	-.137	-.147	-.045	-.049*	-.049*	-.100*
	(.091)	(.091)	(.041)	(.017)	(.017)	(.035)
EDWSQ	.001	.002	.008	.002*	.002*	.003*
	(.004)	(.004)	(.007)	(.001)	(.001)	(.001)
EDH	-.050*	-.010	-.373*	.013*	.012*	.006
	(.022)	(.023)	(.182)	(.004)	(.004)	(.008)
LNINCH	.815*	-.079	-.111	-.180*	-.171*	-.188
	(.347)	(.374)	(.629)	(.066)	(.071)	(.120)
CATH	.477*	.470*	.209	.136*	.136*	.111*
	(.066)	(.133)	(.123)	(.013)	(.013)	(.023)
D1		2.111*	3.765		.079	-.036
		(1.005)	(7.536)		(.192)	(1.437)
D2		6.092*	-.820		.073	-1.237
		(1.228)	(7.604)		(.234)	(1.450)
AGEW·D1		-.074*	-.093*		-.003	-.008
		(.034)	(.038)		(.007)	(.007)
AGEW·D2		-.180*	-.203*		-.003	-.008
		(.036)	(.038)		(.007)	(.007)
EDW·D1			.367			.070
			(.249)			(.047)
EDW·D2			.282			.075
			(.228)			(.043)
EDWSQ·D1			-.011			-.002
			(.010)			(.002)
EDWSQ·D2			-.007			-.002
			(.009)			(.002)
EDH·D1			.066			.011
			(.057)			(.011)
EDH·D2			.019			.005
			(.056)			(.011)
LNINCH·D1			-.534			-.051
			(.915)			(.175)
LNINCH·D2			.521			.086
			(.902)			(.172)
CATH·D1			.287*			.035
			(.162)			(.031)
CATH·D2			.448*			.035
			(.168)			(.032)
S.E.E.	1.482	1.472	1.467	.280	.281	.280
$\bar{R}^2$	.096	.108	0.115	.149	.148	.153

[a]An asterisk indicates that the coefficient is statistically different from zero at the .05 level (two-tail test).

In contrast to the CEB equations, the estimated coefficients of the linear DRAT equation (17), indicate that all the socioeconomic variables, including wife's schooling, are statistically significant determinants of (marital) fertility. Moreover, the results are unaltered when the non-linear age terms, none of which are statistically significant, are added and, as expected, the full set of age interactions doe not add significantly to the explanatory power of the DRAT equation. Thus the linear duration ratio specification appears to be the most acceptable, consistent with the hypothesis that the use of DRAT as a measure of cumulative martial fertility minimizes the non-linear biological age relationships in the "behavioral" variable effects in a population characterized by early fertility control.

While the substantive results on U.S. fertility are not the focus of these empirical exercises, one difference in the results obtained using the DRAT and CEB measures is worth noting--the different signs obtained for the coefficients of permanent income and husband's schooling in the linear specifications. These differences may be due to both the mis-specification of the (linear) CEB equation and to the fact that the coefficients in children ever born regressions pick up the effects of the socioeconomic variables on both age at marriage and on marital fertility. For example, husband's expected income in the sample is correlated negatively with wife's age at marriage and, from the DRAT equation, negatively with marital fertility--the net effect of LNINCH on CEB, even when correctly specified, is thus ambiguous a priori (but appears to be positive). While it would appear that this ambiguity could be resolved if age at marriage were entered in the CEB equation, simply adding age at marriage to the set of X_j's would introduce simultaneous equations bias in all the resulting coefficient estimates since age at marriage is likely to be correlated with fecundity or fertility goals. Moreover, the use of standard simultaneous equations estimation techniques would not solve this latter problem because, as indicated in equation (6), age at marriage should be interacted with all the socioeconomic variables, creating a highly complex, non-linear system whose econometric properties are not known.

It would thus appear that the best means of obtaining estimates of the relationship between socioeconomic variables and cumulative fertility would be by separately examining the determinants of age at marriage and fertility conditional on marriage, using a standardized measure of marital fertility such as DRAT. The interactions between age at marriage and marital fertility are considered more fully in Boulier and Rosenzweig (1978), based on Philippines data.

ii. Results--DRAT, Philippines

To ascertain if the results of the tests performed on the U.S. data are sensitive to the assumption of early fertility control, we ran similar regressions on a sample of rural Filippino women from the 1973 National

Demographic Survey of the Philippines selected according to the same criteria as for the U.S. sample (apart from race and farm residence). Marital status categories in this population are similar to those in the United States but the Filippino population is characterized by both a relatively late starting age, and a low level, of fertility control; based on the same cumulative natural fertility schedule as used in the U.S. sample, the average value of DRAT for the Filippino women is .91.

The set of socioeconomic variables employed is similar to that used in the previous regressions. Religion is excluded, however, and the age of the husband (AGEM) and the provincial probability of survival from birth to exact age five (SURV5) are included. The survival probability estimates are based upon 1970 census questions on the number of children ever born and the number of children surviving to women ages 20 to 24 and 25 to 29 respectively (Coale and Demeny, 1966; Trussell, 1975). The natural logarithm of the expected income of the husband was computed from a regression containing as explanatory variables, the husband's age, age squared, schooling attainment, farm or non-farm residence, the schooling level of the father of the husband, and an occupational skill index. Means and standard deviations of the variables for the Philippines sample are given in Table 1.

The six CEB and DRAT regressions applied to the Philippines sample are reported in Table 3. The results of the tests for age effects are

Table 3. Coefficients of CEB and DRAT REgressions: Rural Philippines, 1973[a]

Independent Variables	CEB	CEB	CEB	DRAT	DRAT	DRAT
Constant	3.525	2.997	-.035	1.734	2.099	1.927
AGEW	.155*	.154*	.156*	-.001	.004	-.018*
	(.014)	(.045)	(.045)	(.002)	(.008)	(.007)
AGEH	-.013	-.009	-.030	-.010*	.005	-.004
	(.021)	(.021)	(.045)	(.003)	(.004)	(.006)
EDW	.078	.074	-.015	-.002	-.002	-.007
	(.049)	(.049)	(.103)	(.007)	(.007)	(.015)
EDWSQ	-.012*	-.012*	-.005	.000	.000	.001
	(.004)	(.004)	(.008)	(.001)	(.001)	(.001)
EDH	-.577*	-.551*	-.206	-.049*	-.053*	-.043
	(.152)	(.152)	(.274)	(.022)	(.022)	(.039)
LNINCH	8.298*	7.848*	3.151	.771*	.819*	.622
	(2.227)	(2.225)	(3.983)	(.317)	(.318)	(.568)
SURV5	.481	.541	.305	-.144	-.139	-.116
	(.580)	(.581)	(2.291)	(.083)	(.083)	(.327)
D1		.807	1.541		-.024	-.310
		(1.738)	(4.902)		(.248)	(.699)
D2		2.288*	6.259*		-.097	.222
		(1.044)	(2.654)		(.149)	(.379)
AGEW·D1		-.011	-.036		.004	.005
		(.059)	(.065)		(.008)	(.009)
AGEW·D2		-.054*	-.043		.005	.010*
		(.031)	(.034)		(.004)	(.005)
AGEH·D1			.015			.002
			(.056)			(.008
AGEH·D2			-.063*			-.009*
			(.029)			(.004)
EDW·D1			.159			.017
			(.130)			(.018)
EDW·D2			.038			-.001
			(.065)			(.009)
EDWSQ·D1			-.012			-.001
			(.010)			(.001)
EDWSQ·D2			-.002			.000
			(.005)			(.001)
EDH·D1			-.141			.027
			(.366)			(.052)
EDH·D2			-.457*			-.022
			(.199)			(.028)
LNINCH·D1			1.567			-.343
			(5.364)			(.765)
LNINCH·D2			6.422*			.365
			(2.909)			(.415)
SURV5·D1			-.076			-.012
			(2.401)			(.343)
SURV5·D2			.482			-.042
			(1.272)			(.182)
S.E.	2.304	2.295	2.294	.328	.328	.329
$\bar{R}^2$	.269	.275	.276	.014	.017	.012

[a]An asterisk indicates that a coefficient is statistically significant from zero at the .05 level (two-tailed test).

similar to those obtained on U.S. data; as before, the non-linear age and age-interaction terms add significantly to the explanatory power of the children ever born regression but do not permit reliable inferences regarding the effects of the individual socioeconomic variables because of severe multicollinearity. Simliarly, in linear regressions with CEB stratified into the three age groups (not reported), only one of the coefficients (the wife's schooling) achieves statistical significance. In contrast the linear duration ratio equation suggests that expected income and husband's education are significant determinants of marital fertility and again comes out best despite violation of the assumption that d is close to zero. Thus the use of DRAT rather than children ever born appears to reduce significantly the contamination of socioeconomic parameter estimates by age-related biological constraints when either data from developing countries or from populations where contraception is initiated early are used.

While a detailed discussion of the substantive results beyond those obtained relating to the tests for age interactions falls outside the scope of this paper, the joint examination of the determinants of DRAT and CEB suggests that socioeconomic differences explain a much greater part of the variation in age at marriage than of fertility control within marriage in the Philippines--the (adjusted) R^2 for the CEB equations, which combine age at marriage and marital fertility effects, is 16 times greater than that for the DRAT regressions, which "explain" only fertility control within marriage. In the U.S. sample, however, a similar set of socioeconomic variables explained a higher proportion of the of the variance in marital fertility control than of children ever born. This suggests not only that the variance of the latter is greater than that of the duration ratio, since DRAT is conditional on marriage, but that socioeconomic variables are highly correlated with fertility control in a developed country, much less so in a setting such as the rural Philippines, where age at marriage effects dominate. The Philippines results using both DRAT and CEB also suggest that the (negative) effect of female schooling on fertility appears to operate solely through age at marriage and not through fertility control within marriage, while the husband's schooling level appears to depress marital fertility.

iii. Results--LNDRAT, U.S., Philippines

Table 4 displays the coefficients obtained using LNDRAT as the dependent variable for the two samples. As can be seen, the qualitative results of the equations in which a different error structure and a non-linear underlying fertility control specification are assumed (equation (18) do not differ from those obtained for DRAT (Tables 2 and 3)--the size and significance levels of the coefficients of the socioeconomic variables obtained from the same data are identical, with the exception of that for the coefficient of L NINCH in the U.S. sample, which is slightly less significant. Thus, results obtained using DRAT do not appear to be sensitive to this transformation of the underlying model. Researchers should, however, be advised to apply the relevant statistical procedures (Box and Cox, 1964) to test whether the DRAT or LNDRAT specifications best fit the data they are using.

TABLE 4: Coefficients of LNDRAT Regressions: United States 1970, Philippines 1973[a]

Independent Variables	United States[b]			Philippines - Rural[c]	
Constant	2.486	1.871	Constant	.829	1.137
AGEW	-.031*	-.026*	AGEW	-.002	-.014
	(.002)	(.009)		(.002)	(.008)
EDW	-.090*	-.090*	EDW	-.002	-.002
	(.030)	(.030)		(.009)	(.009)
EDWSQ	.004*	.004*	EDWSQ	.003	.0003
	(.001)	(.001)		(.006)	(.006)
EDH	.019*	.016*	EDH	-.053*	-.056*
	(.007)	(.008)		(.026)	(.027)
LNINCH	-.212	-.151	LNINCH	.810*	.854*
	(.114)	(.124)		(.392)	(.394)
CATH	.235*	.235*	SURV5	-.188	-.187
	(.022)	(.022)		(.102)	(.102)
D1		.068	AGEH	-.011*	-.011*
		(.333)		(.004)	(.004)
D2		-.500	D1		.041
		(.047)			(.308)
AGEW·D1		.001	D2		-.010
		(.011)			(.185)
AGEW·D2		.010	AGEW·D1		.002
		(.012)			(.010)
			AGEW·D2		.003
					(.005)
S.E.E.	.488	.488	S.E.E.	.40[illegible]	.406
$\bar{R}^2$	.176	.176	$\bar{R}^2$	.015	.015

[a]An asterisk indicates that a coefficient is statistically significant from zero at the .05 level (two-tail test)

[b]Source: 1970 National Fertility Survey

[c]Source: 1973 National Demographic Survey

VI. Empirical Application - DDIF

As we have shown, the use of DRAT in linear form requires the assumption that fertility control begins at (or prior to) the onset of marriage. Although departures from this assumption do not appear to alter significantly the usefulness of the DRAT measures in standardizing for age and duration effects, the estimated values of the level of control (1 - DRAT) implied by a duration-ratio equation do not represent the actual level of control exerted after contraception is initiated but are instead averages over the control and non-control years. While the difference between the actual level of contraception when in use and the DRAT estimates will be small when d is close to m, the time at which control begins is a parameter of interest in its own right as it is an important determinant of the rate of population growth. (Ryder, 1960; Coale and Tye, 1961, Rindfuss and Westoff, 1974). We will now show that the use of the duration difference measure of fertility, DDIF, makes it possible to estimate the age at which fertility control begins and the average level of contraceptive efficiency when contraception is practiced for married women, based only on information on actual cumulative fertility and socioeconomic characteristics.

For simplicity, we will again assume the model of fertility control formulated in Section 4, but also assume that the level of natural fertility in the population is known. Note that the choice of an incorrect level for the n(x) schedule is more critical in the case of DDIF. Let $DDIF_{ti}$ and $DDIF_{ei}$ be the true and estimated values of the duration differences for the ith woman, respectively, then

$$DDIF_{ei} - DDIF_{ti} = (1-k) \int_m^a n(x)\, dx.$$

where k is again the ratio of the true schedule to the one selected for computation.

In this case the magnitude of the measurement error in DDIF depends upon k, the age at marriage m, the duration of marriage (a-m), and the values of the n(x) schedule over the relevant range. It is thus unlikely that unbiased estimates of the effects of socioeconomic variables on fertility can be obtained with DDIF when the measurement error is of this type. It can be shown, however, that if the error in schedule choice is one in which the level of cumulative natural fertility chosen to construct the standardized fertility measures differs from the true cumulative schedules by an additive constant k, unbiased estimates can be obtained, although such an error specification is implausible since this assumption implies that the difference between the true and imposed natural fertility rates declines with age. With n(x) known and equal for all women and letting $\hat{a}(=m+d)$ be the age at which a married woman begins fertility control, then for a married woman for whom $a \geq \hat{a}$, from (7)

$$(24) \quad DDIF(a)_i = -\rho_i[N(a) - N(\hat{a})] + \varepsilon_i,$$

where ε is a stochastic error term with zero mean and constant variance, while DDIF = 0, on average, for married women who have not yet initiated contraception (i.e., $a < \hat{a}$).

In a heterogeneous sample of married women with a proportion R of contraceptors, the average difference between actual and predicted cumulative fertility for women based on the natural fertility schedule ($\overline{DDIF}$) is given by

$$(25) \quad \overline{DDIF} = -R\rho\ [N(a)-N(\hat{a})] + \varepsilon.$$

If the probability r_i that a woman is controlling fertility at any age is determined by

(26) $r_i = a_o + \sum_j a_j X_{ij}$

where the X_j are socioeconomic variables, and ρ is determined by quation (15), then

(27) $DDIF(a)_i = (a_o + \sum_j a_j X_{ij})\ (\gamma_o + \sum_j \gamma_i X_{ij})\ [N(a) - N(\hat{a})] + t_i$

As can be seen, equation (27) contains a large number of parameters and the non-linear $N(\hat{a})$ function and thus would be extremely difficult to estimate. However, for a sample of women who have (essentially) completed their fertility, i.e., for whom $a \geq 45$, $r_i = R = 1$ and $N(a)$ is a constant, equal to the completed family size of non-contracepting women (11.67 in the Coale-Trussell schedule). Moreover, the cumulative natural fertility schedule can be closely approximated with a small number of parameters. We fit a logarithmic reciprocal function, (28), to the single-year cumulative schedule

(28) $N(a) = e^{b_o - b_1 a^{-1} + e}$ $\qquad a = 20 \ldots 45$

used to construct DRAT in the previous sections and obtained a good estimate of $N(a)$, or $N(\hat{a})$ if $\hat{a}$ is known:

(29) $\ln N(\hat{a}) = \underset{(.0277)}{3.6575} - \underset{(.8261)}{50.5366}\ \hat{a}^{-1}$ $\qquad R^2 = .994,\ n = 26$

(standard errors in parentheses) S.E.E = .034

Thus, if the $\hat{a}$ function is of the form

(30) $\hat{a}_i = c_o + \sum_j c_j X_{ij}$

then by substitution of (30) into (29) and (29) into (27), we obtain

(31) $DDIF_i = -(\gamma_o + \sum_j \gamma_j X_{ij})\ [11.67 - \exp(3.6576-50.5366[c_o + \sum_j c_j X_{ij}]^{-1})] + \varepsilon_i$

Estimation of (31), with non-linear methods, provides estimates of the determinants as well as predictions of the age at which control was initiated and the determinants and the level of control for women beginning control at $\hat{a}$ and who have completed their fertility.

To test the applicability of equation (31) in a preliminary way and to obtain additional evidence of the early initiation of contraception in the U.S. population assumed in Section 5, we estimate (31) on a sample of married women aged 45-54 from the 1965 National Fertility Survey. These women were selected according to the same criteria as were used to create the sample of women from the 1970 U.S. data, so that the sample is again restricted to women with single, intact marriages (spouse present) to insure that we are estimating the parameters associated with voluntary control of fertility within marriage. The number of parameters to be estimated are limited to 10 by employing only four variables as determinants of $\hat{a}$ and ρ --EDW, EDH, LNINCH, and CATH--in order to maintain computer expenses at a reasonable level. Table 5 displays the means and standard deviations of these variables and three fertility measures, CEB, DRAT and DDIF for the sample women.

Reported in Table 6 are the results of linear OLS regressions utilizing DRAT and CEB and the coefficients of $1-\rho$ and $\hat{a}$ from equation (31) estimated by applying a non-linear maximum likelihood (NLML) technique--a modified version of quadratic hill climbing (Goldfeld and Quandt, 1972). While the standard errors of the non-linear DDIF regression coefficients are large, and the magnitudes of the individual coefficients are not robust with respect to the initial values chosen, the <u>signs</u> of the coefficients of the control

(1-ρ) equation are identical to those indicated by the duration ratio and children ever born equations and are invariant with respect to the starting points. All specifications indicate that the schooling of the wife and husband's income are positively correlated with the level of fertility control (i.e. the extent to which fertility is depressed below natural fertility), while being Catholic is associated negatively with control. Moreover, the predicted value of â, the age at which fertility begins to fall systematically below natural rates, with the coefficients other than the intercept term considered to be zero in the â equation, is approximately 25 years of age. With the mean age at marriage in the sample of 22.3 years, this estimate is consistent with early control, suggesting an average d of less than 3 years.

The predicted values of ρ, conditional on â, also appear reasonable. Table 7 provides the computed levels of contraceptive control, evaluated at the sample means, for Catholic and non-Catholic women and with â = 22 (â = m) and â = 25 (the value predicted by the duration difference equation).

Table 5. Means and Standard Deviations, Married Women Aged 45-54 United States, 1965[a]

Variable	Mean	Standard Deviation
CEB	2.61	1.80
DRAT	.34	.23
DDIF	5.13	2.23
EDW	11.28	2.75
EDH	11.20	3.22
LNINCH	8.65	.29
CATH	.26	.44
n	363	

[a]Source: 1965 National Fertility Survey

TABLE 6: Coefficients of CEB, DRAT and DDIF Regressions: Married Women, 45-54, U.S. 1965[a]

Dependent Var. =	CEB	DRAT	$1 - \rho$[b]	a[b]
Independent Variables				
Constant	14.420	1.886	-30.200 (53.817)	25.032 (17.850)
EDW	-.113* (.047)	-.014* (.006)	-.100 (.206)	.056 (1.116)
EDH	.020 (.073)	.011 (.010)	.059 (.190)	.055 (1.133)
LNINCH	-1.249* (.787)	-.176 (.104)	-4.297 (7.231)	1.484 (2.561)
CATH	.191 (.210)	.062* (.027)	1.161 (2.004)	.060 (.410)
S.E.E.	1.709	.227		
$\bar{R}^2$	.098	.065		
Est. Technique	OLS	OLS	NLML	NLML

a. Source: 1965 National Fertility Survey

b. From DDIF equation; see text.

Table 7. Estimated Values of Fertility Control (ρ) for Catholics and Non-Catholics by Age of Contraceptive Initiation ($\hat{a}$), U.S. White Women 45-54, 1965

	Religion	
$\hat{a}$	Non-Catholic	Catholic
22	.725	.575
25	.863	.685

The consistency of results is indeed surprising given that the DDIF estimates embody the assumption that the natural fertility schedule utilized is correct. The total sample estimate of ρ (.69), based on the assumption of control beginning at the onset of marriage, should and does approximate the sample value of 1-DRAT (.66) and is also close to the level of 1-DRAT predicted by the 1970 equation with AGEW set at 45 (.62). The results also indicate that the "true" level of contraceptive control, once control is used, is closer to .86 (for non-Catholics). These preliminary results thus suggest that while the DDIF measure of cumulative fertility is inferior to DRAT (or CEB, for women who have completed their childbearing) in terms of identifying and quantifying socioeconomic differences in fertility behavior, the DDIF model appears useful in characterizing aggregate fertility behavior in a sample population with regard to the time of contraceptive initiation and the level of control.

VII. Conclusion

It is well known that the influence of socioeconomic characteristics on fertility is constrained by or works through biological mechanisms such that age and age at marriage, among other variables, must be taken into account in studies of the determinants of cumulative fertility. However, little modelling by social scientists of the precise interactions between biological and behavioral variables has been undertaken and attempts in empirical studies to control for age-related biological factors using conventional measures of cumulative fertility have been unsatisfactory for many reasons, leading to imprecise and ambiguous results. Yet these considerations are particularly important as more researchers explore data sets containg women who have not completed their childbearing in order to analyze recent fertility behavior.

We have proposed two new measures of cumulative marital fertility which are standardized for the age-fecundity relationship and for the length of exposure to the risk of conception associated with marriage duration. One measure, called the duration ratio (or DRAT), is the ratio of the number of children ever born to a woman to predicted cumulative fertility based upon her age at marriage and an age-specific natural fertility schedule; the other measure, the duration difference (or DDIF), is the difference between the number of children ever born and predicted cumulative fertility. These measures appear to be superior to the most common measure of cumulative fertility, children ever born, in allowing more precise estimates of socioeconomic-fertility relationships.

A simple model of fertility behavior which incorporates some of the mechanisms through which socioeconomic factors may condition fertility indicates that the relations between age, marriage duration and socioeconomic effects on children ever born are highly non-linear, thus implying that biased empirical estimates of the relationships between socioeconomic variables and this standard measure of cumulative fertility will be obtained unless very fine sample stratification by age is applied to data samples. Moreover, the coefficient estimates obtained when children ever born is used as a dependent variable, even with such sample division, are also ambiguous in that they reflect the influence of socioeconomic variables on both age at marriage and fertility control within marriage.

The same model indicates, however, that the use of the duration ratio as a dependent variable provides unbiased estimates of the effects of socioeconomic variables on the level of marital fertility control for women of all ages without the need for sample stratification or cumbersome age variables designed to reflect biological factors if fertility control begins soon after marriage in the population. It is also shown that empirical results should not be affected if the level of fecundity varies stochastically in the population or, under most conditions, if the level of the natural fertility schedule chosen to compute DRAT is incorrect. However, the model from which these results are derived assumes that socioeconomic variables do not affect fecundity directly. If this assumption is violated, then estimated relations between socioeconomic variables and the proposed measures (or children ever born) can not be interpreted as purely behavioral responses. Modification of this assumption is an important topic for future research.

Empirical tests performed on U.S. and Philippines household data on women aged 20-44 confirm the highly interactive relationships of age and socioeconomic effects on children ever born and the lack of such relations in regressions using DRAT, thus suggesting that the duration ratio may be used without sample stratification even in populations characterized by late control without significant deterioration of results. The empirical analysis also suggests that substantive conclusions regarding the importance and role of socioeconomic variables are changed dramatically when more careful considerations of biological interactions are taken. Empirical application of the duration difference measure suggests that it can be successfully used to obtain estimates of the time at which fertility control is initiated in a population when no direct information on this parameter is available.

Neither of the models formulated nor the empirical results reported are more than of an exploratory nature. Both suggest, however, that DRAT (and DDIF) may be more informative measures of cumulative fertility behavior than children ever born, particularly if used in conjunction with an analysis of age at marriage. Moreover, they suggest that much more work is needed on modeling the determinants of the timing as well as the level of fertility control chosen by a woman (family) if empirical analysis of data sets containing married women in their childbearing years is to provide meaningful results.

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