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THE FERTILITY REVOLUTION: A REVIEW ESSAY

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The Fertility Revolution: A Review Essay*

The Fertility Revolution: A Supply-Demand Analysis (University of Chicago Press, 1985) by Richard A. Easterlin and Eileen M. Crimmins cogently poses broad issues and seeks to integrate our understanding of the variations in fertility and contraceptive use that underly the demographic transition. The empirical implementation of the proximate determinants framework for the study of fertility is, in the authors' words, "perhaps the most important innovation" (p. 182) in this book. I shall argue, however, that the statistical methodology advanced by Easterlin and Crimmins is seriously flawed and may mislead us in quantifying the developments that are encouraging the world's population to restrict its fertility.

The book is made up of four sections. The first two chapters introduce the problem and the conceptual framework; the latter is derived from Easterlin's essay in a National Academy of Sciences "summary of knowledge" of the determinants of fertility (Bulatao and Lee, 1983: Chap. 15, Vol. II). The second section is the core of the book, two chapters presenting estimates of the determinants of fertility at the household level based on World Fertility Surveys (WFS) from Sri Lanka and Colombia. The third section consists of studies of aggregate data with K. Srinivasan and Shireen J. Jejeebhoy that were previously published in Economic Development and Cultural Change and PDR. Changes in fertility from the 1950s to the 1970s in rural and urban Karnataka (India) and Taiwan are examined in one study, and differences in fertility

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control across ten Indian states are contrasted in another. The concluding chapter summarizes the findings of the book and draws inferences about its implications for understanding the demographic transition and evaluating the role of population policy.

This book seeks to bring empirical content to the Easterlin synthesis framework (1978). The analysis of household data from Colombia and Sri Lanka confirms three implications that the authors derive from their framework: (1) the biological effects of the proximate determinants of fertility show the expected signs; (2) contraceptive use responds positively to the excess supply of births; and (3) contraceptive use increases when proxies for the cost of birth control decrease. Since these are not surprising predictions, the real value of the book is in providing an integrated conceptual framework for the statistical analysis of the biological factors determining fertility and behavioral constraints that explain why couples differ in their "biological" behavior. This review attempts a critical assessment of the framework. For ease of exposition it follows the organizational structure of the book. Most attention is paid to the empirical specification of the model in chapter three and its estimation in chapter four.

Easterlin and Crimmins's conceptual framework takes as its point of departure the organizing taxonomy of the NAS two-thousand page Determinants of Fertility (Bulatao and Lee, 1983). In this taxonomy, fertility determinants are divided into three components: the supply of births, the demand for births, and the cost of fertility regulation. These categories for listing themes of research on fertility determinants have obvious heuristic appeal, but the NAS study does not reveal how this taxonomy can guide integrated empirical analysis of the biological and behavioral determinants of fertility and thereby test interesting hypotheses and quantify critical parameters. Easterlin and

Crimmins (E-C) provide the first attempt I know of to translate these loose categories into a statistical model to interpret combined data on biology and behavior. They face many challenges.

First, the assignment of each fertility determinant, for example, breastfeeding or age at marriage, to a single category, whether to supply, demand, or cost of control, is ambiguous. This hypothesized decomposition of causal processes is not a promising way to structure empirical analysis of fertility determinants. Fertility might be more realistically seen as the outcome of a sequential interaction between exogenous variation in the biological supply of births that is not behaviorally controlled, such as fecundity, on the one hand, and the behavioral demand for births, on the other. The joint roles of biological supply and behavioral demand in determining fertility under a regime of costly fertility control are clear, but it is far from clear how the three categories--supply, demand, cost--can be usefully separated, and yet suitably represented in an integrated statistical model.

Second, there are two distinct sources of persistent variation across couples that affect their fertility. There is fecundity, varying exogenously the biological supply of births; and there are preferences of parents for children varying the demand for births. Neither of these sources of intercouple variation in supply or demand can be directly observed by the researcher or selected by the couple, and therefore they constitute errors in our statistical modeling of these separate processes. But these processes would seem to interact (as in the case of contraceptive practice) and not be separate, as is implicitly assumed in many attempts to estimate the effect of the biological determinants of fertility (Vaughan, et al., 1977; Bongaarts and Potter, 1983, p. 69).[1/] Mathematical decompositions of the sum of biological events can be by definition multiplicatively separable, while at the same time estimation of the consequences of biological events on fertility may not be estimated correctly by a chain of simple associations. The couple's behavior relevant to reproduction may respond to their fecundity, and that response will itself depend on the cost, availability, and acceptability of birth control.

In the case of contraceptive-use, and potentially in the case of the other empirical measures of proximate fertility determinants introduced by E-C, there is likely to be a relationship between the couple's underlying fecundity and their proximate fertility determinants. For example, if a couple experiences an unwanted birth they will be more inclined to adopt birth control or shift to a more effective form of birth control than they would otherwise. It is this covariation between observed determinants and unobserved fecundity that necessitates the adoption of estimation techniques that are different from those used by E-C. These different techniques also force one to distinguish carefully between exogenous background variables and endogenous variables that are partially determined within the model. More precisely, endogenous variables should be defined as those that are statistically associated with either fecundity or preferences, the two sources of unobserved biological or behavioral factors (i.e., statistical errors). Since the NAS compendium may stimulate further empirical work using Easterlin's framework, this review restates this model in some detail.

The Conceptual Framework

The conceptual framework employed by Easterlin and Crimmins and elaborated in the second chapter of the book is, according to their own observation, an evolution of the "proximate determinants of fertility" approach and derivative from Easterlin's (1978) and Tabbarah's (1971) work. Its appeal and its shortcomings can be traced to its origins. As a heuristic taxonomy of fertility determinants, Davis and Blake (1956) first distinguished between an exhaustive set of biological states that are "proximate determinants" of fertility, on the one hand, and a diversity of socioeconomic conditions that may influence fertility as they alter the occurrence of these biological states, on the other. Research associated with the proximate determinants tradition (Bongaarts and Potter, 1983; Bongaarts and Menken, 1983) has proceeded steadily toward a mathematically tractable decomposition of fertility levels that expresses fertility in terms of a few proximate determinants: (1) the onset of the period of exposure to the risk of conception, (2) the period of postpartum sterility, (3) the onset of secondary sterility, (4) the frequency of intercourse or fecundability, (5) pregnancy wastage (including induced abortion), and (6) the period of contraception and (7) its effectiveness. With this schema one can simulate the fertility experience of a woman with given reproductive parameters and describe her duration in the various states as well as her completed fertility. If most of these parameters are assumed more or less biologically constant and independent of each other, it is then possible to deal with differences among individuals and across populations due to, say, contraception or age at marriage, and trace the effects of these variables on fertility. But the conditional sorting of persons among biological states, as a function of their previous history is neglected, whether because there is little agreement on the important dependencies or because little thought has been given to how existing data might be used to determine these facts empirically. The approach provides a method for integrating various assumptions about biological and behavioral interdependencies that sum to reproductive performance. But the background behavioral factors conditioning the biological proximate determinants, which indeed were the starting point for Davis and Blake (1956), have been increasingly neglected. More generally, the probabilistic mechanism determining the assignment of the individual among states tends to be simplified to the point that it does not depend in a satisfactory way on the individual's previous experience, optimizing behavior, or relatively fixed characteristics of the individual that are imperfectly observed by the researcher, such as fecundity (supply) or preferences (demand).

The promise of Easterlin and Crimmins's research is that it could return the study of fertility to the issues of behavioral science that originally motivated Davis and Blake (1956). It also offers an exceedingly simple framework for integrating the biological and behavioral determinants of fertility, and for ascertaining empirically what are the more and less important factors affecting fertility in different times and places. Although the clear and thoughtful writing of these authors may help to refocus study of the determinants of fertility, their analytical framework needs to be reformulated and then applied to better household and community data using a statistically consistent estimation method. Otherwise, the proposed regression model and methods of E-C will not capture accurately the relationships determining fertility.

The Easterlin-Crimmins Model

The model, as set forth in chapter three, consists of three relationships: the biological fertility determinants, the behavioral motivating factors determining contraceptive use, and the behavioral determinants of the biological fertility determinants. The variables, their definitions, and their classification--whether endogenous or exogenous--are summarized in Table 1 according to E-C and alternatively by the author. First, the number of live births, B, of a woman at the end of her childbearing period (empirically age 35 to 44) is specified as a function of eight observable proxies for the biological proximate determinants of fertility:

(1) $$B_k = \alpha_0 + \sum_{i=1}^{i=7} \alpha_i X_{ik} + \alpha_8 U_k + \varepsilon_k$$

where k refers to the individual couple observation. Some of the proximate determinants are chosen by the individual or family and undoubtedly vary by social and economic characteristics, regardless of whether the choice is primarily motivated by fertility regulation; examples are age at marriage (X_1) and duration of breastfeeding (X_5). The measured determinants may also be influenced by the couple's fecundity, represented by the error ε. The first and second birth intervals (X_2 and X_3) and the occurrence of secondary sterility (X_4) are definitionally related to how rapidly births occur once marriage is consummated. It is argued by E-C that these variables (i.e. X_2, X_3, and X_4) capture fecundity, but in fact they define fertility. Including these components of fertility also excludes from the sample women who have fewer than two children or have any premarital births, and leads to the presumption that premarital conception does not occur.

Child mortality (X_7) and pregnancy wastage (X_6) are categorized as supply factors and treated as exogenous, though some have postulated that fertility might affect the level of mortality. The final factor is the duration of contraceptive use (U). No information is introduced on the effectiveness of the contraceptive method used, and this is only one of several reasons to treat this variable as measured with substantial error.

Clearly, there are problems with the functional form of the fertility equation (1) as specified by E-C.[2/] The functional specification for the fertility equation can undoubtedly be improved over E-C's linearized mixture of fertility determinants and intervals. But the data from the World Fertility Survey are not well designed to model the behavioral side of the framework and lack interval specific information on the biological factors. These issues of functional form are not discussed here; I shall rather concentrate on the choice and treatment of empirical proxies and alternative estimation methods.

The second relationship is that determining duration of contraceptive use if currently practicing contraception:

$$(2) \qquad U_k = \beta_0 + \delta(C_{nk} - C_{dk}) + \gamma RC(a)_k + \mu_k$$

where the variables are again summarily defined in Table 1: $C_n - C_d$ is the excess of "natural" fertility (or the biological supply of births) over the desired fertility (or the demand for births). C_d is the respondent's subjective report of her desired fertility, and RC (a) is the cost of regulating that excess supply of births, which is assumed to be a function of "how many methods of birth control" the respondent could identify, without prompting by the interviewer.

For many years economic problems involving dynamic behavior have been formulated as a stock-adjustment process (Nerlove, 1958; Lucas, 1967). The contraceptive-use equation (2) is analogous to this formulation: the demand for contraceptive use depends on the difference between desired fertility and the biological potential fertility and on the cost-of-control. One problem with empirically implementing this stock-adjustment model is that unobservable factors that affect fertility will be serially correlated over time, introducing bias when ordinary least squares is used to estimate the effect of stocks on contraceptive use (Griliches, 1961). To avoid this bias, measures of fertility or the stocks of children must be treated as endogenous serially correlated variables (Schultz, 1980). E-C do not address this econometric problem, though they later treat C_d as an endogenous variable in estimating equation (3).

Table 1
Variables, Their Definitions, and How They Are Treated Within Easterlin-Crimmin's Framework

Variable Notation	Variable Definition	Exogenous or Endogenous: Easterlin-Crimmins	Exogenous or Endogenous: Alternative Specification by Author
I. Fertility and Proximate Determinants of Fertility		In Equations 1 and 2	
B:	Children Ever Born	Endog.	Same
X_1	Duration of Marriage	Exog.	Endog.
X_2	First birth interval	Exog.	Endog.
X_3	Second birth interval	Exog.	Endog.
X_4	Not secondarily sterile (sterile if not now contracepting and no birth in last five years or reported sterile by respondent)	Exog.	Endog.
X_5	Duration of breastfeeding in last closed birth interval	Exog.	Endog.
X_6	Proportion of pregnancy wastage	Exog.	Endog.
X_7	Proportion of child mortality	Exog.	Endog.
U	Period since first used contraception or induced abortion	Endog.	Same
RC:	Cost of fertility control proxies		
RC (a)	Number of birth control methods known	Exog.	Endog.
RC (b)	Efficiency of methods known	Exog.	Endog.
RC (c)	Knowledge and approval of abortion*	Exog.	Endog.
RC (d)	Travel time (or distance) to nearest family planning outlet*	Exog.	Exog. at regional level
C_n	Natural Fertility--constructed see (1a)	Exog.	Endog.
C_d	Subjective demand for children (How many children would you choose to have in your whole life?)	Exog.	Endog.
C	Number of children living $(B(1-X_7))$	Exog.	Endog.
No	Whether respondent wants no more children	Exog.	Endog.
II. Background Conditioning Variables		In Equation 3	
Y:	Modernization proxies		
Y (a)	Wife's education (in years)	Exog.	Same
Y (b)	Rural residence	Exog.	Same
Y (c)	Husband's occupation (farmer, agricultural worker, service worker or other)	Exog.	Same
Y (d)	Wife worked before marriage (farm or nonfarm job)	Exog.	Endog.*
Z:	Cultural variables		
Z (a)	Ethnicity* (Sri Lanka-4 classes)	Exog.	Same
Z (b)	Regional* (Colombia-5 regions)	Exog.	Same

Table 1 continued

III.	**Statistical Errors and Unobservables**	
	ε	Error in fertility equation (1) (includes fecundity)
	μ	Error in contraception equation (2)
	η_i	Errors in reduced from equations (3) for proximate determinants of fertility ($X_1, \ldots, X_7$, etc.).

*Variable not available for both Sri Lanka and Colombia, and in some cases a substantial fraction of WFS sample did not respond to question.

Another empirical problem is that the natural biological supply of births is not observed, but must instead be constructed from the estimates of the fertility equation (1), denoted by the hatted parameter values. The biological supply of living children, C_n, is defined as actual fertility minus the estimated fertility-reducing effect of contraceptive use, minus the estimated couple-specific error containing fecundity, multiplied by the child survival rate:

$$(1a) \qquad C_{nk} = (\hat{\alpha}_0 + \sum_{i=1}^{i=7} \hat{\alpha}_i X_{ik})(1 - X_7) = (B_k - \hat{\alpha}_8 U_k - \hat{\varepsilon}_k)(1 - X_7),$$

Finally, most of the variables treated as exogenous in equations (1) and (2) are later assumed to be endogenous functions of a vector of modernization (Y) and cultural (Z) variables:

$$(3) \qquad W_{jk} = K_j + \pi_j Y_k + P_j Z_k + \eta_{jk}$$

The vector W_j includes X_1 through X_7, C_d, and RC. For some reason, this vector excludes contraceptive use, U, and fertility, B. I found no explanation of why the vector of variables W_j is endogenous in equation (3), but the separate variables are treated as exogenous in equations (1) and (2).

Estimation

Estimates of these three relationships are reported in chapter four of the book, based on household-level data from Sri Lanka and Colombia. Some relationships are estimated by straightforward regression, whereas the structural equations require the use of special estimation techniques and the imposition of identification restrictions. Since these issues of statistical methodology are not directly addressed by Easterlin and Crimmins, I shall describe how they obtain their estimates and how their estimates may be biased. In addition, alternative methods for consistently estimating the fertility and contraception equations are described.

The final reduced-form equations (3) can be estimated by single-equation methods, such as ordinary least squares regression (OLS), because Y and Z are assumed exogenous and are thus uncorrelated with the vector of errors η_j. As indicated in the two right-hand columns in Table 1, one modernization variable in Y might be better classified as endogenous over the wife's life cycle, and that is her premarital working status. Indeed, E-C also note the ambiguous causal role of this variable (p. 190).

Estimation of the proximate determinants of fertility equation (1) is more complex, because many and potentially all of the explanatory variables in this equation are endogenous. In other words, the proximate determinants are likely to be correlated with the couple's unobserved fecundity, which is included in the error, ε. Consequently, the effect of the explanatory variables on fertility cannot be estimated by single-equation methods, as E-C do. Standard ordinary least squares (OLS) regression in this case will be biased and inconsistent. The most serious problem may be with contraceptive-use. More fecund couples will be motivated by excess fertility at an earlier stage in their life cycle to adopt birth control, other things being equal; or, in other words, the expected value of the product of contraceptive use and fecundity will be positive, $E(U\varepsilon) > 0$. Moreover, even if fecundity were a random variable and not serially correlated, the arrival of a surprise birth would lead people to change their contraceptive behavior. By similar logic, premarital conceptions may occur more frequently for more fecund couples, who are therefore likely to marry earlier, $E(X_1\varepsilon) > 0$.

One method to deal with the correlation between the X's and ε is to use exogenous instrumental variables (IV), such as Y and Z, to predict in a first-stage the values of the X's that are thereby uncorrelated with fecundity. These instrumental predictions of the X's could then be employed in the second-stage estimates of the fertility equation (1). These two stage IV estimates converge to the true parameter values as the sample size increases, that is, they are consistent estimators. This and other simultaneous-equation estimation methods depend critically on the identification restrictions, which in this problem might represent background socioeconomic constraints that are believed to affect behavior relevant to reproduction but are independent of fecundity or preferences, such as rural origins or education. When the fertility effect of contraceptive-use is estimated within a properly specified version of the biological fertility framework, the consistent IV estimates differ substantially from the standard single-equation estimates (Rosenzweig and Schultz, 1985a, 1985b; Kelley and Schmidt, 1985).

The contraceptive-use equation (2) poses equally difficult estimation problems. Few social scientists would think that subjective reports of desired fertility are entirely independent of the costs of control. Here again the E-C framework categories suggest distinctions that are empirically ambiguous and not linearly separable. Moreover, do desires incorporate or abstract from the effects of economic constraints such as husband's income or wife's education? The desired level of fertility must be treated as an endogenous outcome shaped by preferences but modified by modernization and cultural variables as well as by exogenous aspects of the local cost of birth control.

It is not surprising that couples who know many methods of contraception (and spouses who communicate about them) have used them for a longer time. Does motivation lead to familiarity, or vice versa? The circularity among the measures of knowledge, attitudes, and practice (KAP) of family planning is another example of a cluster of endogenous covariates that are ill-designed to shed light on how exogenous factors cause change in contraceptive-use to occur by changing the monetary, informational, psychological, and program variables. E-C note this problem in reference to India (p. 156), but they do not draw attention to it earlier in their interpretation of the WFS estimates. Distance (measured linearly or, preferably, in terms of travel time) to a family planning outlet is examined as a proxy of control cost in the Colombian WFS, but this promising variable is later dismissed as endogenous, because it is only reported by a fraction of the Colombian sample who are more likely to be users. E-C are correct not to rely on this cost-of-control variable because it is endogenous at the individual level; but if averaged for all persons at the community level, it might represent a legitimate exogenous cost-of-control for all couples in a prescribed region, regardless of individual responses to the underlying question (Schultz, 1984).3/ In sum, the E-C framework can mislead by its treatment of cost-of-control as a linearly separable factor, and the empirical specification of a proxy for this variable by E-C, namely number of methods known, is unsatisfactory.4/

Because the variables used to explain fertility in equation (1) are endogenous, and hence related to unobserved components of supply (i.e. fecundity) and demand (preferences), reported OLS estimates of this relationship do not have good statistical properties. Similarly, desired fertility and contraceptive knowledge that are used to explain contraceptive use in equation (2) are also endogenous variables. How to deal with these problems of simultaneous-equation bias in the study of fertility determinants has been at the core of empirical economic demography for the last decade. E-C do not discuss this problem of model specification and estimation. Moreover, if the objective is to evaluate how public policy has contributed to the "fertility revolution," it is regrettable that E-C have not introduced into their micro analysis a single exogenous variable measuring local public health and family planning programs or developmental change.

What Do the Micro Empirical Estimates Mean?

With so many sources of estimation bias and likely empirical misspecification of their modeling of fertility determinants, is it possible to speculate on the direction of parameter bias in the empirical exercises reported in chapter 4 of this book? In general, no. But fortunately, in several cases, one source of bias in isolation can be signed and even confirmed by the reported findings. The most obvious and substantial bias probably occurs because more fecund couples are more strongly motivated to contracept. If U were the only endogenous variable and $E(U\varepsilon) > 0$, then the OLS estimate of the contraceptive effect, α_8 (believed to be negative), would be biased in a positive direction. In other words, the depressing effect of contraceptive use on the supply of births would be underestimated. Errors in measurement of contraceptive use, U, would also tend to bias this coefficient toward zero. By similar reasoning, the OLS estimate of the expected positive effect of marriage duration on fertility might be overestimated, and the expected negative effect of breastfeeding on fertility would be underestimated (or biased upward toward zero). But when all these sources of bias are present together, no predictions on the sign of parameter biases are possible without added information.

In the contraceptive-use equation (2) several sources of bias are worth noting. First, the constructed value of the supply of births essentially subtracts from the actual fertility both the estimated effect of contraception ($\underline{\alpha}_8 U$) and the residual (ε) that includes unexplained variation in fecundity.5/

Since higher fecundity should motivate earlier contraceptive use, the expected sign of δ is positive. Removal of ε from C_n biases the estimated value of δ downward toward zero. Second, if OLS underestimates the contraceptive effect, α_8, in the fertility equation (1), then C_n will also appear smaller than it should for couples who are more prolonged users of contraception. The bias in OLS estimates of α_8 suggests that the coefficient on excess supply in equation (2), δ, might also be biased toward zero. An indirect test of this expectation is that the average constructed natural fertility, C_n, is greater than average actual fertility, C, for nonregulators. If the average value of ε is negative for those with $U = 0$, it must be positive for those with $U > 0$, since at least in the linear model the residuals sum to zero. This pattern of selective sorting is noted by E-C (p. 66), but they fail to draw conclusions regarding bias from this pattern in the residuals. Further confirmation of the resulting bias is found in the simple correlation of U and C_n, which increases in the total population when the instrumental variable estimate of α_8 replaces the OLS estimate of α_8 as originally reported in the WFS study by E-C (1982).

Easterlin and Crimmins are encouraged because their measure of motivation--excess fertility--predicts duration of contraceptive use better than does the dichotomous variable whether the couple currently "wants no more children" (pp. 69, 74). The comparison is not ideal, however, because the dichotomous response neglects <u>how long</u> the couple has wanted no more children. If the question were reformulated in terms of this continuous measure of duration of demand for control, the comparison with the performance of $C_n - C_d$ might be of greater interest.

In their original WFS study of Sri Lanka and Colombia, Easterlin and Crimmins (1982) treated U as well as X_1 through X_7 as exogenous; they assumed that U was uncorrelated with the error or fecundity, ε, in the fertility function (1). This is the simplifying assumption generally employed to estimate the use-effectiveness of contraceptives, namely that contraceptive choice is not influenced by fecundability. But this is not plausible, and thus in the book E-C have reestimated their fertility equation, implicitly recognizing the bias introduced by treating U as exogenous. This is an important step in the right direction.

The empirical question is, does this improvement in estimation methodology alter substantially the estimate obtained of α_8, or are we here focusing on minor second- and third-order problems? The instruments Easterlin and Crimmins use to obtain their estimate of U are $X_1, \ldots, X_7$, C_d, RC(a), and X_7 squared (Table 4A.5). All of these variables, however, might be plausibly classified as endogenous in a general household behavioral model. Since $X_1, \ldots, X_7$ are already included in the fertility equation, three identifying variables permit E-C to estimate the effect of contraception on fertility: (1) the square of the child mortality rate, (2) the number of birth control methods known, and (3) the desired fertility. The authors provide no rationale for this choice of identifying restrictions, and I can offer none. The modernization and cultural variables are conceptually cast as exogenous variables, and they would seem appropriately treated as instruments here. Indeed, elsewhere in the volume, E-C include them in the reduced-form background equations (e.g. Tables 4.13 and 4.14).

Despite the shortcomings in the choice of identifying restrictions, one may hope that the instrumental variable estimates (2SLS) are less biased than the single equation (OLS) estimates of contraceptive effectiveness, α_8. In the Sri Lankan sample, the linear (2SLS) coefficient on contraceptive use is -.44 compared with -.11 in the original OLS study. In the Colombian sample the same coefficients are -.34 and -.18, respectively.[6] This two-to-four-fold increase in the estimated effect of contraception occurs when contraceptive use is more properly treated as an endogenous choice variable. Others have also found large increases in the estimates of contraceptive-use-effectiveness when more appropriate instrumental variable estimates are calculated (Rosenzweig and Schultz, 1985a, 1985b, Kelley and Schmidt, 1985).

One might conjecture that if marriage duration, which is a dominant factor determining fertility, and is itself strongly linked to wife's education, were also estimated by appropriate instrumental methods, estimates of α_1 would also change substantially. There is no way to confirm these suspicions from the empirical results reported by E-C; however, it should be clear from their results on contraception that their model estimates are not robust to the use of unsatisfactory statistical methods. Treating behaviorally controllable variables as endogenous could markedly alter their conclusions, as to the particular channels by which modernization affects fertility, how much contraceptive practice reduces fertility, and the role of family planning in facilitating the use of contraception and thereby effecting fertility transition.

More speculatively, I would expect the inclusion of a subjective measure of "desired fertility" as if it were an exogenous determinant of contraceptive-use would bias downward the estimate of γ that purports to represent the effect of an exogenous reduction in the cost of fertility control. Given the many sources of simultaneous equation bias and the lack of a satisfactory community measure of cost-of-control, this expectation also cannot be verified.[7]

Easterlin and Crimmins treat $X_1, \ldots X_7$, C_d and RC(a) as exogenous in estimating the fertility and contraceptive use equations (1) and (2), but they also seem to recognize them as endogenously determined by background variables in reduced form equation (3). Ordinary least squares estimates of these reduced-form equations (3) in Tables 4.13 and 4.14 are informative because they are not conditional on estimates of equations (1) and (2). E-C find the standard result that the wife's education is the best predictor for virtually every one of these variables proximally related to fertility. One only regrets that they do not report such a reduced-form equation for fertility or surviving children (B or C) and duration of contraceptive use (U). If these two additional equations were estimated including a suitable exogenous cost-of-control determinant, such as the community travel time to a family planning outlet (RC(d)), social scientists and policy makers could have learned about the effects of public policy on the demographic transition.[8/]

Aggregate Analyses

While the micro studies used retrospective data from cross-sectional household surveys, chapters five and six of the Easterlin-Crimmins volume attempt to account for changes in fertility and contraceptive use at the aggregate level, over time and across states. Chapter five attempts to show that the E-C framework explains levels and changes in fertility in rural Karnataka and urban Bangalore by constructing fertility variables for 1951 and 1975 and for all of Taiwan from 1957 to 1973. Four observations for India and five for Taiwan are not sufficient to test hypotheses in a statistical sense. Rather, these aggregate figures are used to illustrate how the approximate stability of fertility in Karnataka in this period of 25 years concealed cumulative changes. Child mortality declined and birth control increased, but not by a sufficient amount to restrain the rise in surviving children per couple. Nonetheless, the number of births averted by contraception increased from .5 to 1.5 in urban Bangalore. The story is plausible, but the assumptions used to generate natural fertility measures are debatable. Early phases of the demographic transition often exhibit a relaxation of birth spacing practices, either because modern methods of birth control are viewed as sufficiently reliable that "spacing" to achieve a specific target family size becomes relatively more costly than "stopping," or because other considerations make the traditional wide spacing of births less attractive (e.g., the wife may want to work outside of the family). In either case, the increase in marital fertility rates among young women is a covariate with contraceptive-use at older ages, not necessarily a cause.9/ Since the pace of early childbearing is not exogenous, the constructed measure of natural fertility cannot be viewed as occurring causally prior to the adoption of contraception. The observed covariation could be due to a third factor, such as the improvements in health and education reducing child mortality and lowering the desired levels of fertility. Regardless, Easterlin and Crimmins's interpretation that an increase in constructed natural fertility, C_n, was <u>the</u> factor behind the increase in contraceptive-use overreaches the evidence. The awkward assignment by the E-C framework of marriage-timing and child mortality to the supply side of the ledger may reinforce this confusion. The timing of marriage must ultimately be viewed as a social structural constraint on reproductive performance that many social scientists since Malthus believe adjusts to serve the reproductive interests of the society and the individual. Marriage cannot be viewed as exogenous in the estimation of the proximate fertility equation, particularly when a plausible case can also be made in many societies for fecundity selectively influencing when marriage occurs.

Chapter six reports an analysis in 1970 of fertility and contraceptive-use across ten states in India. It starts with estimates from a promising household survey of the proximate determinants of fertility equation (1). Unfortunately, in this regression analysis, summarized in Table 6A.1, the use of contraception is inconsistently treated as exogenous; it will be recalled that this inappropriate methodology led to a 50 to 75 percent underestimate of the crucial coefficient on contraceptive-use (α_8) in the analysis of the Colombian and Sri Lankan WFS data. Moreover, the individual data are then aggregated to ten states, for no obvious reason. At the state level the specified family planning and health program variables are shown to be frequently unrelated to one another, suggesting that these indicators of the cost-of-fertility-control need to be scrutinized more closely. In conclusion, comparisons across ten states do not provide convincing evidence on any of the major empirical objectives of the "synthesis framework."

Summary

Does the framework developed in this book provide us with a satisfactory model for estimating the biological and behavioral parameters underlying fertility? The path from general theory to a particular statistically defensible model for estimating the biological and behavioral determinants of fertility is long and hard. We are not yet there. Chapter two of this book presents an elegant statement of one approach to viewing the "fertility revolution" that has many adherents. But Easterlin and Crimmins have not succeeded in translating their conceptual framework into an empirically workable model in this book. Their estimates are consequently flawed and their interpretations of their empirical findings must be evaluated with caution.

Because the specification of the fertility equation (1) has mixed together on the right-hand side proximate determinants and definitional components of fertility (e.g., birth intervals) in a linear additive function, it is hard to evaluate what is being approximated in the regressions. Treating contraceptive use as an endogenous variable is an important advance, but the other determinants of fertility are still treated as exogenous and unrelated to the error in the fertility equation (e.g., fecundity). The estimation methods used for this equation are, therefore, subject to many sources of inconsistency and bias and the resulting parameter estimates cannot be viewed as reliable.

The contraceptive use equation (2) is specified in such a manner that the motivational variable, excess supply of births, omits births that are not statistically explained (e.g., part of fecundity). Omitting from this supply of births the unobserved variation across couples in their fecundity undoubtedly biases down the estimate reported of the contraceptive use parameter, δ.

Finally, the estimated effect of reducing the cost of birth control, γ, on contraceptive use depends on the implausible assumption that the number of contraceptive methods known to a couple is an exogenous cost-of-control variable that is causally prior to use or motivation to use. If knowledge and use are jointly determined, as would seem only reasonable, the observed partial correlation between knowledge and use sheds little light on the third empirical issue addressed in this book.

Empirically implementing the Easterlin framework as set forth in the National Academy of Sciences' Determinants of Fertility is an intrinsically difficult job and may not be building on the most promising structure. More work on this topic should be stimulated by this book. Combined the study of biological and behavioral determinants of fertility is required to represent the biological determinants as subject to behavioral modification (Davis and Blake, 1956), but a simultaneous or, ideally, fully dynamic framework is called for. A new model of the supply of births must make clear that unobservable components of fertility such as fecundity, introduce biological supply variation to which couples respond behaviorally. In modeling behavioral constraints future work might build on recent empirical studies of the demand for children, investigations of the effectiveness of family planning programs, and the handful of dynamic life-cycle models of reproduction. Growing experience in low-income countries using household survey data to study individual variation in reproductive behavior should assist in this process. The Fertility Revolution by Easterlin and Crimmins is the first attempt to link these widely separated endeavors by demographers, sociologists, and economists. They deserve credit for bringing these disciplines together on this common mission.

Footnotes

1/The literature on the biological proximate determinants of fertility may simulate populations assuming a covariance exists between fecundity and contraceptive choice (Bongaarts and Potter, 1983). The problem referred to here is that of estimating the basic parameters on contraceptive effectiveness when there is self-selection of contraceptive method (Rosenzweig and Schultz, 1985b). To my knowledge, covariation between contraceptive choice and fecundity is generally ignored in the best studies we have to date on contraceptive use-effectiveness (Vaughan et al., 1977). These biased estimates of use-effectiveness then make their way into the simulation models explored in the proximate determinants of fertility field (Bongaarts and Potter, 1983; p. 69).

2/It is, moreover, difficult to relate estimates of the parameters of this equation to previous work guided by biomathematical models of the proximate determinants of fertility, such as that of Bongaarts (1978) or even the more rudimentary approach of Tabbarah (1971).

3/Of course even the community-level measure of the cost-of-control might be endogenous. On the one hand, the availability of a family planning program might selectively attract migrants to the community who attached high value to these services. Thus, preferences for children or motivations for birth control would systematically differ in communities with and without family planning. On the other hand, the family planning program might be allocated by the government to communities where unwanted births were frequent, and hence the allocation of program activity would be associated with unobserved community demand (or excess supply) factors.

4/Unfortunately, the authors do not report estimates of the standard error of the Tobit function that defines the nonlinear expected-value locus that is analogous to the linear regression function (Tables 4.8, 4.9, 4A.2-5, 4A.8-10). Consequently, for comparison purposes I subsequently refer to the linearized 2SLS (instrumental variable) estimates that should be similar to the Tobit expected-value estimates at the sample mean. See also footnote 6 below.

5/Because X_2, X_3, and X_4 are treated as exogenous when equation (1) is estimated, the OLS residual will not contain all the fecundity variation across individuals. Nonetheless, the linear regress accounts for only 31 and 51 percent of the variance in fertility in the Sri Lankan and Colombian samples (Table 4.2). To estimate properly the fertility equation with X_2, X_3, and X_4 endogenous would tend to leave more of the fecundity variation across individuals in the residual or error, ε.

6/Because E-C do not report the standard error of the Tobit estimates, it is impossible to calculate how the slope of the preferred estimates of the Tobit expected-value locus varies nonlinearly. E-C compare the coefficients on the Tobit linear index function with those of the linear 2SLS regression. These comparisons should be disregarded by the reader. The asymptotic properties of the OLS and Tobit estimator in a multinomial setting (Greene, 1981) can be used to infer the slope of the expected value locus at the sample mean. The Tobit index coefficient reported by E-C (Table 4A.3) is multiplied by the proportion of nonlimit observations on U in the sample (Table 4.7). For Sri Lanka the Tobit index estimates would suggest an expected value locus slope of .96 (i.e., 1.75*(875/1588)) compared with the analogous 2SLS estimate reported as .93. For Colombia our inference is that the Tobit slope of the expected value locus is .66 (i.e. .694*(352/507)) versus the 2SLS estimate of .63. The Tobit model, therefore, does not greatly affect the estimates at sample means, but presumably provides a more realistic nonlinear functional representation of the relationship away from the sample means.

7/There are other reasons for suspecting the validity and replicability of the "desired fertility" variable. Knodel and Piampiti (1977: Table 2) illustrate the relatively low level of reliability of subjective responses to survey questions on desired fertility. In the highly regarded Thai NLS Survey they report that the reliability ratio for "ideal fertility" for married women from one round to the next is .19, compared with responses on objective questions such as educational attainment of .81, and even on retrospective questions such as the size of marriage payments at first marriage, where it was .64. Additional problems with desired fertility as it is employed in micro-analytical models of fertility are discussed by Ryder (1977: 18) with particular reference to the Easterlin (1983) or NAS approach.

8/A final issue of model specification is how to deal with a limited dependent variable. Since "duration of contraceptive-use" cannot be negative, a large fraction of the sample of couples report a zero for this variable. If the decision whether and how long to use contraception is explained by the same index function, and errors are normally distributed around that index, the model is called Tobit. The Tobit formulation is therefore used quite appropriately by E-C to estimate the contraceptive-use equation (2) for the entire sample. The authors never explain why they estimate Tobit parameters for the sample restricted to contraceptors, namely $U_k > 0$, since for the selected sample the estimates are biased and no longer truncated (Table 4.9).

9/The logic is taken to the extreme when it is proposed that couples have children earlier and then, only when they exceed their lifetime target number of births, attempt to slow their reproduction rate (p. 141-43). No foresight is admitted in this stylized view of the world.

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