THE DEMAND FOR AND SUPPLY OF BIRTHS: FERTILITY AND ITS LIFE - CYCLE CONSEQUENCES

by

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Discussion Paper No. 211, March 1985

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Abstract

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This paper describes and implements a methodology for disentangling empirically in households the biologically-determined supply of births from the demand for births in order to assess the consequences of exogenous variations in fertility supply for household behavior. The estimation problems arising when there is heterogeneity both in preferences for family size and in the biological capacity to bear children (fecundity) are illustrated with a dynamic optimizing model incorporating stochastic fertility.

The methodology is applied to monthly longitudinal data on contraceptive use, fertility, and female labor supply in the United States from 1970-75. The empirical results indicate that more than ten percent of the cross-sectional variation in the number of live births in the U.S. is due to interhousehold variation in the exogenous supply of births. Biologically-determined fertility supply variation also significantly affects married women's labor supply and earnings. Moreover, use of actual fertility as a proxy for fertility supply results in underestimates of contraceptive effectiveness, and to biased estimates of the consequences of exogenous variations in fertility supply for couples' choice of contraceptives, for female earnings, and for the labor supply of married women.

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The Demand for and Supply of Births: Fertility and its Life-Cycle Consequences

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Economists and other social scientists have studied since Malthus the determinants and consequences of fertility, but without evolving a consistent framework. Two lines of fertility-related research have emerged in the economics literature. The first, concerned chiefly with the determinants of fertility, emphasizes the preferences of parents and treats the number of children born to a household as wholly demand-determined. Children are viewed as one manifestation of the set of household decisions constrained by costs and income (Schultz (1969), Willis (1973), Rosenzweig and Evenson (1977), Butz and Ward (1979)). Within this tradition, estimates of the "effects" of fertility variation on household behavior are obtained using simultaneous equations techniques (e.g., Nerlove and Schultz (1969), Fleisher and Rhodes (1979)); however, since both fertility and other household goods are viewed as jointly "demanded" by the household, identification appears arbitrary, in which case such estimates provide little information about the consequences of fertility change.

A second line of research assumes that births are wholly supply-determined, and treats fertility as purely random and exogenous. The number and ages of children in a household do not enter the household's preference function and/or are treated as exogenous (unexplained) determinants of or constraints on household allocation decisions, in particular, the supply of female time to the market (Heckman and MaCurdy (1980), Hausman and Ruud (1984)) and household consumption expenditures (Pollak and Wales (1980), Deaton (1982)).[1]

The coexistence of these mutually inconsistent approaches to the study of fertility-related behavior may reflect the special nature of fertility. Unlike the consumption by households of television sets or food, the level of fertility is determined by the allocation of resources to limit the biologically-determined production of births--fertility supply. Given that such control is costly and imperfect and the biological capacity to bear children (fecundity) is stochastic and mostly unaffected by choice behavior, the number of children born to a couple (society) may not exactly correspond to either the couple's (societal) expectations of or preferences for (given costless control) its family (population) size. Moreover, an individual couple may learn about its own specific supply constraints over time; planned resource allocations to control births or to earn income, therefore, may be altered by fertility experience both directly and indirectly as it influences supply expectations.

Fertility within a household is determined by the dynamic interaction between its supply of and demand for births, and variation in births across households reflect exogenous intercouple variation in both the supply of births and prices, income, and preferences for children, or demand.[2] Economists have recognized the joint relevance of biological and behavioral factors in determining fertility under a regime of costly fertility control (e.g. Easterlin, Pollak, and Wachter (1980)), but this perception has not been suitably incorporated into the empirical study of fertility.[3] In particular, this insight has not been employed in estimating the effectiveness of contraceptive methods, or in estimating the "effects" of fertility variation on labor supply behavior, on earnings, or on the demand for fertility control. When there is heterogeneity in both the biological supply of births and in preferences for family size, neither of which are directly observed by the researcher, a new analytical approach is needed.

In this paper we develop and implement a methodology for identifying empirically the supply function for births in order to assess the consequences of exogenous variation in the supply of births for fertility, for couples' choice of contraceptive techniques, and for the life-cycle labor supply and earnings of married women. In part 2, we describe an illustrative dynamic optimization model of contraceptive choice and labor supply incorporating uncertain fertility and persistent heterogeneity in preferences and fecundity. Section 3 describes the strategy for obtaining estimates of the biological components of fertility and the efficacy of contraceptive techniques, given household optimizing behavior and heterogeneity in fertility supply and preferences. In sections 4, 5 and 6, the methodology is applied to monthly longitudinal data on contraceptive use, fertility, and female labor supply in the United States.

The empirical results indicate that, because of the costliness of contraception, more than 10 percent of the cross-sectional variation in the number of live births in the U.S. is due to interhousehold variation in the exogenous supply of births, with couples offsetting 25 percent of the underlying variation in fertility supply through their choice of contraceptives. Such compensatory behavior appears to lead to significant underestimates of the efficacy of contraceptive methods, unless heterogeneity is taken into account. Biologically-determined fertility supply variation appears also to affect significantly married women's labor supply and earnings. Moreover, use of actual fertility as a proxy for fertility supply, as in prior studies, overestimates the true life-cycle labor supply response of married women to exogenous variations in fertility associated with imperfect and costly fertility control, but underestimates their consequences for female earnings and for the life-cycle adjustment in couples' choice of contraceptive methods.

1. A Dynamic Model of Fertility Control and Labor Supply with Exogenous Fecundity Variation

Assume that the number of births N_{ij} of couple j in period i in which the mother is age i + a is a random variable that can be reduced by the use of resources to control fertility, Z_{ij}, such that

$$N_{ij} = \mu_j + \varepsilon_{ij} + \gamma(a+i)_j - \beta Z_{ij}, \tag{1}$$

where μ_j is a time invariant fertility component specific to couple j, ε_{ij} is an independently-distributed, serially uncorrelated disturbance, and γ and β are biological-technical parameters to be estimated.[4]

Equation (1) describes the technology of birth production, or what is called hereafter the reproduction function. The potential number of births or fecundity is the sum of the first three exogenous terms and may be referred to as the "supply" of births; since the number of births actually produced (fertility) depends as well on the use of fertility control, realized births N_{ij} depend on both the preferences of parents (demand) and the supply of births.

Assume that parents in each period maximize the expected value of an intertemporally separable utility function that has as arguments the number of children born in the period, the cumulated number of children M_i (where $M_i = M_{i-1} + N_i$), a consumption good X_i, and leisure L_i of the mother. The parents' problem at period s is described by

$$\max E[\sum_{i=s}^{t} \delta^{i-1} U(N_i, M_i, X_i, L_i; \tau)] \tag{2}$$

subject to (1) and to a within-period income constraint,

$$W_i(T-L_i) + V_i = pZ_i + X_i + cM_i, \tag{3}$$

where the couple subscript j is suppressed, W is the wage of the mother, T is her total available time, V is income of the husband, p is the cost of fertility control, c the per-period cost of a child, τ is a time-invariant, couple-specific random preference variable, where $E(\tau_j\tau_k) = \sigma_\tau^2$ if $j = k$ and zero otherwise and $E(\tau_j\mu_k) = 0$ for all j and k.[5] This latter assumption presumes that fecundity is not influenced by behavior. See note 2. Parents are thus heterogenous in preferences (τ_j) and in the technologically persistent potential supply of births (μ_j).

The household chooses whether to use fertility control (Z=1) in each period, and whether or not the mother is to work (L=0), based on the information set Ω at the beginning of the period.[6] At the onset of period i, then, parents know the outcomes of their past decisions, the technology of birth production β, the wage rate, prices and their preferences; they thus know M_{i-1} but do not know the fertility they will experience in period i. They <u>may</u> know that component of the random fertility "draw" which is time-invariant (μ).

In such dynamic problems it is not generally feasible to derive analytically decision rules for L_i and Z_i in any period (Wolpin, 1984). However, comparative statics can be performed for the final-period decisions, when parents need not take into account the impact of their current decisions on future decisions. To see how variations in "fertility" are related to decisions concerning both contraception and labor supply as functions of technology, preferences and costs, assume that the utility function in each period is linear quadratic:

$$U_i = a_1N_i - 0.5a_2N_i^2 + a_3M_i - 0.5a_4M_i^2 + a_5(\tau)X_i - 0.5a_6X_i^2 + a_7L_i - 0.5a_8L_i^2 + a_9L_iM_i \;, \quad (4)$$

where $a_1, \ldots a_8 > 0$, to reflect diminishing marginal utility of all commodities. Note that mother's leisure and fertility are allowed to interact ($a_9 \neq 0$), reflecting the presumption of the household production literature that these two variables are not independent. We abstract from other interactions in (4) for simplicity, as is common in labor supply and fertility models. Preference parameters are constant across all periods, but preferences for the consumption good X vary across households, such that $\alpha_5(\tau)' > 0$, for all i.[7]

Consider first for illustrative purposes the decision whether to use fertility control in the last period, t. It can be shown that the difference in expected utilities, J_t^Z, associated with the use and non-use of contraception is:

$$J_t^Z = E_t(U_t | Z_t = 1; \Omega_t) - E_t(U_t | Z_t = 0; \Omega_t). \qquad (5)$$

The relationship between variations in prior fertility M_{t-1} and the probability of using birth control, whether J_t^Z is greater than or less than zero, depends on the information held by parents and on whether the variation in cumulated births is due to preferences or technology. To see this, consider two cases: First, assume that parents know the persistent, family-specific part of fecundity, and thus can distinguish random from systematic fertility outcomes, i.e., $\Omega_t = \{\mu, \beta, \gamma, M_{t-1}, p, c, W\}$. The effect of a purely random increase in the stock of children in period t-1 on J_t^Z is:

$$\frac{\partial J_t^Z}{\partial \varepsilon_{t-1}}\bigg|_{\Omega=\{\mu\}} = \alpha_4\beta - \alpha_6 c(p-\beta c) \qquad (6)$$

which, due to diminishing marginal utility, is positive as long as the "savings" from an averted birth βc exceed the cost of using fertility control p. An unanticipated random birth in period t-1 increases the likelihood that birth control is used in period t; this effect is stronger the lower the cost of contraception p and the greater its effectiveness β.

The effect of variation in that part of fecundity which is persistent (and known) on the probability of using contraception in period t is given by:

$$\frac{\partial J_t^Z}{\partial \mu}\bigg|_{\Omega=\{\mu\}} = \alpha_4\beta(1+dM_{t-1}/d\mu) + \alpha_2\beta + \alpha_6 c(p-\beta c) = \frac{\partial J_t^Z}{\partial \varepsilon_{t-1}} + \beta(\alpha_2 + \alpha_4 dM_{t-2}/d\mu). \qquad (7)$$

Expression (7) describes how contraceptive use varies across households with differing fecundity, when fecundity is known by the households. Households containing more fecund women are more likely to use fertility control because: (i) they will have more children at the beginning of the period and (ii) they can expect more children in the future period. As long as more fecund women also have more realized births cumulatively, i.e., $dM_{t-2}/d\mu > 0$, there will be a positive association between individually persistent fecundity and use of contraceptives.

In the case where households treat "excess" births (net of control) as purely random even though fecundity persistence exists, the association between J_t^Z and fecundity is

$$\frac{\partial J_t^Z}{\partial \mu} = \alpha_4\beta(1+dM_{t-1}/d\mu) + \alpha_6 c(p-\beta c) = \frac{dJ_t^Z}{d\varepsilon_{t-1}} + \alpha_4\beta\ (dM_{t-1}/d\mu) \tag{8}$$

More fecund women will still be more likely than less fecund women to use contraception. As long as higher fecundity increases realized births, lack of knowledge about individually-persistent fecundity decreases, but does not eliminate, the positive association between the likelihood of control and fecundity.

Women thus modify their selection of contraceptives on the basis of their realized births. Given the persistence of fecundity over time, estimates of the effect of contraceptive use on fertility, based on samples of women who have already had some fertility experience, will be biased, if heterogeneity is not taken into account. In particular, if, as our framework suggests, more fecund women use contraceptives more often or more efficaciously, contraceptive effectiveness will be underestimated.

If there is also heterogeneity in preferences, the direct association between prior fertility and current contraceptive use, as estimated in Michael (1973), Michael and Willis (1975), and McFadden (1975), will not indicate how fecundity affects contraceptive choice.[8] Thus the direction and magnitude of the bias in studies of contraceptive effectiveness cannot be inferred from these studies, since the distribution of actual cumulative fertility across women will reflect both variation in preferences, τ, and in fecundity, μ. The slope of the association between cumulative fertility and current values of the utility differential associated with contraceptive choice in a population heterogenous in fecundity and in preferences consists of three terms:

$$\frac{dJ_t^Z}{dM_{t-1}} = \frac{\partial J_t^Z}{\partial \varepsilon_{t-1}} + [\frac{dM_{t-1}}{d\tau}]^{-1}(\beta c-p)\alpha_6 + \beta\alpha_2 + \alpha_4(dM_{t-1}/d\mu). \tag{9}$$

Women with higher cumulative fertility at the start of period t are likely to be more fecund, and thus will be more likely to use contraception in period t, for given preferences; however, higher-fertility women are also more likely to prefer children relative to other goods X, for given fecundity ($dM_{t-1}/d\tau < 0$), and thus will be less likely to contracept in period t, since they will derive less utility from the savings generated ($\beta c-p$) by contraception. The estimated relationship between prior fertility and current contraception is likely to underestimate both the effect on contraceptive practice of an unanticipated change in fertility and the effect of fecundity variation on contraceptive choice; clearly, the estimated relationship between lagged fertility and contraceptive use does not correspond to either of these analytically distinct effects.

Similar considerations apply to associations between past fertility and the woman's current labor supply decisions, as estimated in most female labor supply studies (Smith (1980)). The model indicates that women at the start of period t will compare expected utilities in period t with respect to the labor force participation decision L_t; i.e.,

$$J_t^L = E_t(U_t | L_t = 1; \Omega_t) - E_t(U_t | L_t = 0; \Omega_t). \tag{10}$$

The effect on the expected utility differential J_t^L of an unanticipated increase in the number of births in period t-1 is given by:

$$\frac{\partial J_t^L}{\partial \varepsilon_{\tau-1}} = \alpha_9 - \alpha_6 \, Wc. \qquad (11)$$

The sign of (11) is ambiguous. Unanticipated "excess" fertility increases the marginal utility of the X-good relative to that of children and thus increases the returns to work. However, if children and the mother's home time are complements $(\alpha_9 > 0)$, the returns to remaining at home also increase. The relationship between labor force participation and fecundity is given by:

$$\frac{\partial J_t^L}{\partial \mu} = (\alpha_9 - \alpha_6 Wc)\ (1 + dM_{t-1}/d\mu), \qquad (12)$$

which again depends on whether or not more-fecund women have higher cumulative fertility at any age. However, the estimated association between prior fertility and the expected utility differential associated with the current labor supply decision in a population characterized by latent variation in both fecundity and preferences (for X) is:

$$\frac{dJ_t^L}{\delta M_{t-1}} = \frac{\partial J_t^L}{\partial \mu} - [\frac{dM_{t-1}}{d\tau}]\ W\alpha_6. \qquad (13)$$

The dynamic response in mother's leisure (or conversely market labor supply) to exogenous variation in fertility due to persistent and random fecundity is confounded by preferences. Since families with higher preferences for consumption good X are likely to have lower cumulative fertility at any age, lower-fertility couples will be more likely to prefer increased X or market income; the labor supply "response" to prior fertility "shocks" measured by (13) rather than by (11) or (12) will be biased upwards in absolute value.

2. Estimating Dynamic Responses to Fertility Supply Variation

The simple dynamic formulation of the contraceptive choice and labor supply problems in the presence of costly fertility control and exogenous variation in fecundity implies that when a couple realizes an unanticipated birth, this "supply shock" is likely to reduce fertility demand, and be manifested (1) in the subsequent adoption of a contraceptive regime that is more effective than it would otherwise have been, and (2) in a subsequent reduction in labor supply, if home time and children are complements. If the source of the positive shock in fertility is a persistent individual effect, called here "fecundity," then the tendencies to use more effective contraceptives and to restrict labor supply are strengthened, for persistence implies that the couple will already have more births before the current period and the couple may appreciate that they can expect more births in subsequent periods, other factors being equal. This larger number of births cumulated before the current period strengthens the motivation to restrict further births, whether or not the couple can identify its individual fecundity. Thus, the absolute size of the behavioral response to innovations from fecundity (μ) should (i) be larger than the response to random shocks, (ε), and (ii) increase as the couple ages, since older couples will have cumulated more fertility experience. Older couples are also more likely to be able to distinguish random from couple-specific persistent errors, compared to younger couples.

As noted, since realized births may reflect both persistent and unobserved preferences and biological supply factors, tests of propositions about the consequences of fertility supply variation require the isolation of the persistent and exogenous supply components of fertility from their demand components. As can be seen from the reproduction function (1), knowledge of β, the effect of contraception on fertility (or a vector of β's if there are multiple contraceptive devices), combined with information on contraceptive use and realized births, would enable estimation of the μ and ε_{ij} as in any period i, $\mu_j + \varepsilon_{ij} = N_{ij} + \beta Z_{ij} - \gamma(a+i)_j$.

The dynamic interactions between the supply of and demand for births implied by the model, combined with heterogeneity in couple-specific supply propensities imply, however, that information on the effectiveness of contraceptives based on observed associations between conception rates and contraceptive use will be misleading. Heckman and Willis (1975) have shown that persistence in couple-specific fecundity yields biased estimates of the β's, and estimate that the couple-specific intertemporal correlation between monthly conception rates is over .5. Their maximum likelihood procedures, however, do not take into account relationships between contraception and fecundity, i.e., couples discontinuing use of a particular contraceptive or switching contraceptives in response to their fertility (or non-fertility) experience. Our model implies that couples using a particular technique (after some fertility experience) will not be randomly (self) selected with respect to fecundity.

Our strategy for obtaining consistent estimates of the β's, and thus of the exogenous supply components of fertility, is to use time-aggregated information on conceptions, pregnancies, and contraceptive use in an instrumental variable procedure.[9] We estimate the conception rate for a couple over some period as a function of the fractions of that aggregated period the couple used different types of contraceptives. If equation (1) is aggregated over S periods and fertility control Z is used in f of these periods then the time-aggregated version of (1) is

$$n_j=\mu_j+\sum_{i=1}^{S}\varepsilon_{ij}+\gamma A_j - \beta F_j \quad , \tag{1'}$$

where $F_j = f_j/S$ = the fraction of the aggregate period of exposure in which birth control is used, $n = \sum_{i=1}^{s} N_{ij}/S$ = birth or conception rate, and A = average age in the period.

The model implies that F_j will be correlated with both the ε_{ij} and with μ_j (serial correlation is not necessary), as couples will, during the period, exercise control or not in response to within-period supply shocks. Instrumental variable estimates of the self-selected inputs would provide, however, consistent estimates of β, and thus of μ_j and the aggregated ε_{ij}. Because F_j reflects the couple's demand for children, it is a function of preferences, prices (p, c, W_j) and income (V_j). As long as these variables are orthogonal to fecundity, the usual set of fertility demand variables may thus serve as instruments for F_j and permit identification of the supply technology.[10]

3. Data and Estimation of the Reproduction Technology: The Supply of Births

Data are drawn from a longitudinal sample of women from the 1970 National Fertility Survey (NFS) who were reinterviewed in 1975. The 1970 sample was a national representative sample of 6752 ever-married women born since July 1, 1925. Two thousand three hundred and sixty one women of the original 1970 sample were reinterviewed in 1975. Their selection was based on being in intact first marriages (for both spouses), where the wife's age at marriage was less than 25, and the duration of the marriage was less than twenty years at the time of the first interview in 1970. Only white couples were included in the 1970–1975 panel. A description of the 1970 NFS and an outline of the design of the 1975 resurvey are presented in Westoff and Ryder (1977).

The survey provides a month-by-month calendar of contraceptive use, by technique; pregnancies, pregnancy outcomes, intercourse behavior of the couple (abstinence or not), and labor market behavior by the wife from the 1970 to the interview date in 1975, as well as the usual socioeconomic information in both 1970 and 1975. The residential location of the couple in 1970, which is assumed relevant for reproduction in the period, is also provided. Based on this latter information, a series of variables were appended to the micro data to describe the state or SMSA in which each couple resides, including local prices, labor market characteristics, and measures of the availability of public health and family planning services.

The dependent variable measuring fertility is the number of conceptions occurring between the interview dates divided by the months of exposure to the risk of conception, namely, the months in which the wife was not pregnant and/or in which the couple was not abstaining from intercourse.[11] Four fertility control variables are constructed based on the monthly calendar information: the proportions of the total exposure period between 1970 and 1975 (during which the woman was subject to the risk of conception) that the couple was (1) sterilized, (2) using the pill or IUD, (3) using the diaphragm or condom, (4) using "ineffective" techniques (foam, jelly, rhythm, etc.). The grouping of contraceptive methods is based on standard conventions and beliefs on the relative effectiveness of such methods in the U.S. population (Vaughan, Trussell and Menken, (1977), Westoff and Ryder, (1977), Bongaarts and Potter (1983)).[12] Note, however, that none of these studies has taken into account biases associated with self selection of birth control techniques.

Also included in the reproduction function, and treated as endogenous, are the number of children born by 1970, the monthly frequency of intercourse, and the wife's smoking.[13] The monthly frequency of intercourse is reported in 1970 and 1975, and the average is assumed to apply uniformly throughout the period of exposure. Months of abstinence from intercourse during the five-year period, as noted, are excluded from the period at risk. Smoking by the mother in 1970 may influence reproductive capacity, since it appears that smoking reduces gestation and birth weight, and elevates infant mortality and fetal wastage (e.g. Rosenzweig and Schultz (1983), Praeger et al. (1984)) and thus could influence pregnancy wastage and the likelihood of conception. Unfortunately, the amount of smoking during the period is not known, only whether the woman smoked in 1970 (Note in Table 1 that coding is inverted for this variable).

The set of instruments characterizing the couple's tastes, opportunities and constraints is extensive; information is employed on the personal characteristics of the couple that were thought to be exogenous with respect to the fertility decision, such as the husband's earnings (not that of the wife's) and the husband's and wife's education, religious affiliation, and age, and features of the residential area that influence employment opportunities and the relative costs of children and other goods, including medical and family planning infrastructure and services, and local sales taxes and prices (See Table 1 for full list.)

The final sample with complete reproductive histories and sets of characteristics and who were capable of conceiving at the 1970 interview date contains 1753 couples.[14] The average age of the wife was 27.4 years in 1970, and ranges from 15 to 42; the couples had on average 1.9 children in 1970 and had 2.5 children by the second interview in 1975. Descriptive statistics for the working sample and variable definitions are reported in Table 1.

Because the exposure period is relatively short — a maximum of five years — and the overall demand for children among U.S. couples is low, a large proportion of the sample had no conceptions (53 percent). As a consequence, use of least squares, even with instruments, will yield inconsistent estimates of the reproduction technology and thus of the exogenous supply of births among the

Table 1

Variable Definitions and Sample Characteristics

Variables	Definition	Mean	Standard Deviation
Endogenous Variables			
Average Monthly Conception Rate, 1970-1975	Ratio of the number of conceptions, to the number of months of pregnancy risk (exposure period).[a]	.0128	.0181
Sterilization	Proportion of exposure period, 1970-75, that is protected by sterilization.	.155	.277
Pill or IUD	Proportion of exposure period, 1970-75, using the pill or IUD.	.408	.397
Diaphragm or Condom	Proportion of exposure period, 1970-75, using the diaphragm or condom.	.146	.304
Ineffective Methods	Proportion of exposure period, 1970-75, using jelly, foam, douche, withdrawal, rhythm or other methods.	.132	.281
No Method	Proportion of exposure period, 1970-75, using no method (or do not know).	.160	.286
Births	Number of live births born to mother before 1970.	1.95	1.49
Not Smoking	Mother is smoking in 1970. (1=Yes, 2=No).	1.65	.477
Coital Frequency	Average monthly coital frequency, 1970 and 1975.	8.65	4.91
Exogenous Individual Characteristics			
Education	Years of Schooling completed by wife.	12.7	2.00
Income 1970	Husband's earned yearly income before taxes in 1970 ($).	9420	3820
Income 1975	Husband's earned yearly income before taxes in 1975 ($).	16100	8040
Husband's Age	Age of husband in months in 1970.	359.	77.2

Table 1 continued

Variables	Definition	Mean	Standard Deviation
Wife's Age	Age of wife in months in 1970.	329	69.4
Wife Protestant		.609	.238
Husband Protestant		.600	.241
Wife Catholic		.290	.206
Husband Catholic		.276	.200
Wife Jewish		.0164	.0161
Husband Jewish		.0169	.0166
Wife Mormon		.0327	.0316
Husband Mormon		.0304	.0295
<u>Exogenous Area Characteristics</u> [b]			
Health Expenditures	Local government health and hospital expenditures in thousands of dollars per capita, 1965, at state or SMSA level ($x10^2$).	.294	.119
Family Planning in Health Dept.	Number of health departments with family planning services per capita, 1969, at state or SMSA level ($x10^5$).	.907	3.73
Family Planning in Hospitals	Number of hospitals with departments with services per capita, 1969, at state level ($x10^5$).	.286	.462
Population per M.D.	Number of persons per medical doctor, 1969, at state or SMSA level.	1630	1030
Metropolitan	One if located in standard metro politan statistical area, 0 otherwise.	.538	.499
City Size	Population in SMSA in 1970 ($x10^{-3}$).	1280	2460
Hospital Beds	Number of hospital beds per capita ($x10^2$), 1965, state level.	.480	.111

Table 1 continued

Variables	Definition	Mean	Standard Deviation
Obstetrician-Gynecologists per Capita	Number of obstetricians-gynecologists per capita at state or SMSA level ($x10^4$).	.755	.687
Female Unemployment Proportion	Proportion of women in labor force, age 15-59, unemployed, 1970, at state level.	.0510	.00978
General Unemployment Proportion	Proportion of the labor force unemployed, 1970, at state level.	.0407	.0110
Share of Jobs in Services	Percent of persons employed in services, 1970, at state level (x10)	75.5	18.0
Share of Jobs Sales	Percent of persons employed in sales, 1970, at state level (x10)	167	61.8
Share of Jobs in Government	Percent of persons employed in government, 1970, at state level (x10).	167	61.8
Cigarette Price	Price of cigarettes before taxes, cents per pack, 1967-69, at state level.	34.4	3.18
Sales Tax	Retail sales tax on cigarettes, cents per pack, 1967-69, at state level.	1.22	.873
Milk Price	Retail price of milk per quart, 1970, at state level.	26.9	2.40

a. The period of exposure approximates the number of months between the two interviews that the woman is exposed to the risk of conception. Those months are excluded during which the couple abstain from intercourse and in which the woman is pregnant. The average period of exposure for the sample is 62 months, and if abstinent months were included, the average period of exposure would be increased by 1.3 percent.

b. Sources of the area characteristics are described in Rosenzweig and Schultz (1983). Where both state and SMSA characteristics are used, those individuals residing in an SMSA are attributed the characteristics for that SMSA, and those residing outside of a SMSA are attributed the average characteristic for their state.

sample couples.[15] Accordingly, we employ maximum likelihood methods to estimate a limited dependent variable (Tobit) model. Because the properties of the Tobit model estimates may be sensitive to the imposed and unverifiable assumption of normality of the underlying distribution of unobservables, the Tobit estimates could be more asymptotically biased than those estimates obtained using the linear specification (Nelson, 1981). We report coefficient estimates from the linear and censored normal models. Both are estimated with and without instruments to assess the role of selection bias associated with fertility supply variation.

4. Estimates of the Reproduction Technology

Table 2 reports the ordinary least squares (OLS), two-stage least squares (TSLS), and single and two-stage Tobit estimates of the reproduction function, with the expected value derivatives derived from the Tobit linear coefficients reported in brackets adjacent to the relevant Tobit index coefficients.[16] The specified nine inputs directly explain (OLS) 26 percent of the variation in the monthly conception rate. However, Wu (1974)-Hausman (1978) specification tests confirm, at the one percent level of confidence, that the seven conception inputs, excluding age, are jointly correlated with the "fecundity" residual. Indeed, as predicted, the estimates of the reproductive effects of all of the contraceptive methods are understated by the single-stage estimates compared with the consistent, but somewhat less precise, two-stage estimates designed to deal with contraception selectivity. The estimated effectiveness of the pill/IUD is understated by 100 percent (linear) and 38 percent (Tobit), respectively; the estimated effectiveness of the diaphragm and condom increases by 107 percent in either specification when

Table 2

Linear and Censored Normal (Tobit) Specifications of the Reproduction Function: Single-Stage and Two-Stage Estimates

Functional Specification/ Estimation Method	Linear Model Coefficients OLS	TSLS	ML Tobit Index Coefficients Single Stage		Two Stage	
Explanatory Variables:	(1)	(2)	(3)		(4)	
Proportion of exposure period protected by:						
Sterilization[a]	-.00453	-.0399	-.00448	[-.00236][d]	-.0722	[-.0380][d]
	(2.44)[b]	(2.93)[b]	(1.22)[c]		(3.18)[c]	
Pill or IUD[a]	-.0112	-.0232	-.0229	[-.0120]	-.0315	[-.0165]
	(7.39)	(2.27)	(7.52)		(1.86)	
Diaphragm or condom[a]	-.00509	-.0161	-.0115	[-.00604]	-.0295	[-.0155]
	(2.99)	(1.38)	(3.27)		(1.51)	
Ineffective methods[a]	-.00277	-.00861	-.00388	[-.00204]	-.00751	[-.00395]
	(1.52)	(0.58)	(1.07)		(0.31)	
Births before 1970	-.0940	.0539	-.184		.0225	
($x10^2$)[a]	(2.91)	(0.35)	(2.76)		(0.09)	
Coital frequency	-.143	.122	-.358		.138	
($x10^{-3}$)[a]	(1.85)	(0.17)	(2.41)		(0.11)	
Not smoking[a]	.00133	.0172	.00266		.0291	
	(1.70)	(3.41)	(1.71)		(3.51)	
Age of woman ($x10^{-3}$)	-.364	-.284	-.225		-.0481	
	(7.14)	(3.01)	(2.09)		(0.30)	
Age squared ($x10^{-6}$)	.356	.241	-.0869		-.304	
	(4.88)	(1.95)	(0.54)		(1.40)	
Intercept	.0994	.0677	-.0967		.0283	
	(11.46)	(4.23)	(5.49)		(1.05)	
Standard error	-	-	.0262		.0270	
	-	-	(38.99)		(38.67)	
R^2	.264	-	-		-	
F/lnlikelihood	69.45	42.47	1361		1322	

[a]Endogenous variable. For instrument list, see table 1.
[b]Absolute value of t-ratios reported in parentheses beneath regression coefficients.
[c]Absolute values of asymptotic t-ratios in parentheses beneath regression coefficients.
[d]Bracketed terms are the derivatives of the expected value of the conception rate evaluated at the sample mean values.

instruments are used. The most significant bias appears to be imparted to the sterilization coefficient; the two-stage instrumented coefficients are almost 9 times (linear) and over 16 times (Tobit) the size of their single-stage counterparts. Notable is the implication of the two-stage estimates that the diaphragm and condom methods are on a par with the pill and IUD in contraceptive effectiveness as used by a representative couple; both methods, however, are less than half as "use-effective" as sterilization.

The consistent two-stage Tobit point estimates suggest that the sample mean conception rate when no method of contraception is practiced is about 2.5 percent per month.[17] The change in conception rates associated with the use of a specific contraceptive based on the estimated Tobit index coefficients suggests that switching from no method to sterilization, the pill or IUD and the diaphragm or condom reduces the probability of conception, given sample usage, to zero, by 55 percent, and by 52 percent, respectively. The coefficient for ineffective methods is not statistically different from zero, indicating that such methods are classified appropriately. The two-stage Tobit coefficients for the wife's age are also estimated too imprecisely to accurately depict the age trajectory of potential fertility supply. However, the age variables are jointly statistically significant (χ^2 test, .05 significance level).

Of the other reproduction variables, the number of births accumulated prior to 1970 is negatively correlated with the monthly probability of conception from 1970 to 1975 (OLS and single-stage Tobit estimates); however, this pattern is apparently not rooted in reproductive biology, as neither the two-stage linear nor the Tobit estimates reveal any statistically significant relationship between prior fertility and subsequent conception rates, given contraception. Not smoking appears to increase the conception rate according to the two-stage estimates, as is consistent with recent findings in the medical literature (Praeger *et al*. (1984). The data do not confirm any significant effect of coital frequency on fertility: the direct association (single stage) is weak but inverse, whereas the two-stage estimates are essentially zero, though of the anticipated sign. The imprecise estimate of the coital frequency effect may be in part due to the inability of the instruments to predict well the variation in this variable (R^2=.067).

5. Fecundity, Fertility and Life-Cycle Adjustments in Contraception, Female Labor Supply, and Earnings.

The two-stage Tobit estimates of the effects of contraception on the monthly probability of conception, while interesting by themselves, enable the separation of the behaviorial and biological components of fertility so that the consequences of variation in fertility supply can be assessed. The two-stage estimates provide a consistent prediction for each couple of its fertility (conception rate) based on its actual choice of contraceptives. The difference between this consistent prediction, based on the reproduction technology and actual behavior, and the couple's actual conception rate contains the persistent and random components of fertility that are beyond the couple's control, namely, unexplained deviations in fertility supply. These prediction "errors" can be computed for different segments of the life cycle in order to decompose the supply errors into their persistent and random parts.[18]

Because of the truncation at zero of the conception probability, and hence the use of the Tobit estimation procedure, the predicted or expected value of the conception rate n^e_{ij} for each couple j in period i is computed from the formula:

$$n^e_{ij} = E(n_{ij}) = \Phi_{ij} B'F_{ij} + \sigma\phi_{ij}, \qquad (15)$$

where B' is the vector of estimated (two-stage) Tobit index coefficients (Table 2, column 4), F_{ij} is the vector of actual input values for couple j in period i, Φ and ϕ are the cumulative normal and normal density values evaluated on the basis of the couples' actual input values, and σ is the estimated Tobit standard error. A consistent (i.e., as t goes to infinity) estimate of the persistent or fixed component of fertility supply for a couple j for whom fertility, net of inputs, is computed for each of t periods, from (15), is:

$$\mu_j = \sum_{i=1}^{t} (n_{ij} - n^e_{ij})/t \tag{16}$$

and thus the period-specific, unanticipated fertility component is:

$$\varepsilon_{ij} = n_{ij} - n^e_{ij} - \mu_j. \tag{17}$$

To estimate a couples' response to variation in the persistent and transitory supply components, we divide the five-year period containing the calendar information from which the reproduction technology was estimated into two equal two and one-half year segments to compute μ and ε. Our estimates imply that somewhat more than half of the unexplained variation in fertility is persistent, that is $\sigma^2_\mu/(\sigma^2_\mu+\sigma^2_\varepsilon) = .56$. While a greater number of interval segments might be desirable for estimating the permanent and transitory components of fertility supply, short intervals provide little information about fecundity in a setting where the average level of contraceptive effectiveness is high, as in our sample.

If the measure of fecundity μ based on the average of the two intervals from 1970-75 reflects that component of fertility supply that is persistent, then, given imperfect and costly fertility control, variation in μ should explain a significant proportion of the variance in the number of total births born to couples.[19] Moreover, since μ is denominated as a conception rate, its effect on cumulated births should increase over the life-cycle of the couple. Columns one and two of Table 3 report regressions of the number of children ever born on a set of socioeconomic variables reflecting the demand for births excluding and including, respectively, the constructed measure of couple-specific fecundity and its interaction with the wife's age. As expected, couples with a higher biological propensity to conceive, net of their efforts to reduce conceptions or births, do accumulate increasingly more births as they age, after age 20. Indeed, explanatory power increases by 60 percent when the fertility supply and supply-age interaction variables are added to the set of demand (instrumental) variables. Inter-couple heterogeneity in the exogenous supply of births accounts for slightly more than 10 percent of the total variation in cumulated births across families.

Figure 1 plots the cumulative effects on children ever born of variation in μ of one standard deviation around the sample mean, based on the μ coefficients in Column 2 of Table 3. As shown, couples with a fecundity level that is one-standard deviation above the mean accumulate 0.44 "extra" births by the time the wife is age 30, 0.68 additional births at age 35, and 0.90 additional births when the wife reaches age 40.

The positive association between μ and cumulative fertility that increases with age could be merely an artifact of μ being measured in the last five years of each couple's life cycle. The same regression is reported, therefore, employing children ever born in 1970 as the dependent variable. Fecundity, as measured in the 1970-75 period, should be related to fertility before 1970, if μ represents a persistent biological predisposition to conceive,

Table 3

Effects of Exogenous Fertility Supply on Actual Fertility in 1975 and 1970[a]

Dependent Variable:	Children Ever Born-1975		Children Ever Born-1970
Specification:	(1)	(2)	(2)
Explanatory Variables:			
μ-persistant individual fixed effect (fecundity)	-	-49.0	-42.6
	-	(4.37)	(5.03)
μ x wife's age	-	.202	.147
		(6.45)	(5.07)
Education	-.104	-.111	-.131
	(5.02)	(5.72)	(7.27)
Income 1970 ($x10^{-4}$)	.144	.140	.207
	(1.26)	(1.30)	(2.07)
Income 1975 ($x10^{-4}$)	.0526	.0272	.0150
	(1.02)	9.56)	(0.33)
Wife's age	.0235	.0261	.0371
	(4.50)	(5.31)	(9.66)
Wife's age squared ($x10^{-4}$)	-.245	-.263	-.407
	(3.90)	(4.47)	(7.44)
Husband Protestant	.206	.139	.0345
	(1.42)	(1.02)	(0.27)
Husband Catholic	.409	.389	.289
	(2.54)	(2.58)	(2.06)
Husband Jewish	-.0650	-.0361	-.00824
	(0.10)	(0.06)	(0.01)
Husband Mormon	.775	.619	.281
	(1.73)	(1.47)	(0.71)
Female unemployment rate	1.61	2.85	-4.02
	(0.16)	(0.31)	(0.47)
Family Planning in Health Department	-1839	-2355	-1515
	(1.40)	(1.92)	(1.33)
Health Expenditures	99.1	127	100
	(2.28)	(3.11)	(2.64)
Intercept	-6.75	-4.93	-4.94
	(1.99)	(1.54)	(1.71)
R^2	.181	.282	.412
F	11.85	19.80	35.34

[a]All instruments in Table 1 are included, but only selected socioeconomic variables are reported. Absolute values of t-ratio's in parentheses beneath regression coefficients.

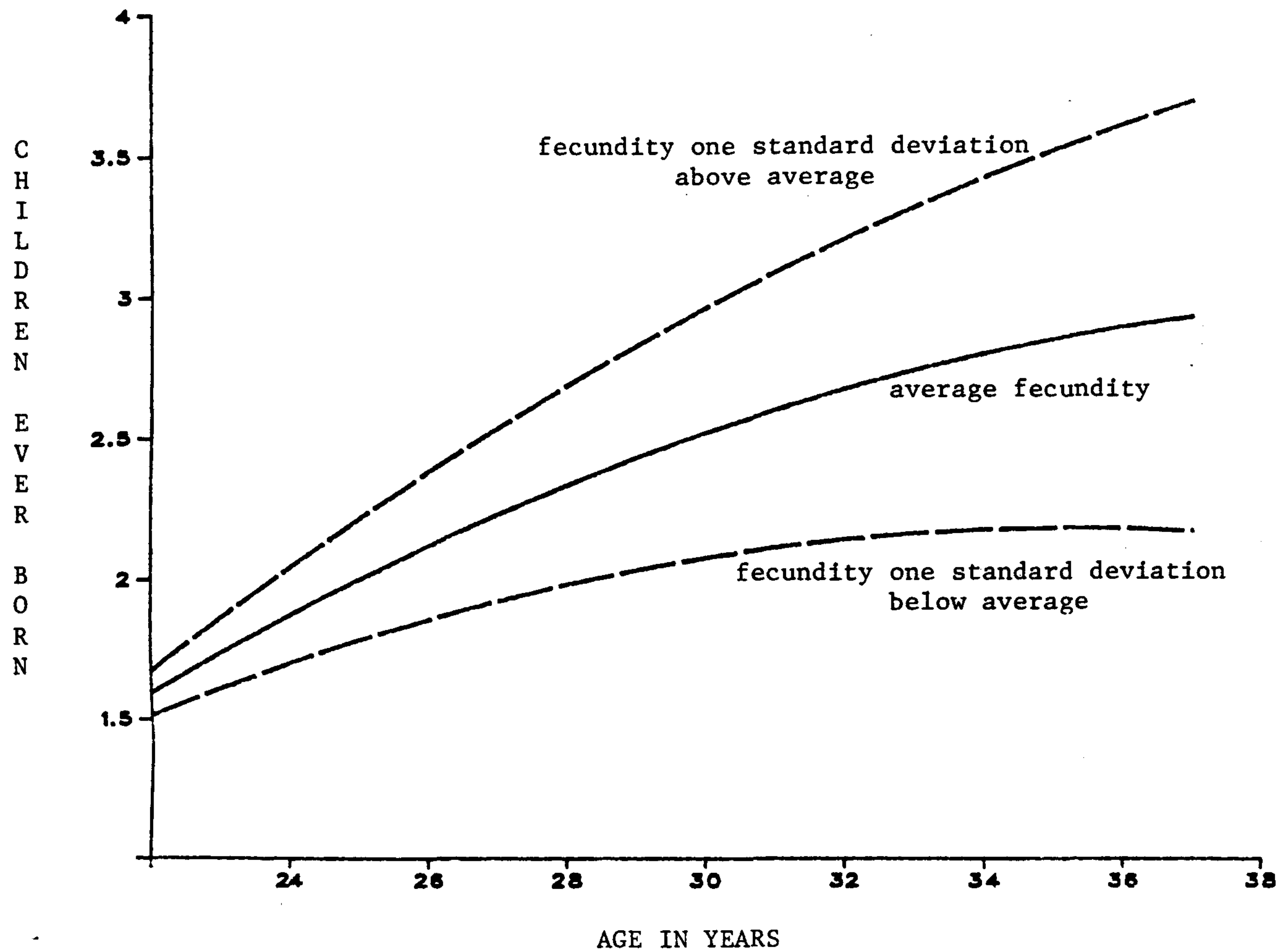

Figure 1. Children Ever Born by Age and Fecundity

and column 3 of Table 3 displays essentially the same patterns as when the later measure of fertility is employed. Couples observed to have higher fecundity in the 1970-75 period also appear to have accumulated a greater number of births by 1970, if the wife was then over age 24. We feel justified, therefore, in tentatively interpreting our estimate of μ as the individually persistent component of fertility supply, as a measure of couple fecundity .

a. Contraceptive Selection

The shortfall or excess in births associated with fecundity variation is the net result of both the inherent propensities to conceive and a couple's allocative response to such supply constraints. As the model suggested, whether or not couples can distinguish persistent from random supply shocks, they will react to them over time by reallocating reproductive inputs in order to better equilibrate their realized supply of births to their demand for births. Table 4 reports maximum likelihood Tobit coefficients describing how variations in fecundity (μ) and how random fertility shocks (ε), as measured in the first 2.5 years of the 1970-75 interval, affect (1) the mix of contraceptive methods chosen in the second 2.5-year period and (2) the demand for additional births at the end of the interval in 1975, as measured by the couples' responses to a question concerning their "intended" number of children. All coefficients are estimated using maximum likelihood Tobit to take account of the concentration of observations at zero for each dependent variable.

The findings in Table 4 indicate that couples with above-average fecundity become sterilized earlier, use the diaphragm or condom more frequently, and use ineffective methods less frequently in the later interval. For given fecundity, couples experiencing an unexpectedly higher conception rate in the first interval spend a smaller proportion of the next interval without any protection and employ ineffective methods less frequently compared to couples who had experienced no fertility "shock." Such couples are also marginally more likely to use the pill or IUD and marginally less likely to become sterlized. The evident reluctance of couples with only a temporary shock

Table 4
Effects of Exogenous Fertility Supply in 1970-1972, on Contraceptive Use in 1973-75, By Method, and on Fertility Demand in 1975[a]

Dependent Variable:	Proportion of Period June 1972 to 1975 Using Method: Sterilization	Pill or IUD	Diaphragm or Condom	Ineffective Methods	No Method	Demand for Additional Births in 1975
Estimation Method:	ML Tobit	ML Tobit	ML Tobit	ML Tobit	ML Tobit	ML Tobit
Explanatory Variable:						
μ -persistant individual fixed effect (fecundity)	14.5	-1.15	5.25	-5.58	.152	-13.0
	(5.52)	(1.06)	(3.02)	(3.25)	(0.14)	(3.07)
ε -random effect	-2.64	1.83	-2.49	-3.26	-10.8	1.20
	(1.43)	(1.49)	(1.26)	(1.69)	(7.69)	(0.34)
Intercept	-.445	.101	-.751	-.795	-.418	-2.30
	(2.97)	(4.74)	(14.0)	(14.94)	(9.92)	(13.7)
Standard error	.970	.745	.996	.958	.714	2.25
	(5.38)	(41.4)	(23.1)	(22.2)	(17.1)	(18.5)
Log Likelihood	1364	1651	1093	1000	1095	1040

[a]Absolute values of asymptotic t-ratios in parentheses beneath index coefficients.

to fertility to employ the more permanent and irreversible form of contraception compared to couples with higher fecundity is further confirmation that μ is measuring the more persistent component of fertility supply. Finally, the last column of Table 4 indicates that, as expected, more fecund couples reduced their demand for additional births or, conversely, sub-fecund couples had a higher unmet demand for children by 1975.[20]

A natural way to summarize quantitatively the contraceptive adjustments made over the life-cycle by couples experiencing different fertility supplies is to weight, for each couple, the contraceptive effectiveness of each of the methods, as estimated in Column 4, Table 2, by the proportions of the interval each method was employed by the couple. Table 5 reports regressions of this measure of the average effectiveness of contraceptive practices employed in the 1973-75 interval on μ and ε, as measured in the 1970-72 interval, and on the set of socioeconomic variables. In column 1, Table 5, the hypotheses are confirmed at the 1 percent level that (i) couples with higher fecundity choose more efficient methods and (ii) the reallocation of methods is stronger when μ varies than when there are changes in the serially uncorrelated supply of births, ε. In column 2, the hypothesis that the adjustments to persistent fertility supply effects grow stronger over the life-cycle is also confirmed -- as higher-μ couples age, they adjust upward their contraceptive effectiveness.[21] The point estimates indicate, as plotted in Figure 2, that couples whose fecundity is one standard deviation higher than the sample mean exhibit an average contraceptive effectiveness that is 13 percent higher when the wife is age 25, 23 percent higher when she is 30, and 45 percent higher when she is 40, compared to couples of the same age with average fecundity. As shown in Table 3 and Figure 1, however, these adjustments are not sufficient to offset fully the persistently higher conception rate. The offset to the higher "supply" level is 10 percent by age 25 and reaches only 43 percent by age 40. Unwanted births according to these estimates are still a substantial share of all U.S. births in 1970-75, as is consistent with subjectively-ascertained responses from fertility surveys (Westoff and Ryder (1977)).

Table 5

Effects of Exogenous Fertility Supply and Actual Fertility, by 1972, on Contraceptive Effectiveness in 1973-75[a]

Explanatory Variable:	Specification (1)	(2)	(3)	(4)
μ - persistent individual fixed effect (fecundity)	.137 (10.16)	-.443 (5.09)	- -	- -
μ x wife's age (x10^{-2})	-	.180 (6.75)	-	-
ε - random effect	.0350 (2.28)	.0151 (0.15)	-	-
ε x wife's age (x10^{-4})	-	.659 (0.21)	-	-
Children ever born, 1972 (x10^{-2})	-	-	.236 (11.5)	.567 (4.72)
CEB x wife's age (x10^{-5})	-	-	-	-.814 (2.78)
Children born 1970-72 (x10^{-3})	-	-	.373 (0.72)	-.927 (0.29)
CB x wife's age (x10^{-5})	-	-	-	.205 (0.22)
Education (x10^{-3})	-.434 (2.78)	-.487 (3.16)	-.143 (0.91)	-.0771 (0.49)
Income 1970 (x10^{-7})	.102 (1.19)	.0941 (1.10)	.490 (0.57)	.310 (0.36)
Income 1975 (x10^{-7})	.0013 (0.29)	.0493 (0.13)	.153 (0.40)	.147 (0.38)
Wife's age (x10^{-3})	.204 (5.60)	.198 (5.50)	.112 (3.01)	.0710 (1.50)
Wife's age squared (x10^{-6})	-.239 (5.05)	-.230 (4.91)	-.143 (2.99)	-.0696 (1.09)
Husband Protestant (x10^{-2})	-.0917 (0.84)	-.0885 (-.82)	-.0792 (0.73)	-.0734 (0.68)
Husband Catholic (x10^{-2})	-.0602 (0.50)	-.0749 (0.63)	-1.42 (1.19)	-1.31 (1.10)
Husband Jewish (x10^{-2})	-.917 (1.96)	-8.78 (1.91)	-7.88 (1.70)	-7.65 (1.66)
Husband Mormon (x10^{2})	-.511 (1.51)	-4.35 (1.31)	-5.12 (1.53)	-5.14 (1.54)
Female unemployment rate	-.0219 (0.30)	-.0235 (0.32)	-.0357 (0.49)	-.0365 (0.50)
Family planning in health department	150 (2.51)	146 (2.47)	99.1 (1.68)	92.9 (1.59)
Health expenditures	-.148 (0.45)	-.0737 (0.23)	-.512 (1.58)	-.546 (1.69)
Intercept	.0170 (0.67)	.0154 (0.62)	.0202 (0.81)	.0250 (0.99)
R^2	.118	.145	.138	.143
F	6.77	8.10	8.11	7.95

[a]All instruments in Table 1 are included, but only selected socioeconomic variables are reported. Absolute values of t-ratios in parentheses beneath regression coefficients.

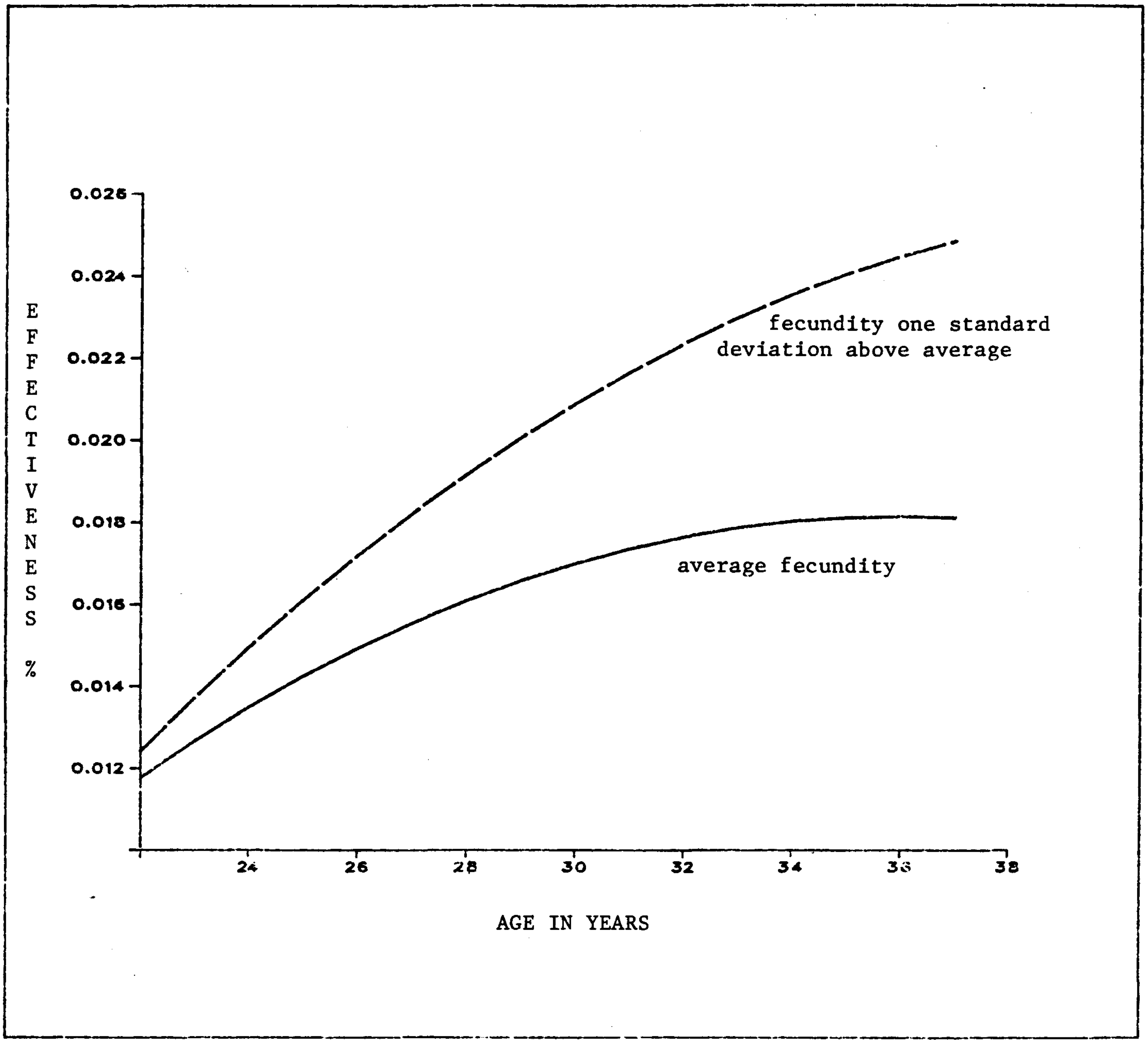

Figure 2. Contraceptive Effectiveness by Age and Fecundity

In columns 3 and 4 of Table 5, the persistant and temporary measures of fertility supply are replaced by the couple's actual fertility — its cumulated births through 1972 and actual births occuring in the interval 1970-72 — in order to assess how well actual prior fertility serves as a proxy for exogenous fertility supply. This comparison enables us to measure the bias from or the consequences of specifying actual fertility as a variable conditioning household decisions, when fertility itself also embodies the effects of household preferences. As discussed in section 2, the existence of a serial correlation in couple-specific preferences should bias downward the effect of fertility supply variation on contraceptive choice when actual fertility is used to represent exogenous supply. This is confirmed in Table 5: The estimates of Table 3 indicate that μ must be higher by .0427 in order for cumulated births to increase by one for a woman whose age is at the sample mean in 1972 (age 30). The estimates of column 2 in Table 5 indicate that this increase in fecundity, sufficient to raise actual fertility by one birth, would increase contraceptive effectiveness by .0087 or by 54 percent. In contrast, a one-birth rise in actual fertility (column 4) is associated with only a .0028 or 17 percent increase in contraceptive effectiveness at the sample means. The life-cycle adjustment in contraceptive choice to fertility supply variation, as measured by actual fertility, is less than one-third that measured by using μ, which presumably is purged of any fertility-preference component. The magnitude of bias is, therefore, considerable in treating fertility as exogenous in the study of contraceptive practice.

The understatement of the dynamic adjustments in contraception to fecundity variation is not the only consequence of regressing, essentially, current fertility demand variables (i.e. contraception) on lagged fertility, as in most previous studies of contraceptive choice (Michael (1973); Michael and Willis (1975)). Since actual fertility, because it is partially demand-determined, is conditioned by prices and characteristics of the parents, lagged fertility will pick up the effects of these fertility determinants on current contraceptive choice. This is also seen in Table 5. In column 2, in which μ and ε are included, the two most significant "demand" determinants of the effectiveness of contraception, aside from age, are the wife's education and the extent of local family planning programs.[22] In the specifications in which measures of prior fertility are included as regressors, however, the coefficients on these two variables are reduced substantially: the wife's schooling coefficient is reduced in absolute value by 75 percent and loses its statistical significance; the statistically significant positive family planning coefficient is reduced in absolute value by a third.

b. Female Life-Cycle Labor Supply and Earnings.

In the second half of the five-year interval between the 1970 and 1975 interview dates, 64 percent of the sample wives worked at least four days per week in one month. Wives' participation in the labor market, according to this definition, rose from 51 percent in any month during 1973 to 54 percent in the year preceding the last interview in 1975. Columns 1, 3 and 5 in Table 6 report Tobit maximum likelihood estimates of the effects of variations in the persistent and transitory measures of fertility supply on these measures of the wife's labor supply.[23] In all equations, the fertility supply variables add significantly to the likelihood function. The estimates indicate that among couples whose fecundity is one standard deviation above the population mean, the proportion of months between 1973 and 1975 in which the wife participated in the labor market was reduced by 16 percent. As was evident for fertility and contraception, moreover, the effects of fecundity variation appear to increase over the life-cycle — among the highly-fecund couples, the probability that the wife participated in the labor market was 12 percent lower in 1973 and was 17 percent lower in 1975.

Table 6
Effects of Exogenous Fertility Supply and Actual Fertility on Subsequent Measures of Female Labor Supply[a]

Dependent Variable:	Proportion of Interval Employed in 1973-1975		Participation in 1973		Participation in 1975	
Estimation Method:	ML Tobit		ML Probit		ML Probit	
	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variable:						
μ -persistant individual fixed effect (fecundity)	-5.55 (6.75)	-	-7.84 (4.48)	-	-12.4 (6.90)	-
ε -random effect	.162 (0.17)	-	-4.50 (2.27)	-	4.13 (2.04)	-
Children ever born, 1970	-	-.00371 (0.31)	-	-.0411 (1.56)	-	.0369 (1.41)
Children born 1970-1972	-	-.236 (8.28)	-	-.502 (8.14)	-	-.388 (6.42)
Education	.0545 (7.07)	.0555 (7.03)	.115 (6.81)	.116 (6.62)	.107 (6.34)	.113 (6.53)
Income 1970 ($x10^{-4}$)	-.0678 (1.35)	-.0638 (1.27)	-.237 (2.19)	-.231 (2.11)	-.149 (1.38)	-.138 (1.27)
Income 1975 ($x10^{-4}$)	-.155 (6.68)	-.156 (6.71)	-.238 (4.79)	-.243 (4.85)	-.259 (5.25)	-.261 (5.29)
Wife's age	-.00232 (1.09)	-.00421 (1.92)	-.0117 (2.54)	-.0136 (2.83)	.00330 (0.72)	-.00197 (0.42)
Wife's age squared ($x10^{-4}$)	.0443 (1.59)	.0606 (2.14)	.169 (2.80)	.181 (2.92)	.0145 (0.24)	.0338 (0.55)
Husband Protestant	-.126 (2.35)	-.116 (2.19)	-.218 (1.85)	-.204 (1.71)	-.199 (1.67)	-.189 (7.59)
Husband Catholic	-.182 (3.15)	-.165 (2.85)	-.258 (2.03)	-.213 (1.65)	-.298 (2.33)	-.300 (2.35)
Husband Jewish	-.0706 (0.58)	.0930 (0.76)	-.0937 (0.35)	-.169 (0.63)	.0588 (0.22)	.0495 (0.18)
Husband Mormon	-.219 (2.22)	-.190 (1.94)	-.593 (2.77)	-.510 (2.35)	-.433 (2.06)	-.425 (2.03)
Female unemployment rate	-1.02 (0.65)	-.908 (0.59)	-5.32 (1.59)	-5.30 (1.58)	-1.47 (0.44)	-1.19 (0.35)
Family planning in health department	1871 (0.60)	2616 (0.84)	-3641 (0.54)	-1776 (0.26)	2706 (0.40)	3719 (0.55)
Health expenditures	-3.96 (0.31)	-3.34 (0.26)	13.6 (0.50)	18.3 (0.67)	1.16 (0.04)	.362 (0.13)
Intercept	.320 (0.79)	.850 (2.04)	1.58 (1.80)	2.33 (2.55)	-1.42 (1.63)	-.183 (0.20)
Standard error	.563 (49.2)	.560 (48.9)	-	-	-	-
Log Likelihood	1475	1465	1150	1130	1139	1142

[a]Absolute values of asymptotic t ratios in parentheses beneath slope coefficients.

In contrast to the persistent fecundity effects embodied in μ, a transitory increase in the supply of births appears to have little or no lasting effect on the proportion of time spent by the wife in the labor market in the 2.5-year interval following the unanticipated birth (column 1). While the wife's probability of participation falls in the year immediately following the interval during which the fertility supply shock occurs (column 3), the likelihood of her participating increases by almost as much two years later (column 5). This compensatory pattern of life-cycle labor supply response to exogenous, transitory changes in fertility is similar to that found by Rosenzweig and Wolpin (1980) in their study of the labor supply responses of women experiencing an (unanticipated) multiple birth in their first pregnancy.

Estimates of the associations between actual cumulative and recent fertility and female labor supply (columns 2, 4 and 6 of Table 6) provide a different picture of the causal relationship between the timing of labor supply and exogenous changes in fertility. The number of children ever born prior to 1970 has no significant association with the wife's labor market time in the 1973-75 period; higher cumulated births prior to 1970 are associated with a marginally lower participation probability in 1973, but are associated with a marginally higher participation probability in 1975. The number of children born between 1970 and 1972, however, is significantly and negatively associated with time worked by the wife in the 1973-75 period and with labor-force participation probabilities in both 1973 and 1975.

These labor supply-fertility results, based on actual fertility values, are often interpreted as reflecting the greater "time-intensity" of younger children (Willis (1973)). However, in contrast with μ and ε, which are independent of preferences by construction, actual fertility will be correlated with latent taste factors that also influence labor supply. It is thus not possible to rule out the hypothesis, for example, that women who postpone births do so in order to participate in the labor market while young. With respect to quantitative effects, the associations between actual fertility in the 1970-72 period and the wife's participation in 1973 and 1975 overstate both the immediate (1973) negative and longer term labor supply responses to an unanticipated birth. The wife's probability of labor force participation is reduced at the sample means by 40 percent in 1973, and by 28 percent in 1975, in response to an actual birth between 1970-72. The arrival of an unanticipated birth in the same 30-month period (less 9 months for the pregnancy) would require an increase in the monthly conception rate of approximately 1/21; this increase in ε sufficient to yield one unanticipated extra birth would reduce the wife's likelihood of participation by only 18 percent in the following year (1973), and increases the participation probability by 14 percent in 1975.[24]

Given heterogeneity in preferences, it would be expected that the use of actual fertility might lead to negatively-biased estimates of labor supply responses to exogenous variations in fertility supply. However, the estimates in Table 6 suggest that none of the other estimated coefficients in the labor supply equations are importantly affected by whether or not actual fertility variables are included as regressors in place of the fertility supply variables. This is in marked contrast to the estimates of the contraception equations.

One important labor supply determinant left out of the equations reported in Table 6, and likely to be correlated with fertility, is the wife's wage. This was deliberate, since we regard the wage rate received by the wife as endogenously-determined, a function of work experience and thus of prior labor supply decisions. Our estimates thus show the reduced-form effects of exogenous variation in fertility supply on life-cycle allocation decisions. We can, however, also examine the net effect of unanticipated fertility variation on the earning of the wife. If children and the wife's home time are complements, as our labor supply estimates suggest, and there are important payoffs to work experience, then we would expect that more fecund wives would have less labor force experience and thus would receive a lower wage rate at any age. Variation in the supply of births should also account for a significant proportion of the wage variation among married women.

Mincer and Polachek (1974) estimated the effect of fertility on the earnings of married women using actual cumulative fertility as a regressor. While they recognized the endogeneity of fertility, simultaneous equations methods were eschewed (correctly) because, as they noted, "...the fertility function would be estimated by the same variables as the labor supply function." (p. 599). Our procedure, which takes account of the reproductive technology, permits the estimation of the effects of exogenous variation in the supply of births on the earnings of married women without the need to impose arbitrary identification restrictions on the household demand system.

Table 7 reports estimates from three specifications of the determinants of the log of the weekly earnings for the subset of 972 wives working in 1975. Since human capital theory indicates that an individual's current wage is a function of his or her labor force experience, all determinants of the wife's labor supply are included in each specification. Note that this means that correction for selectivity bias resulting from self-selection by women into the labor market must rely on differences in functional form between the sample inclusion (labor force participation) and wage equations or on distributional assumptions. Use of the probit procedure to estimate the participation equation allows one test (Heckman (1974)) for selectivity bias. On the basis of this, we could not reject the hypothesis of no selectivity when either μ or actual fertility was included in the earnings equation (specifications (2) and

Table 7

Effects of Exogenous Fertility Supply and Actual Fertility on (Log) Weekly Earnings of Married Women, 1975[a]

Explanatory Variable:	Specification (1)	(2)	(3)
μ- persistent individual fixed effect (fecundity)	—	-5.28 (3.20)	—
Children ever born, 1975	—	—	-.0885 (4.27)
Education	.0632 (4.22)	.0648 (4.36)	.0533 (3.55)
Income 1970 ($x10^{-4}$)	-.128 (2.57)	-.134 (2.72)	-.133 (2.70)
Income 1975 ($x10^{-4}$)	-.156 (1.50)	-.155 1.50)	-.151 (1.47)
Wife's age ($x10^{-2}$)	-.279 (0.61)	-.409 (0.90)	-.111 (0.24)
Wife's age squared ($x10^{-5}$)	.596 (1.09)	.753 (.137)	.461 (0.85)
Husband Protestant	-.0481 (0.46)	-.0522 (0.50)	-.0348 (0.34)
Husband Catholic	-.114 (0.99)	-.122 (1.06)	-.0506 (0.44)
Husband Jewish	.137 (0.61)	.146 (0.65)	.148 (0.67)
Husband Mormon	-.383 (1.93)	-.350 (1.77)	-.284 (1.44)
Female unemployment rate	5.76 (1.87)	5.69 (1.86)	5.62 (1.84)
Family planning in health department	3200 (0.53)	3808 (0.63)	2851 (0.48)
Health expenditures	-10.8 (0.44)	-10.4 (0.42)	-5.59 (0.23)
Intercept	3.71 (3.95)	3.95 (4.22)	3.58 (3.84)
R^2	.0518	.0618	.0695
F	4.36	4.86	5.50

[a]All instruments in Table 1 included, but only selected socioeconomic variables are reported. Absolute values of t-ratios in parentheses beneath slope coefficients.

(3)). The hypothesis was rejected for the specification excluding fertility; however, coefficient estimates were essentially identical whether or not selectivity was "corrected" and the uncorrected estimates are reported for comparability across specifications in Table 7.

The findings reported in Table 7 confirm that inclusion of the fecundity variable increases the explanatory power of the female earnings regression, by 20 percent; persistent fertility supply variation alone accounts for about one percent of the total variation in earnings among married women. The coefficient on μ implies that a one standard-deviation increase in fecundity is associated with a 10 percent loss in the wife's weekly earnings, with the absolute amount of the earnings loss increasing over the life-cycle (since earnings rise). Variations in fecundity combined with imperfect and costly fertility control thus exert substantial effects on the distribution of market human capital accumulated by American wives, presumably by varying their experience and training in the labor market.

Actual cumulative fertility and the wife's earnings are also significantly and negatively associated. However, the coefficient on children ever born understates the decrease in female earnings due to variation in fertility supply — a rise in fecundity sufficient to yield an increase in one unanticipated or "excess" birth (from Table 3) for women aged 33 (the mean age of the sample women in 1975) would lower earnings by 17 percent, compared to the 9 percent reduction associated with a one-child increase in children ever born. Conditioning earnings on actual fertility also biases downward the coefficient on the wife's schooling in her earnings function by 18 percent.

Both of the estimates of the effects of fertility on the earnings of married women in Table 7 exceed those found by Mincer and Polachek; however, their earnings specifications included as regressors prior work experience.

When predicted work experience variables were used by them, in recognition of the endogeneity of labor supply, the coefficient on children ever born became positive. The positive relationship between actual fertility, net of cumulative labor supply effects, and female earnings found by Mincer and Polachek suggests that an (exogenous) increase in female earnings may increase the demand for children; use of actual fertility, reflecting both the demand for and supply of births, thus underpredicts the earnings loss from purely supply-induced or "unwanted" variations in fertility.

6. Conclusion

In our sample of white, married women in the United States in 1970, 27 percent of the couples reported that they had one or more unwanted children by 1975, while 62 percent reported that they had experienced one or more births earlier than they had intended. Thus, in a society which is relatively sophisticated with respect to contraception, the number and timing of births serves to constrain resource allocations for a significant proportion of households, and the stochastic nature of fertility is an important aspect of their decision-making. In this paper, we have developed a methodology for disentangling empirically in households the biologically-determined supply of births from the demand for births in order to assess the consequences of exogenous variation in fertility supply on household fertility behavior and their household allocation decisions. Our estimates indicate that variation in fertility reflects heterogeneity in both the preferences of households and inherant, couple-specific reproductive potential, with one-third of the explained variance in births due to heterogeneity in supply. Neither studies which have viewed fertility solely as an expression of individual choice, constrained and conditioned by prices and income, nor studies which have treated family size and age-composition as purely exogenous determinants of behavior thus provide appropriate estimates of the effects of fertility supply on household behavior or even of the consequences of contraception for the birth rate.

Our findings suggest that couples alter their mix of contraceptive methods over their life-cycle in response to their fertility supply experience. As a consequence of this dynamic behavior, estimates of the effectiveness of contraceptive methods that ignore heterogeneity in fertility supply significantly understate their effectiveness in reducing conceptions. Life-cycle patterns of labor force participation by married women are also shown to be sensitive to variations in the exogenous supply of births, and married women who experience excess fertility due to the lack of costless or perfect control over fertility supply incur a substantial loss in earnings when they enter the labor force.

Our attempt to isolate that component of fertility that is independent of preferences required estimation of the direct biological/technical relationships between endogenous and exogenous factors influencing the production of births. Our results thus could be sensitive to the specification and estimation of the reproductive technology. The data and approach appear to confirm, however, the importance of fecundity variation in motivating couples to pursue distinctive contraceptive and labor supply strategies. They also suggest the potential importance of the costs of and access to contraceptive technology in accounting for patterns of resource allocations among households, which should be of even greater importance in low income countries where contraceptive knowledge may be less pervasive.

Footnotes

* Professors of Economics, University of Minnesota and Yale University, respectively. This research was supported in part by grants from NIH, Center for Population Research, HD-12172 and the Hewlett Foundation to the Economic Demography Program at Yale. The authors have benefitted from the comments of the referees, Jere Behrman, Julie DaVanzo, James Heckman, Evelyn Lehrer, Daniel McFadden, and members of the Yale Labor and Population Workshop and the MIT Econometrics Workshop.

1. Exceptions to these traditions are Heckman and Willis (1975) and Rosenzweig and Wolpin (1980). Heckman and Willis construct a dynamic model of contraceptive choice incorporating stochastic fertility. However, their econometric application does not consider the behavioral implications of their model (see section 2, below). Rosenzweig and Wolpin exploit the incidence of twins to estimate the exogenous impact of an additional birth on life-cycle labor supply, but in the context of a perfect foresight, deterministic model.

2. It is widely believed that fecundity varies substantially across couples but that this reproductive potential is not greatly affected by contemporary socioeconomic conditions. Although acute malnutrition and certain diseases may induce premature sterility and thereby influence the distribution of fecundity in low income populations, fecundity is essentially exogenous in a high income population today, such as that of the U.S. in 1970-1975 (Bongaarts and Menken, 1983). In the U.S., contraceptive behavior is naturally seen as the important source of behavioral variation in fertility. Nonetheless, an integrated framework for analyzing both the supply of and demand for births is needed if the consequences of specific sources of fertility variation are to be assessed.

3. In the social science literature, Bulatao and Lee (1983) distinguish among the determinants of fertility supply and demand and the costs of fertility regulation without attention to the underlying sources of stochastic variability and to how covariation between them might complicate the task of statistically identifying the effects of exogenous biological supply from those of endogenous behavioral demand factors. Using an analogous framework, Bongaarts and Potter (1983) examine the proximate determinants of fertility. They also ignore the manner in which the biological proximate factors determining fertility are self-selected, and thus are a potential source of bias in conventional calculations of contraceptive use-effectiveness from non-experimental populations represented in survey data. Easterlin and Crimmens (1983) demonstrate some of the difficulties in estimating elements of a supply and demand model, but they ignore the stochastic interplay of demand and supply, the involuntary sources of biological variation in fecundity, and the individual optimization process.

4. It is assumed that $E(\mu_j \mu_k) = 0$ if $j \neq k$, $= \sigma_\mu^2$ if $j=k$; $E(\mu_j \varepsilon_{ij}) = 0$, $E(\varepsilon_{ij} \varepsilon_{kj}) = 0$ if $i \neq k$, $= \sigma_\varepsilon^2$ if $i=k$. We abstract in (1) from the role of sexual intercourse and other behavioral determinants (diet, exercise) of reproductive potential for simplicity. Intercourse behavior and smoking by the mother are incorporated in the empirical analysis below.

5. We abstract from the dependence of wage rates on prior labor force experience. In the empirical analysis below we estimate the cumulative effects on female earnings due to the adjustments in labor force experience resulting from exogenous variation in the supply of births.

6. In the empirical work below, we consider a variety of methods and the choice among them.

7. Other preference parameters may also vary across the population; we show that heterogeneity in one parameter is sufficient to generate biases in estimates of the effects of fertility supply variation on allocative behavior based on associations between household choices and actual fertility.

8. In each of these studies of contraceptive choice, the samples are stratified by the number of children born.

9. An alternative strategy would be to parameterize the distribution of unobservables and to estimate jointly the reproductive technology and preference parameters associated with the model of section 2. However, this estimation cum dynamic programming approach is extremely expensive and would necessitate severe simplifications with regard to functional forms and especially with regard to the number of control variables (Wolpin (1984)). Instead, we employ a method which enables estimation of a more complex technology, involving multiple methods of control. We estimate reduced-form effects of persistent and random fertility supply shocks, reconstructed from the estimates of the reproduction technology, on resource allocations over the life-cycle. These are based on estimating equations in which only variables predetermined as of the first period of the planning horizon or lagged random shocks occuring within the planning interval appear as determinants of life-cycle resource allocations.

10. There are three reasons why prices and personal characteristics of the couple might be correlated with fecundity. First, if there are omitted inputs in the reporduction function, the determinants of those inputs will appear to be correlated with the conception rate. Second, even if all endogenous inputs are accounted for, there may exist latent, couple-specific health factors which jointly influence fecundity and the couple's earnings potential or ability to obtain schooling. Third, local-area input prices may be related to the couple's endowments if the couple's choice of location is influenced by such endowments.

11. Exposure to the risk of conception is also reduced by one month following each birth (postpartum amenorrhea). Estimates were also obtained with the postpartum period assumed to be as long as three months for each live birth, but the results were essentially unchanged, with coefficient standard errors somewhat higher. The period during which either partner was sterilized was not subtracted from months of exposure; sterilization is treated as a contraceptive method which, unlike abstinence, has a failure rate.

12. F tests were performed to determine if these groups appeared to combine inputs of different effectiveness, but the statistical tests based on the linear, two-stage estimation methodology described below did not support further disaggregation; e.g., the effect of no method could not be distinguished from that of unknown or uncertain methods.

13. The age of the mother, and her age squared, are also included in the reproduction function. Inclusion of the husband's age did not produce a statistically significant effect in the basic specification of the fertility production function. It has been suggested by Anderson (1975) that in Ireland, prior to 1911, census data indicate that increasing male age is associated with decreasing marital fertility, holding constant for the age of the female. This hypothesis is also employed by Coale, Anderson and Harm (1979) to account for unexpected increases in age specific marital fertility rates in central Asian regions of the U.S.S.R. where the age gap between spouses may have decreased in the twentieth century. We also included the number of children breast fed during the five-year period as an endogenous determinant of the risk of conception (Jain and Bongaarts (1981)). However, in none of the two-stage specifications did this variable display any significant effect on the conception rate and it is dropped from the reported analysis.

14. 191 couples (10 percent of observations with complete responses on other characteristics) were excluded because either the husband or the wife had already become sterilized prior to the interview in 1970. Exclusion of these couples may introduce some selection bias into our estimates and may lead to an underestimate of the adjustments to and consequences of fertility supply variability.

15. In particular, the conception probability should be constrained to be non-negative for all possible values of the conditioning variables, which is not the case in the linear model.

16. Estimates of the more flexible Diewert generalization of the linear (Leontief) specification of the reproduction technology were also obtained. Though the values of fertility implied by the two-stage estimates are plausible, the indirect estimation of the collinear inputs does not provide any precise estimates (i.e., low t's) and there is no basis on statistical grounds for preferring this flexible functional form to the functional form reported here.

17. Underreporting of pregnancy wastage and perhaps induced abortion are a source of measurement error that may render this estimate somewhat lower than the true "natural" conception rate, and could explain the unexpectedly high effectiveness of the presumptively "less effective" diaphragm/condom methods; in other words, when couples who use these methods fail, they may resort to (unreported) abortions.

18. There are several sources of unexplained variation in birth rates that might be subsumed in μ and the ε_i in equation (1). Statistical noise that arises from errors in measuring the explanatory inputs would be captured in the residuals, along with misspecifications in functional form and omissions of minor inputs that are not correlated with the included inputs. As a consequence, our estimates of the effects of fecundity variation will be biased toward zero.

19. The most important properties of the μ and s estimates are their independence from preferences and their correlation with exogenous variation in the supply of births. Two tests of these propositions were performed. First, we regressed intended births reported in the 1970 interview on the estimated measures of fecundity obtained from the 1970-75 period and on actual fertility in that interval. While this subjective measure of future fertility demand was a statistically significant predictor of actual births occuring in the subsequent 5-year period, it was not statistically correlated with either μ or s. In the 1975 interview, respondents reported, for each pregnancy, whether or not they had wanted additional children prior to the pregnancy and, if so, whether they might have preferred to have the conception occur later. Regressions of the number of "unwanted" pregnancies and/or the number of errors in the timing of pregnancies on μ and μ interacted with the mother's age indicated that these direct, subjective measures of excess fertility supply were significantly and positively correlated with our indirect (but non- subjective) measure of couple-specific fecundity.

20. While couples make substantial adjustments in their selection of fertility control methods in response to variations in the supply of births, fecundity has no spillover effect on sexual activity among married couples. Neither the frequency of sexual intercourse reported in 1970, nor that reported in 1975, nor the incidence of abstinence were significantly correlated with our measures of exogenous fertility supply or the fertility demand variables. These results are supportive of one of the basic assumptions in Malthus (1798), that there is a "constant passion between the sexes."

21. Duration of marriage might provide a more accurate indicator of the couple's accumulated knowledge of their fecundity than would the wife's age.. However, there is no reason to believe that age at marriage is unrelated to preferences for family size and/or for life-cycle labor supply. Testing this hypothesis, anyway, we used duration of marriage and duration of marriage

interacted with our measure of fecundity in the contraceptive choice equations, analogous to the specifications reported in Table 4. In all specifications, the coefficients on "marriage duration" were statistically significant at the .1 percent level. The explanatory power of the regression, corrected for degrees of freedom, exceeded that reported in the age-fecundity interaction specification reported in Table 4, with the positive effect of fecundity on contraceptive efficiency increasing after 19 months of marriage.

22 . Note that in the 1970-75 period, more educated mothers use effective techniques less often; however, they also have distinctly fewer births before 1970 (Table 3, column 3), and thus appear to be headed for a smaller completed family size. It is widely observed that more educated women marry later and experience a period of 'catching up" with their cumulative fertility, (Rosenzweig and Seiver (1982)); consistent with this, a majority of the more educated mothers appear to be employing their knowledge of the reproductive process (i.e. technology) to increase their birth rate rather than decrease it in the period observed from 1970 to 1975.

23 . Because of the limitations of the Tobit and Probit computer programs, we could not include all of the exogenous instruments in the labor supply equations. The variables reported in Table 6 thus are the complete set of " regressors". Least-squares estimates of the labor supply equations, including and excluding the variables excluded from the Tobit and Probit models, suggest that the results are only trivially affected. Similar tests performed on the children-ever-born and contraceptive efficiency equations confirmed the robustness of the results to this change in specification.

24 . This value is derived as follows: $(1/21)\ (\beta_s \phi(Z'\beta)) = .0972$ for 1973, where β_s = the estimated s coefficient in the probit equation and ϕ is the normal density evaluated at the sample means of the variables Z using the vector of estimated probit coefficients β.

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