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Abstract

In this paper, we describe and utilize methods to estimate the consequences for children's schooling and birthweight of the exogenous variability in the supply of births in one low income country, Malaysia. The method utilizes information on contraceptive techniques employed by couples to estimate directly the technology of reproduction and provides a means of disentangling the biological and demand factors that contribute to the variation in fertility across couples under a regime of imperfect fertility control. Our results suggest that imperfect fertility control significantly influences both the average schooling attainment and birthweight of children in Malaysia, with couples having above-average propensities to conceive reporting higher levels of actual fertility, significantly lower expectations of and actual schooling attainment for their children, and lower birthweight children, on average, due to smaller intervals between births.

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The division of the resources allocated by households between family size and investments in the human capital of each of their children is a critical element in the determination of per-capita income levels and the growth of economies. Accordingly, attention has been devoted to the issue of how improvements in birth control methods might lead to greater investments in the "quality" of children and thus to higher levels of development. Indeed, researchers have frequently sought to evaluate the consequences of family size on parental investments in the qualitative characteristics of their children (e.g., Wray, 1971; Belmont and Marolla, 1973; Terhune, 1974; Blake, 1981; Angst and Ernst, 1983; Becker and Lewis, 1974). Becker (1960) posed the question somewhat differently, reasoning that the number of children parents desired and the resources they chose to spend on each child were substitutes for each other. Families with excess children would consume less of other goods, especially of goods that are close substitutes for the quantity of children. Accordingly, an increase in contraceptive knowledge would raise the quality of children as well as reduce their quantity (Becker, 1960) Although the trade-off between child quantity and child "quality" has become a commonly accepted problem in sociology, psychology, and economics, there are no widely accepted estimates of the consequences of imperfect birth control technology on child quality measured by health, schooling, or later achievements of the child.

The attention given to the issue of how family planning initiatives might importantly facilitate income growth via the acceleration of human capital investments is buttressed by the pervasive finding, across many countries, that households with larger numbers of children also tend to invest less in each. Such correlational evidence, however, does not necessarily support the view that the costliness of contraception plays a major role in attenuating human capital levels. The difficulty in assessing the effects on resource allocations of the surfeit of children induced by the costliness of contraceptive methods arises for two principal reasons. First, actual fertility and subjectively ascertained measures of "excess" fertility are not independent of the preferences of couples. Since both intensive investments in children and family size reflect at least in part the tastes of parents and the costs and opportunities they face, associations between fertility or excess fertility and such investments reveal little about the consequences of imperfect fertility control. Second, contraceptive costs or availability are difficult to measure and often do not vary significantly across couples in most of the environments from which survey data are derived. Reduced form estimates of the effects of variation in contraceptive prices on measures of human capital investment are thus absent from the literature.

Another common finding, from data from both low and high income countries, is the inverse association between maternal schooling and fertility. This statistic has been interpreted by some to suggest that more educated women are better able to contracept, a hypothesis consistent with findings, principally from the United States, that more educated women tend to use more efficient contraceptive methods (Michael (1973), Rosenzweig and Seiver (1982)). However, since the use of contraceptives presumably derives from the demand for children, these findings do not necessarily imply that schooling, independent of its influence on preferences for family size, improves couples' abilities to contracept.

In this paper, we describe and utilize methods, developed in Rosenzweig and Schultz (1985), to estimate the consequences for children's schooling and birthweight of the exogenous variability in the supply of births in one low income country, Malaysia. The method utilizes information on contraceptive techniques employed by couples to estimate directly the technology of reproduction and provides a means of disentangling the biological and demand factors that contribute to the variation in fertility across couples under a regime of imperfect fertility control. The methodology also permits an assessment of the role of maternal schooling in facilitating control over fertility supply. In Section 1, a model incorporating human capital investments and the reproductive technology is set out to compare the methods used in the paper with those employed in prior work to estimate the "quantity-quality" tradeoff. Section 2 describes the data and the implementation of the framework using the Malaysia data. In Section 3, estimates are presented of the reproduction function, which describes how couples' choices of fertility control methods influence their fertility outcomes. The consequences of variability in couples' exogenous propensities to conceive for cumulative fertility and for couples' selection of contraceptive strategies, by maternal schooling level, are also presented. Section 4 presents estimates of how such biological variation in fertility, as mediated by maternal schooling attainment, is reflected in the schooling attainment of children and their weight at birth, and traces out the mechanisms by which imperfect fertility control influences children's birthweight. Section 5 contains a summary and conclusion.

1. The Basic Framework and Estimation Strategy

To clarify the relationships between contraceptive costs, fertility and human capital investments and to contrast our methodology with other methods used in the literature to estimate the effects of fertility on human capital we present a simple illustrative model. Central to the model, and to our estimation strategy, is the existence of a reproduction function, which describes how the use of fertility control methods, age, and other biological "inputs" directly affect conceptions or births. The number of births n_{ij} of couple j in period i is a random variable that can be reduced by the use of a fertility control input Z_{ij} (contraception); i.e.,

$$n_{ij} = n(Z_{ij};i) + \mu_j + \varepsilon_{ij},\ n_z < 0,\ n_{zz} < 0 \quad (1)$$

where μ_j is a time-invariant, couple-specific component of fertility that is unaffected by the couple's behavior and ε_{ij} is an independently distributed, serially uncorrelated disturbance. For simplicity, we abstract in (1) from the role of behavioral determinants of reproductive potential other than contraception (e.g., frequency of sexual intercourse, breastfeeding). The potential number of births (fecundity) in any period is the sum of the last two exogenous terms in (1), while the actual number of births produced (fertility) depends as well on the couple's use of fertility control. Realized births thus depend on both biological, stochastic factors beyond the couple's control and on the preferences of parents, as expressed by the use of the fertility control input.

To depict the couple's preferences and the "problem" parents solve, a two-period model suffices. Assume that the couple maximizes the expected value of the discounted sum of utilities over two periods, such that

$$\max_{Z_{ij} X_{ij}\, s_j} E\,\{U(n_{1j}, X_{1j}) + \delta U(N_j, H_j, X_{2j}; \alpha_j)\} \quad i = 1, 2 \quad (2)$$

where X_{ij} = consumption goods consumed by couple j in period i, δ = discount rate, α_j = household-specific taste parameter, $N_j = n_{1j} + n_{2j}$ (cumulative fertility), H_j = per-child human capital for couple j, and s_j = per-child human capital input (e.g., schooling), where human capital is produced according to (3):

$$H_j = h(s_j, N_j) + V_j \quad (3)$$

Note that we have allowed cumulative births to directly affect human capital (e.g., biological birth order effects, children learning from each other), although it is not necessary that births directly affect H for "family planning" to affect human capital investments.[1] We have also allowed a fixed family human capital endowment V_j. There are thus three sources of population heterogeneity depicted in the model, as each couple is characterized by its own "taste" parameter α_j, fecundity μ_j, and V_j. We assume that α_j and μ_j are uncorrelated, that the distributions of preferences and fecundity in the population are independent. Only if reproductive inputs controlled by the couple are omitted from (1) will the "error" from that equation be correlated with the α_j. The biological fecundity and human capital endowments may be correlated, however, even if all inputs in (1) are accounted for. We present estimates of these endowments correlations below.

To close the model, assume that each couple has an income endowment F_i in each period and cannot borrow or save (this is not critical, but permits a simpler exposition), so that the per-period budget constraints are:

$$F_1 = X_1 P_x + Z_1 P_Z$$

$$F_2 = X_2 P_x + Z_2 P_Z + N s P_s \qquad (4)$$

where the P_x, P_z, P_s are the relevant prices of X, Z and s respectively.

In the first period, each couple knows all prices and incomes (future and contemporaneous) and its preferences α_j, but does not know either its fecundity μ_j, or ε_{ij}. The second-period information set, however, contains in addition to the first-period elements, the persistent component of fecundity μ_j, the human capital endowment V_j, and the first-period fertility shock ε_{1j}. The reduced-form demand equations for the second-period fertility control variable and human capital inputs thus are given by (5):

$$K_j = \psi^K(\mu_j, \varepsilon_{1j}, \alpha_j, V_j, P_x, P_z, P_s, F_2) \qquad K = Z_2, H, s \qquad (5)$$

In general, a couple's choice of fertility control and its level of investments in human capital will depend on its prior realizations of fertility, perceptions about its fertility "supply" or fecundity, and on prices and preferences. To see how the supply of births affects the demand for each input, we can solve the model for the effect of a change in μ_j on s_j and on Z_{2j}. To simplify, assume that ε_{2j} is non-random so that the second period solution is deterministic. This additional assumption does not affect the basic result. The effects of an increase in fecundity on the level of second-period fertility control and on human capital investments (schooling) are:

$$\frac{dZ_{2j}}{d\mu_j} = \frac{P_z}{n_z} [-n_{zz} (\frac{dZ_j}{dP_z})^c + \frac{dZ_j}{dF_2}] \qquad (6)$$

$$\frac{ds_j}{d\mu_j} = \frac{P_z}{n_z} [-n_{zz} (\frac{dH_j}{dP_z})^c + \frac{ds_j}{dF_2}] \qquad (7)$$

where $(dZ_j/dP_z)^c$ and $(ds_j/dP_z)^c$ are the own and cross-compensated substitution effects for Z_{2j} and s_j with respect to P_z respectively and ds_j/dF_2 and dZ_{2j}/dF_2 are the respective income effects.

Expressions (6) and (7) indicate the following:

a. Couples with higher biologically-determined propensities to conceive (fecundity) will select greater levels of fertility control.

b. Couples with higher fecundity will invest less in their children's human capital, if the number of children N and human capital per child H are gross substitutes (the Becker hypothesis); i.e., if $(dH_j/dP_z)^c < 0$, since an increase in P_z increases the number of children.

c. The strength of the association between fecundity, contraceptive intensity and human capital investments depends positively on the magnitude of contraceptive costs (P_z). Thus, if fertility control is costless ($P_z = 0$), variations in μ_j influence neither actual fertility nor human capital investments.

Implication (a) suggests that estimates of the reproduction function (1), of the effects of fertility control methods on births, will be biased unless the correlation between unobserved (to the econometrician) fecundity, to which couples adjust, and contraception is taken into account. Implication (b) suggests that knowledge of how fecundity or fertility supply affects human capital investments is equivalent, qualitatively, to knowing how changes in the costs of contraception affect human capital investments.

Our estimation strategy is to estimate the reproduction function (1), taking into account implication (a), in order to estimate the effects of exogenous fertility supply on human capital investments. We can then test (i) whether family planning initiatives, which lower fertility control costs, would lead to increases in the resources allocated to human capital investment and (ii) whether costs of fertility control significantly affect fertility outcomes, i.e., implication (c).

Prior studies of the family size-human capital interaction have employed three strategies: In one strategy, a conditional demand equation is estimated, using least squares, in which some human capital input is the dependent variable and family size or actual fertility is a right-hand side regressor. As equation (5) indicates, however, if the population is heterogeneous in preferences (α_i), this estimate does not provide unbiased estimates of the effects of either fertility supply or the costs of contraception on H or s. A second strategy employs instrumental variables methods to take into account the correlation between fertility and the error term in the conditional human-capital demand equation. The only theoretically justified identifying instrument in the human capital demand equation conditioned only on the quantity of children is P_Z, or its proxies, since all the other exogenous variables in the demand system must be included in the equation. However, (i) no studies provide information on actual contraceptive costs, so that in practice identification restrictions have been ad hoc (e.g., that mother's schooling influences directly only fertility but not human capital investments) and (ii) even if measures of P_Z are available, and vary across couples (or over time), the instrumental variable estimates of fertility on H or s do not provide any more information than does estimation of the reduced form equations; i.e., estimating directly the effect of P_Z on H (Rosenzweig and Wolpin (1980a)).

A third strategy that has been employed (Rosenzweig and Wolpin (1980b)) is to compare the investments in human capital across couples who do and do not experience a twin on their first birth. This method has the advantage that multiple births (at the first birth) are not correlated with preferences, so that an unbiased estimate of the effect of an early (positive) stochastic shock to fertility (i.e., ε_{1j} in the model) on consequent couple behavior can be obtained. A practical disadvantage of the technique is that very large data sets are required (with the requisite fertility and human capital information) for precise estimates, since multiple births occur in less than one percent of first pregnancies in most populations. In addition, a twin on the first birth represents a temporary shock to fertility; estimates of its effects do not reveal the consequences of couples' differences in persistent components of fecundity in determining the variability in human capital investments.

Our procedure estimates (1) to retrieve that part of realized fertility that is not under couple's control, but which affects their subsequent decisions, in order to obtain information on how contraceptive costs influence human capital investments when data on P_Z are absent. As can be seen from the reproduction function (1), knowlege of the effects of contraception on fertility combined with information on contraceptive use and realized births, enables estimation of the μ_j and ε_{ij}, as in any period i, $\mu_j + \varepsilon_{ij} = n_{ij} - n(Z_{ij})$.

Such estimates thus permit inferences about the consequences of exogenous variations in the supply of births that occur involuntarily. In particular, those couples with higher-than-average propensities to conceive face higher costs of controlling fertility when such control is not costless. They will, accordingly, experience (choose) higher realized fertility and will reallocate their diminished resources across other goods.

If the "natural" cross-couple endowment distribution of fecundity is uncorrelated with preferences, estimation of the effects of variation in the μ_j on the resources allocated to children will reveal the consequences for human capital investments of imperfect fertility control. To the extent to which there is measurement error in the estimates in μ_j such estimates will be lower-bound estimates (are biased to zero). As noted, the directly-observed associations betweeen actual fertility and measures of resource allocations or the outcome of such allocations are also biased due to unobserved taste factors, but the bias associated with tastes heterogeneity cannot be known a priori. That is, as long as fertility and other household allocations reflect joint decisions made by households, their associations will reflect the unknown distributions of preferences for particular allocations as well as the consequences of imperfect fertility control. Nor does use of predicted fertility in a simultaneous equations approach, as noted, provide estimates of the effects of fertility supply constraints.

To obtain consistent estimates of the parameters describing how the endogenously-determined contraceptive methods and other behavior of the couple affect fertility, we can use as instruments all of the right-hand side observed variables in the reduced form equation (5). Note that we do not need direct measures of contraceptive costs P_Z to identify (1). Proxies for P_Z, prices of other goods (e.g., P_X) and income all contribute to achieving identification, since neither prices nor income directly influence realized fertility, given the contraceptive methods and other reproductive inputs chosen by the couple, but do affect the choice of inputs.

2. The Data and Specification

To estimate (1) requires a detailed pregnancy and contraceptive history for the couple as well as information on exogenous variables that potentially influence the demand for goods (inclusive of children) that yield utility. In addition, if the consequences of exogenous fertility variation and imperfect fertility control are to be estimated, data are needed for the same couples on other resource allocations and on the outcomes of those decisions. The data requirements are thus formidable, and are not met, for example, by most of the World Fertility Survey (WFS) data sets, chiefly because of the lack of information on exogenous variables or instruments needed to disentangle the exogenous biological components of realized fertility outcomes from "demand" components. Also, contraceptive behavior is not extensively documented in these data except for the last birth interval. Moreover, U. S. Fertility surveys, which do provide extensive contraceptive histories, do not include information on human capital investments in children, so that the consequences of fertility supply, if estimable, cannot be assessed in terms of these variables.

The Malaysian Family Life Survey (MFLS), a probability sample of 1262 households in Malaysia containing at least one ever-married woman less than 50 years of age at the initial interview, is one data set that meets many of the data requirements. As can be seen in Table 1, while contraceptive use in Malaysia is less prevalent than among U.S. couples in a comparable period (as indicated in the NSFG-Cycle II), more than one-half of the Malaysian couples are using some method (excluding breastfeeding). Fertility in Malaysia evidently reflects both demand and "supply" factors. Among couples above age 30, interestingly, the proportion of couples who have used the contraceptive pill is

Table 1

Percent of Couples Who Ever Used Contraceptive Methods, By Method, Age Group, and Country

Contraceptive Method Ever Used	Country: United States (NSFG-Cycle II)	Country: Malaysia (MFLS)
Age < 30		
No method ever used	8.7	52.1
Pill	69.1	32.0
IUD	14.1	0.7
Condom	17.5	5.8
Sterilized (male or female)	12.1	1.9
Age 30-35		
No method ever used	8.9	37.5
Pill	37.7	41.7
IUD	13.2	0.7
Condom	16.0	7.1
Sterilized (male or female)	39.9	13.6
Age 35-40		
No method ever used	11.6	46.4
Pill	23.4	31.2
IUD	8.9	2.1
Condom	12.7	7.2
Sterilized (male or female)	47.4	8.4
Age 40-45		
No method ever used	13.3	52.3
Pill	15.8	16.9
IUD	4.5	1.7
Condom	15.0	4.7
Sterilized (male or female)	51.6	8.1

higher in Malaysia than in the United States; significantly fewer Malaysian couples above age 30 had undergone sterilization operations compared to U.S. couples, however. Malaysia also exhibits, as displayed in Table 2, the classic inverse correlations between actual cumulative fertility and measures of the human capital of children, including mean schooling attainment (or expected attainment) and birthweight, although the latter is not statistically significant. However, Table 2 also shows that desired family size and children's schooling are also inversely associated; the human capital-fertility correlations thus may simply reflect preference patterns among Malaysian couples rather than the combined influence of heterogenous fecundity and imperfect fertility control.

The Malaysia data also exhibit the typical patterns of fertility and children's schooling levels by mother's schooling attainment. Table 3 displays the means and variances in children-ever-born, desired completed family size and in couple-specific children's (mean) schooling attainment (or expected attainment) for five maternal schooling groups. Aside from the fall in both actual and desired fertility and the rise in mean children's schooling with increases in the schooling attainment of the mother, a striking feature of Table 3 is the decline in cumulative fertility and cross-couple child schooling variances across successively higher maternal schooling groups for all but the small highest schooling group. That the variances in family size goals do not display an inverse association with maternal schooling suggests that there may be significant variability in the supply of births and that better educated couples may be better able to control fertility supply variability. The inverse association between the variance in cumulative fertility and maternal schooling is also evident in the United States (Michael and Willis (1975) and Rosenzweig and Schultz (1987)) but has not been documented for children's schooling. We

Table 2

Correlation Matrix: Fertility, Desired Family Size, Child Schooling and Birthweight in Malaysia

	Children Ever Born	Desired Family Size	Children's Mean Birthweight
Children's mean schooling attainment[a]	-.275	-.226	.061
Children's mean birthweight	-.002	.0138	1.0

a. Includes parents' expectations of schooling attainment for children currently attending school.

Table 3

Means and Variances in Children-Ever-Born, Desired Family Size and Children's Schooling Attainment[a] by the Schooling Attainment of the Mother

Mother's Schooling (percent sample)	Children Ever Born		Desired Family Size[a]		Children's Schooling[b]	
	Mean	Variance	Mean	Variance	Mean	Variance
0 years (35.8)	5.98	9.61	4.49	2.69	8.99	11.0
1-3 years (19.2)	5.26	8.82	4.78	2.19	10.2	10.4
4-6 years (32.5	3.64	5.71	4.35	3.53	16.3	10.2
7-11 years (7.9)	2.66	3.39	4.09	3.28	13.9	9.24
12+ years (4.6)	2.10	3.57	3.26	1.66	15.6	11.6

a. Women less than 30 years old.

b. Includes parental expectations of children's schooling attainment when children are currently attending school.

will test whether mother's schooling attainment mitigates the consequences of exogenous changes in the supply of births in Section 4 below.

Our strategy for obtaining consistent estimates of the reproductive technology, and thus of the exogenous "supply" components of fertility, is to use time-aggregated information on conceptions, pregnancies, and contraceptive use from the MFLS pregnancy histories to estimate (1) by an instrumental variable procedure. That is, we estimate the conception rate for a couple over the most recent 5-year period (to minimize recall error) 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

$$n_j = \mu_j + \Sigma_{i=1}^{S} \varepsilon_{ij} - \beta Z_j \qquad (8)$$

where Z is a vector of contraceptive methods and other biological determinants of conceptions (e.g., age, breastfeeding) and β is a vector of associated coefficients, $F_j = f_j/S$=the fraction of the aggregate period control is used, and $n_j = \Sigma_{i=1}^{S} N_{ij}/S =$ conception rate.

The dependent variable used in the estimation of the reproductive history is the total number of conceptions occurring over the 5-year period preceding the last interview divided by the total months in that period that the women were exposed to the risk of conception, namely, the months in which the wife was not pregnant or in which the couple was not abstaining from intercourse, sterilized or separated. Three fertility control variables are constructed based on the contraception history: the proportions of the total exposure period during which the woman was subject to the risk of conception that the couple was using the (i) pill or IUD, (ii) using the condom, (iii) using "inefffective" techniques (foam, jelly, rhythm, folk methods, etc.). The grouping of contraceptive methods is similar to that employed in our U.S. study and is based on standard conventions and beliefs on the relative effectiveness of such methods in the U.S. population (Vaughan, Trussel and Menken 1977; Westoff and Ryder, 1977; Bongaarts and Potter, 1983). The number of intervals in which a woman reported using more than one technique from each contraceptive category was 110, less than 2 percent of total intervals. In such cases we attributed the interval to the more effective technique. Experimentation with changing the attribution of the "crossover" intervals indicated that the results are not sensitive to how we treat this ambiguity in the data.[2]

Two additional inputs are included in the reproduction function (1): the nunber of months the mother was continuously and exclusively breastfeeding any children from the time of the birth of each child, and the wife's age. Only the latter is treated as an exogenous variable, as the relevant interval used for each woman is based on the interview dates, which should be orthogonal to the couples' preferences and reproductive capacity in a random sample. All other inputs are treated as endogenous variables, potentially correlated with the unobserved biological propensity to conceive. Note that since breastfeeding is also a human capital input applied to each child, it is clearly correlated with the error term in (1), even if couples do not consciously adjust their contraceptive strategies to their fertility realizations.[3]

For instruments, we use information on the schooling of the parents, husband's earnings (cash and kind), and community-level information provided in the MLFS, including the distances of the households to the nearest doctor, nurse, family-planning clinic, private medical center and midwife.

3. Estimates of the Reproduction Function and of Fecundity

Table 4 reports both ordinary least squares (OLS) and two-stage least squares (2SLS) estimates of a linear approximation to the reproduction function (1), with, however, age effects allowed to be non-linear. Estimates from U.S.

Table 4

Estimates of the Linear Reproduction Function

Variable	Estimation Procedure OLS	2SLS
Pill/IUD[a]	-.0241	-.0713
	(2.77)[b]	(2.02)[c]
Condom[a]	-.0233	-.0291
	(1.43)	(0.38)
Ineffective methods[a]	-.00079	-.00881
	(0.07)	(0.17)
Breastfed children (months)[a] ($X10^{-2}$)	-.00737	-.131
	(0.6)	(2.91)
Mother's age, in months ($X10^{-3}$)	.218	.0418
	(0.71)	(0.93)
Mother's age squared ($X10^{-6}$)	-.631	-.758
	(1.71)	(1.52)
Constant	.0436	.134
	(0.71)	(1.60)
R^2	.10	-
F	8.90	8.17

a. Endogenous variable.
b. t-ratios in parentheses in column.
c. Asymptotic t-ratios in parentheses in column.

data led to acceptance of the linear approximation compared to alternative generalized approximations employing higher-order-terms. Tobit and two-stage Tobit estimates were almost identical to the results reported, in part due to the low number of women experiencing no conceptions over the 5-year period (in contrast to the U.S. data) employed in Rosenzweig and Schultz (1985)).

Durbin-Wu-Hausman tests reject the hypothesis that the contraceptive inputs and breastfeeding variables are uncorrelated with the residual (F(4,809) = 23.7). The change in point estimates across estimation procedures indicates that the OLS estimates understate by 300 percent the effectiveness of the pill and understate by a factor of 18 the "contraceptive" effects of full breastfeeding. Ineffective methods, however, appear to be aptly named according to either estimation procedure. The bias in the pill coefficient is consistent with the hypothesis that less fecund women employ the less-effective methods (as is confirmed directly below); the breastfeeding effect bias arises because breastfeeding only occurs when there is a baby to feed. The duration of breastfeeding is positively correlated with the number of conceptions in the data because a live birth causes breastfeeding to commence. The breastfeeding-conception association is a classic example of a simultaneous equations problem.

Except for the estimated effect of breastfeeding, which was not an important determinant of the conception rate in the United States, the results reported for Malaysia in Table 4 are similar to those obtained from a larger contemporary U.S. sample (Rosenzweig and Schultz (1985)), with the U.S. estimates being somewhat more precise. However, the lack of precision for the condom effect may be due to the low incidence of this method in the Malaysian population (Table 1) compared to that among U.S. couples.

The similarity between the Malaysia reproduction function estimates and those from the U.S. sample, despite the vastly different socioeconomic environments in the two countries, gives us confidence that we are measuring technical-biological relationships in Table 4 rather than demand relationships. If so, the estimates of the reproduction technology enable the separation of the endogenous behavioral and exogenous biological components of fertility, so that the consequences of exogenous 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. A consistent (as the number of periods approaches ∞) 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, is:

$$\hat{\mu}_j = \Sigma_{i=1}^{t} (n_{ij} - n_{ij}^{e})/t. \tag{9}$$

If the μ_j are, as they are constructed to be, independent of preferences but correlated with the exogenous supply of births, they should not be related to couples' family size goals. If fertility control is costly, however, μ_j will affect the extent to which couples are successful in meeting those goals. Costless control would imply as we have discussed, that variations in μ_j should not only be uncorrelated with fertility goals but should also be uncorrelated with actual cumulative births; couples would adjust their contraceptive strategies appropriately as they observed how well their past efforts to control fertility had succeeded.

To test whether fertility control is "imperfect", whether our constructed estimates of fecundity are uncorrelated with family size preferences, and whether couples' adjust their use of contraceptives to their biological propensities to conceive, we present in Table 5 estimates of the effects of μ on the cumulative births of couples aged 25-40; on couples' reports of their desired total births, for couples aged less than 30,[4] and on couple's average contraceptive efficiency over the 2.5 year interval preceding the last interview. The contraceptive efficiency measure is the weighted average of the absolute values of the 2SLS method-specific slope coefficients of Table 4, where the weights are the actual shares of time that the couple used each specific method. We also test whether couples with more educated wives are able to control fertility supply better, by interacting maternal schooling with μ in all equations.

The fertility and desired family size estimates were obtained using the consistent variance-covariance matrix (CVM) estimator proposed by White (1980). The reported standard errors are thus robust to heteroscedasticity, consistent but inefficient. Indeed, for these equations, Breusch-Pagan tests indicated rejection of homoscedasticity. Maximum-likelihood Tobit was employed to obtain estimates of the determinants of contraceptive efficiency, since a non-trivial proportion (30 percent) of couples were using no method in the last interval.

The cumulative fertility estimates in column 1 of Table 5 indicate that couples do not control fertility perfectly; among couples with the same maternal schooling attainment and husband's income, those with a higher measure of fecundity experienced significantly more actual births, even though, as indicated in column 3, couples' preferences for family size are <u>not</u> significantly associated with our measure of their fecundity level. Explained variance rises by 9 percent when μ is included in the cumulative fertility equation, with fertility supply variability contributing about 2 percent to the total variance in fertility in Malaysia. The interactive fertility specification, column 2, suggests that among couples with more educated wives, however, fecundity

Table 5

Effects of Fecundity Level on Cumulative Actual Fertility, Desired Family Size, and on Contraceptive Efficiency in Last Interval: Married Women Aged 25-40

Variable	Children Ever Born		Desired Family Size		Contraceptive Efficiency	
Estimation Procedure	CCM[a] (1)	CCM[a] (2)	CCM[a] (3)	CCM[a] (4)	MLTobit (5)	MLTobit (6)
Fecundity (μ)	3.49	5.12	.301	-.893	.0799	.168
	(3.15)[b]	(3.90)[b]	(0.31)[b]	(0.46)[b]	(2.35)[c]	(2.28)[c]
Fecundity x wife's schooling	-	-.525	-	.309	-	-.0187
		(1.76)		(1.03)		(1.37)
Wife's schooling	-.175	-.174	-.156	-.159	.00214	.00198
	(6.97)	(6.87)	(6.75)	(6.85)	(2.83)	(2.62)
Husband's earnings ($X10^{-4}$)	-1.40	-1.34	-2.03	-2.03	.0373	.0385
	(2.35)	(2.24)	(3.51)	(3.52)	(2.53)	(2.60)
Wife's age (months)	.0827	.0824	.0123	.0125	.00037	.00034
	(2.62)	(2.61)	(1.74)	(1.77)	(0.55)	(0.51)
Wife's age squared ($X10^{-5}$)	-8.15	-8.13	-.306	-.332	-5.71	-5.34
	(1.97)	(1.97)	(0.35)	(0.38)	(0.67)	(0.63)
Constant	-14.2	-14.2	1.95	1.94	-.0689	-.0620
	(2.39)	(2.39)	(1.43)	(1.42)	(0.53)	(0.48)
R^2	.296	.299	.252	.253	-	-
F	40.1	33.8	54.0	45.2	-	-
Breusch-Pagan χ^2	74.8	75.2	77.7	78.1	-	-
χ^2	-	-	-	-	40.7	44.8

a. White (1980) consistent covariance matrix estimator.

b. Absolute value of t-ratios in parentheses in column.

c. Absolute value of asymptotic t-ratios in parentheses in column.

variation less strongly influences cumulative births. The fecundity and fecundity-schooling interaction terms do not, however, jointly significantly influence couples' fertility goals in column 4.

The contraception efficiency estimates in the final two columns of Table 5 indicate that couples do attempt to adjust their selection of contraceptives to their supply of births, as more fecund couples were using significantly more effective contraceptive methods at the time of the survey. Couples with more educated wives did not adjust as strongly, although the interaction is not precisely estimated. This may be due to such couples having already successfully compensated for the effects of fecundity in prior intervals, as is implied by the results in colunn 2. Moreover, such couples may also use the less effective methods more efficiently, a hypothesis we have tested (and confirmed) by estimating from a U.S. sample method-specific education interactions in the reproduction function (Rosenzweig and Schultz, 1987).

4. Fecundity Variation and the Human Capital of Children

The lack of a statistically significant association between our measure of fertility supply and family size preferences implies that the residual measure of fecundity based on the estimates of the reproduction technology reflects biological capacities and not preferences. The evidence in Table 5 of less-than-fully compensatory adjustment by couples to their inherently biological propensities to conceive therefore indicates that couples are in part constrained by their fertility outcomes; fertility control is imperfect. To test whether among couples experiencing above-average "supplies" of births, children receive less human capital, we look at the association among children's schooling attainment, their birthweight (a proxy for health human capital) and their parents' fecundity level. Table 6 reports linear regressions of these measures on fecundity and on other characteristics of the parents. Schooling

Table 6

Effects of Fecundity Level on Mean Schooling Attainment (Years)[a] and Mean Birthweight of Children: CCM Estimators[b]

Variable	Children's Schooling (1)	Birthweight (2)
Fecundity (μ)	-4.91	-1.19
	(2.89)[c]	(2.60)
Fecundity x mother's schooling	.700	.195
	(1.34)	(2.26)
Mother's schooling	.501	.00421
	(11.4)	(0.44)
Father's earnings ($X10^{-4}$)	2.55	.581
	(2.29)	(2.86)
Mother's age	-.00765	-.000183
	(4.94)	(0.54)
Constant	12.6	6.77
	(16.9)	(41.5)
R^2	.303	.0179
F	55.7	3.57
Breusch-Pagan χ^2	7.41	21.5

a. Includes parental expectations of children's schooling attainment when children are currently attending school.

b. White (1980) estimates.

c. Absolute values of t-ratios in parentheses.

attainment is measured by the mean, across all the children of the couple, of completed schooling and/or <u>expected</u> schooling attainment (for children currently in school). The standard errors in the schooling and birthweight equations are again estimated using the robust CCV procedure. However, Breusch-Pagan tests indicate rejection of the hypothesis that the errors are homoscedastic only for the birthweight equation.

The estimates indicate that both mean child schooling levels and birthweight are lower among more fecund couples; improvements in contraceptive technology would raise schooling levels and average levels of children's weight at birth. The (lower-bound) point estimates indicate that schooling attainment is lower by one-half year (4 percent) for children born to couples with fecundity one standard-deviation above the mean and their birthweight is lower by .08 pounds (12 percent) for the children of such couples.

Columns 1 and 2 indicate that the negative effects of fertility supply on both children's schooling and birthweight are attenuated, however, for couples with more educated wives. These results are consistent with the finding in Table 5 that among high-fecund couples, those with more-educated wives experience fewer actual births. They also suggest that the decline in the variance in mean children's schooling levels with maternal schooling (for all but the small group of mothers at the highest schooling levels) seen in Table 3 may be in part due to the greater ability of more educated mother's to cope with fecundity variability. As noted, fecundity may be (potentially) correlated with the family's human capital endowment; the exclusion of the latter may thus bias our results. We explore this possibility below.

While the consequences of fertility supply constraints associated with costly fertility control on the schooling of children can be straightforwardly interpreted as reflecting parental adjustments induced by diminished household resources per child, the mechanisms by which fertility supply influences birthweight are less clear. To the extent that both order and birth spacing directly influence the weight of children at birth, variations in fecundity across couples will be directly reflected in birthweight.

To explore empirically the direct linkages between couples' inherent propensities to conceive and the birthweight of their children, we estimate the birthweight technology--the effects of actual fertility outcomes on birthweight. Assume that the birthweight of a child of order i born to couple j is given by:

$$B_{ij} = \gamma_0 \, age_{ij} + \gamma_1(age_{ij} - age_{i-1j}) + \gamma_2 i + \gamma_3 sex_{ij} + \gamma_4 \Gamma_j + v_j + e_{ij}, \quad (10)$$

where age_i = age of the mother at child i's birth, Γ_j = household-specific biological determinants of birthweight other than birth intervals, order and mother's age at birth that parents choose, v_j = family-specific birthweight endowment, and e_{ij} = child-specific birthweight endowment.

In Rosenzweig and Schultz (1983), it is shown that decisions concerning the timing of births are correlated with family-specific health endowments; estimation of (10) by least squares would therefore yield biased estimates. Using a family fixed-effect procedure, as in Olsen and Wolpin (1984), would purge out the additive family endowment v_j. However, as shown in Rosenzweig (1986) for U.S. couples and Rosenzweig and Wolpin (1984) for Colombian couples, such a procedure yields inconsistent estimates, as parents' decisions about fertility depend on prior individual child outcomes; i.e., the timing of the births subsequent to child i depends on i's healthiness. To avoid these problems, we estimate (10) using a family fixed effect procedure with instruments. We difference equation (10) across the second and third child in all families with at least three children and use as instruments parental schooling, husband's income and the local community program variables to purge prior interval length, birth order and mother's age at birth of covariation with the remaining child-specific errors in the birthweight function. This procedure yields consistent estimates of the effects of both order (between children two and three), birth intervals and age of the mother at birth assuming these effects (the γ parameters) are the same across all couples. In that case, there is no selectivity bias associated with the selection of households with at least three live births, even though birthweight endowments differ across households and such endowments influence fertility. Moreover, the procedure is robust to the omission of any household-specific birthweight inputs, which are impounded in the fixed effect.

Table 7 presents the instrumental fixed effect estimates of the birthweight production function. The results, although not very precise, indicate that longer birth intervals and postponement of births directly increase birthweight, while birth order is negatively associated with birthweight, although not significantly so at conventional levels of significance. Thus, a higher inherent conception rate under a regime of costly contraception should, on average, be associated with lower weights of children at birth, as suggested in Table 6.

The estimates of birthweight technology (10) permit, as with the reproduction technology estimates, computation of a measure of the children's human capital endowments. In this case, the difference between each child's actual birthweight and its birthweight predicted on the basis of the effects of its order, spacing, sex, and mother's age at birth from Table 7 contain the child and family human capital endowments e_{ij} and v_j as well as family human capital investments common to all children. Averaging these residual human capital measures across children yields a noisy estimate of the sum of the family human capital endowment and family prenatal investments influencing birthweight. If the latter have little impact on birthweight or vary insignificantly across households, we can assess whether family human capital

Table 7

Instrumental Fixed Effects Estimates: Effects of Birth Spacing and Birth Order on Birthweight for Second and Third Births

Variable	
Age of mother at birth[a]	.196
	(1.50)[b]
Prior birth interval[a]	.0783
	(1.62)
Sex of child (1=female, 0=male)	-.0947
	(1.42)
Birth order (1=third, 0=second)[a]	-.456
	(1.17)

a. Endogenous variable.
b. Asymptotic t-values in parentheses.

Table 8

Correlation Matrix: Fecundity, Birthweight Endowment and Child Schooling

	Fecundity	Children's Mean Schooling
Birthweight endowment	.0116	.0933*
Fecundity	1.0	-.0400**

a. Includes parents' expectations of schooling attainment for children currently attending school.

* Significant at .006 level.

**Significant at .24 level.

endowments are correlated with our measures of fecundity. We can also ascertain whether the family human capital endowment, measured on the basis of the birth outcomes, predicts children's schooling achievement across households, as has been found based on U.S. data (Chernichovsky and Coate, 1979).

Table 8 presents the correlations between fecundity, mean schoooling attainment and the human capital endowment, based on the residual measure of birthweight for the first and second children in families with only two children (11 percent of the sample) and on the average of residuals for children one through three in families with at least three children (89 percent of the sample). While mean children's schooling and the birth outcome human capital endowment are positively and significantly correlated, as expected, the correlation between fecundity and the human capital endowment is not significant by conventional standards, although it also is positive. If the measurement errors in both the residual fecundity and human capital measures are not solely responsible for the lack of correlation between the two endowments, the estimated negative effects of fecundity on birthweight and children's schooling in Table 5 are thus not likely to be importantly biased (positively) by the omission of human capital endowments in those equations.

5. Conclusion

The determination of fertility, unlike the consumption of market-supplied consumer and producer durables or other goods, necessitates the allocation of resources to limit supply. The extent to which control of fertility supply is not costless and the biological capacity to bear children (fecundity) is largely independent of the couple's choice behavior, many couples will be constrained by their fertility outcomes to some degree. In this paper, we described and implemented a method for estimating the influence of exogenous fertility supply constraints on the resources allocated by parents to children. Based on household data from Malaysia, our estimates indicated that Malaysian couples adjust their selection of contraceptive methods in response to their own exogenous supply of births but, due to the evident costliness of contraceptive control, do not fully eradicate the influence of supply constraints on their actual cumulation of births. Our results also suggested that imperfect fertility control significantly influences both the birthweight and the average schooling attainment of children in Malaysia, with couples having above-average propensities to conceive reporting significantly lower expectations of and actual schooling attainment for their children and bearing lower birthweight children, on average, due to their shorter intervals between births. The influence of fecundity on both cumulative fertility and on the "quality" of each child was, however, attenuated among couples with wives having higher levels of schooling. The schooling attainment of women may consequently be associated with improved efficiency in the control of fertility.

The measurement of that component of actual fertility associated with exogenous biological factors but unrelated to couples' preferences for family size requires the estimation of the influence of all forms of couple behavior that directly affect fertility. Thus, a byproduct of our research is information on the effectiveness of contraceptive methods and the influence of other forms of couple behavior on fertility. Our results with respect to the direct or biological determinants of fertility in Malaysia were in accord with our prior work based on data from the United States, with the pill, among contraceptive techniques, displaying the most powerful negative influence on fertility, and with "traditional" methods of contraceptive control appearing almost completely ineffective. However, once the simultaneous relationship between live births and breastfeeding is taken into account, breastfeeding evidently exerts a substantial negative influence on the supply of births. Our results thus imply that the improved dissemination of contraceptive information, particularly among less educated women, may increase the level of investments in per-child human resources and lower the variance in the human capital acquired by children in Malaysia.

While our estimates were sufficiently precise to permit rejection on statistical grounds of hypotheses concerning the influence of exogenous fertility supply constraints on parental investments in the human capital of their children and on their actual fertility, the magnitudes of the influence of our measure of supply variability were small. While variability in fecundity increased the explained variance in actual births across Malaysian couples by almost 10 percent, it accounted for only two percent of the total variability in fertility and in the schooling attainment of children. In our U.S. data, variability in fecundity, measured using the same procedure, accounted for 10 percent of the total cumulative fertility variance across U.S. couples. Since fecundity is a residual measure, our results with respect to the influence of fertility supply constraints depend critically on the quality of the underlying fertility and contraceptive information. The Malaysian contraceptive information, as noted, is less detailed than that available from the U.S. fertility survey, and less precise estimates of the influence of contraceptive methods were presumably obtained. Thus, we believe that our estimates may underestimate the magnitude of the consequences of imperfect fertility control in Malaysia. Alternatively, the variance in preferences for family size may be substantially greater in a low-income country in the midst of its demographic transition compared to that in the contemporary United States, with biological variability therefore playing a relatively smaller role.

FOOTNOTES

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1. Note that infant mortality, an important phenomenon in low-income countries, is an extreme indicator of H, having both endogenous investment and exogenous components. Of course, an infant death directly affects family size, so that an explicit modeling of mortality would complicate the model somewhat, without altering the basic conclusions.

2. One shortcoming of the Malaysian data set is that contraceptive information was collected by pregnancy interval rather than on the basis of a month-by-month calendar basis (as in some U.S. fertility surveys). While length of contraceptive and principal and secondary methods of contraception are reported for each interval, it is not possible to compute the length of time each method is used, by interval, when more than one method is employed within the interval (switches in methods across intervals present no problem). Since the information on contraceptive use is critical for estimating the reproduction function we have investigated the consequences for estimation arising from the less complete contraceptive information available in the Malaysian survey. We used the calendar information from the 1975 U. S. National Fertility Survey to simulate the information provided in the Malaysian data. Thus, we estimated a variant of the reproduction function (1), making use of the exact duration of each method used as provided in the calendar and attributing within each pregnancy interval the longest-duration methods to the full length of the "protected" period, as is necessary with the Malaysian interval data. The results indicated that estimates from the (artificially) less precise data were similar to but less precise than those from the exact histories.

3. The MFLS does not include information on frequency of intercourse, leaving open the possibility that tastes may be impounded in the residual to the extent that preferences for family size influence this variable. In our U.S. study (Rosenzweig and Schultz, (1985)), we found that U.S. couples did not adjust their frequency of intercourse in response to past exogenous fertility outcomes or fecundity, nor was the variable a significant determinant of the conception rate. We test directly for a relationship between family size preferences and our measure of fecundity in the Malaysia data below.

4. We selected a sample of women less than 30 to reduce the probability that couples will rationalize their actual cumulative fertility. However, even in the full sample of women aged 15-45, our measure of fecundity was not significantly, related, at even the .4 level, to the couples' reports of desired family size.

REFERENCES

Becker, G. S. 1960, An economic analysis of fertility, in Demographic and economic change in developed countries, NBER conference series II, Princeton, NJ: Princeton University Press.

Becker, G. S. and H. G. Lewis 1974, Interaction between quantity and quality of children, in (ed.) T. W. Schultz, Economics of the family, Chicago: University of Chicago Press.

Belmont, L. and F. A. Marolla, 1973, Birth order, family size and intelligence, Science 182, 1096-1101.

Blake, J. 1981, Family size and the quality of children, Demography 18, no. 4 November, 421-443.

Bongaarts, J. and R. G. Potter, 1983, Fertility, biology and behavior, New York: Academic Press.

Chernichovsky, Dov and Douglas Coate, 1979, An economic analysis of the diet, growth and health of young children in the United States, Working paper no. 416, National Bureau of Economic Research, December.

Easterlin, R. A., R. A. Pollak and M. L. Wachter, 1980, Toward a more general economic model of fertility determinations, in Population and Economic Change in Developing Countries, (ed.) R. A. Easterlin, NBER, Chicago: University of Chicago Press.

Ernst, C. and J. Angst, 1983, Birth order: its influence on personality, Berlin: Springer-Verlag.

Michael, Robert, 1973, Education and the derived demand for children, Journal of Political Economy 31, March/April, 128-164.

Michael, Robert and R. Willis, 1975, Contraception and fertility: household production under uncertainty, in N. E. Terleckyj (ed.), Household production and consumption, New York: Columbia University Press, 27-93.

Rosenzweig, M. R., 1986, Birth spacing and sibling inequality: asymmetric information within the household, International Economic Review 27, no. 1.

Rosenzweig, M. R. and T. P. Schultz, 1983, Estimating a household production function: heterogeneity, the demand for health inputs and their effects on birthweight, Journal of Political Economy 91, no. 5, pp. 723-746.

__________ and __________, 1985, The demand for and the supply of births: fertility and its life cycle consequences, American Economic Review 75, no. 5, 992-1015.

---------- and ----------, 1987, Schooling, information and non-market productivity contraceptive use and its effectiveness, February.

Rosenzweig, M. R. and D. Seiver, 1982, Education and contraceptive choice: A conditional demand framework, International Economic Review 70, no. 1.

Rosenzweig, M. R. and K. I. Wolpin, 1980a, Life cycle labor supply and fertility, Journal of Political Economy 89, no. 6, 1059-1085.

__________ and __________, 1980b, Testing the quantity-quality model of fertility: the use of twins as a natural experiment, Econometrica 48, no. 1.

__________ and __________, 1984, Heterogeneity, intra-family distribution, and child health, Discussion paper no. 463, September, New Haven, CT: Economic Growth Center, Yale University.

Terhune, K. W., 1974, A review of the actual and expected consequences of family size, Report to the Center for Population Research, National Institute for Child Health and Human Development.

Tietze, C., 1959, Differential fecundity and effectiveness of contraception, Eugenics Review 50, January, 231-237.

Vaughan, B., J. Trussell, J. Menken and E. R. Jones, 1977, Contraceptive failure among married women in the U.S.: 1970-73, Family Planning Perspectives 9, no. 6, 251-258.

Westoff, C. F. and N. B. Ryder, 1977, The contraceptive revolution, Princeton, NJ: Princeton University Press.

White, Halbert, 1980, A heteroscedasticity consistent covariance matrix and a direct test for heteroscedasticity, Econometrica 48, May, 817-838.

Wray, J. D., 1971, Population pressure on families: family size and child spacing, in Rapid population growth, National Academy of Sciences, Baltimore, MD: Johns Hopkins University.