TABLE 7

REGRESSIONS ON MONTHLY BIRTH PROBABILITY IN FIRST AND THIRD PREGNANCY INTERVALS FOR NON-CATHOLIC WHITE WOMEN AGE 30–34 BY USER STATUS (WITH EDUCATION DUMMY VARIABLES)

Pregnancy Interval	HS(W)	COLL(W)	HS(H)	COLL(H)	Number of Children Intended	R^2 s.e.e.
	A. Contraceptive Users and Nonusers					
First interval	−506.11	−261.14			10.22	.102
	(128.02)*	(95.75)			(2.64)	848.
			−375.77	−187.07	11.32	.093
			(110.63)	(88.22)	(2.62)	852.
	−373.72	−196.15	−255.45	−80.68	9.82	.114
	(137.89)	(106.80)	(117.19)	(97.84)	(2.63)	844.
Third interval	−427.09	104.91			7.15	.065
	(143.32)	(116.65)			(3.16)	793.
			−509.07	48.78	7.88	.087
			(119.19)	(99.30)	(3.04)	783.
	−266.15	−129.52	−439.20	116.46	6.35	.099
	(150.10)	(129.13)	(125.13)	(111.28)	(3.13)	781.
	B. Contraceptive Users Only (Excludes Couples That Used No Method)					
First interval	−35.95	−21.70			1.13	.058
	(23.53)	(11.36)			(0.44)	86.
			−1.14	−25.28	1.35	.056
			(17.11)	(10.77)	(0.43)	86.
	−35.70	−12.99	7.55	−18.80	1.14	.066
	(24.85)	(12.76)	(17.96)	(12.01)	(0.44)	86.
Third interval	−47.55	−26.13			0.95	.074
	(20.98)	(13.69)			(0.48)	83.
			−34.02	−30.68	1.21	.091
			(16.73)	(11.79)	(0.45)	82.
	−32.29	−8.39	−25.52	−25.82	0.99	.101
	(21.98)	(15.56)	(17.59)	(13.44)	(0.48)	82.

NOTE.—HS(W) is 1 if wife's schooling level was 1 year of high school or more; COLL(W) is 1 if wife's schooling level was 1 year of college or more; HS(H) and COLL(H) are similarly defined dummy variables for the husband's schooling level.

* Standard error in parentheses.

sample into groups for which $(N^* - N) > 0$ (designated as "child spacers") and $(N^* - N) \leq 0$, Part II of table 6 reestimates the regressions in the first part of table 6 for the subset "child spacers." That is, for each pregnancy interval, the couple was included in the regressions in the second part of table 6 if and only if the "number of children inferred wanted by the wife" was equal to or greater than the interval number; for example, women who "wanted" two children were excluded from the regressions pertaining to the third interval, and so on.[24]

[24] The sample sizes for the residual subsets (couples for which $[N^* - N] \leq 0$) were

Finally, table 7 again makes use of the same observations as does Part II of table 5 and reports regressions for white women for the first and third intervals only, using dummy variables for the education levels of the wife and the husband. In all cases, the high school dummy's coefficient is larger (negative) and stronger than the college dummy's coefficient for the wife's education, and similarly for the husband's education in Part A. That is, the effect of high school education relative to grade school education appears to be greater than the effect of college education relative to high school; the statistical significance of the differences in these pairs of coefficients has not been computed. It clearly is not the case that the negative effects reported for the education coefficients throughout tables 5 and 6 result predominantly from the effects of the high level of schooling (and the high time values) of the most-educated women.

iv) *Conclusion*

The empirical analysis in this section has only begun to investigate observed contraceptive behavior in the context of an economic framework. The results reported here represent initial findings with respect to the selection of contraceptive techniques in low-parity pregnancy intervals for non-Catholic women between the ages of 25 and 40 (in 1965). While the observed effects of the husband's and wife's education levels on the use of contraceptives are often not large and frequently not statistically significant, the effects are quite consistently negative for all age-, color-, and parity-specific regressions. They also appear to be insensitive to the definition of the proxy variable for N^*.

If it is tentatively concluded that the husband's and wife's education levels do have a negative partial effect on the monthly birth probability as defined in this study—that more-educated couples, *ceteris paribus*, select contraceptive techniques which on the average are more effective in preventing pregnancy—the interpretation of this result is not yet clear. One cannot distinguish, by the statistical procedure followed, between two quite distinct interpretations: (1) education lowers contraceptive costs by reducing information costs; and (2) education lowers contraceptive costs by raising the marginal product of the couple's time used in conjunction with any specific contraceptive device. Moreover, an alternative explanation for the observed negative relationship emphasizes an effect of education on the marginal benefit function: (3) "unwanted children" represent a bigger loss to more-educated couples, and hence the more-educated are induced to make a greater effort to prevent timing and quantity failures.

This third explanation, however, requires information about the shape

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quite small for these low-parity intervals and were not, therefore, analyzed. By the fourth pregnancy interval, however, one would expect to find a sizable number of observations with $(N^* - N) \leqslant 0$; I hope to determine whether the behavior of these couples differs appreciably from the behavior of those for whom $(N^* - N) > 0$.

of the marginal-cost and marginal-benefit functions around the equilibrium at N^*.[25] Also, the use of the interval-specific regressions which include a proxy for the desired number of children is designed to standardize for just such differences in contraceptive motivation. Finally, the finding from the regressions in table 7 that the high school dummy variable has a stronger effect on the monthly birth probability than does the college dummy variable does not support explanation (3). Thus, this interpretation of the observed negative education effects does not seem persuasive.

The results in this paper cannot help us distinguish between the first two explanations, since it is not possible to tell whether better-educated couples (*a*) select contraceptive techniques which are inherently more effective in use or (*b*) simply select some techniques systematically and proceed to use them relatively effectively. As long as the selection is systematic—different distributions by education for different techniques—either a differential inherent use effectiveness or a differential effectiveness by education for any given technique could yield the negative effects observed in tables 5, 6, and 7. It would be very useful to analyze the observed use effectiveness of a given technique by education level. This is not feasible with the data I have used here. Other studies, however, do suggest a differential use effectiveness by socioeconomic status (see, e.g., Tietze [1959*b*], table I, p. 353).

The interpretation of the results reported in this section based on differential knowledge or awareness of contraceptives may seem strained for contemporary U.S. women. It is interesting to note, however, that for the non-Catholic women in the 1965 NFS data, the correlation of wife's and husband's education level with a dummy variable for knowledge of the pill (defined as 1 for women who had never heard of the "pill" at the time of the interview) ranged between —.10 and —.30 for all six subsamples defined in table 2 for each spouse's education level. So knowledge of new contraceptives may not diffuse uniformly across education groups.[26] For the period of time covered by the data used in the regressions here—primarily from the late 1940s into the early 1960s—there were few changes in contraceptive technology until the pill became available. So it would

[25] It is not sufficient simply to argue that the higher price of time of the better-educated couple raises the cost of a child and thereby creates a differential motivation. The child also yields a flow of benefits, and N^* is defined in terms of equality of the marginal-benefit and marginal-cost functions. The economic motivation to avoid an additional child is a function of the differences in the heights of these two marginal curves around their point of intersection.

[26] Since medical care or exposure to medical advice is positively related to income, the simple correlations of the knowledge-of-the-pill dummy variable and the husband's income, which also range between —.12 and —.24 for the same six color- and age-specific groups, suggest that the information differential may work through this channel. For more information on the use of the pill derived from these data, see Ryder and Westoff (1971, chap. VI).

seem likely that the observed effects result from factors other than differential rates of adoption of new techniques—perhaps differential use effectiveness of a given technique, or perhaps differential knowledge of the different proficiencies of existing techniques. Unlike the survival test applicable to market firms, long-run differences in households' marginal as well as average efficiencies can and do exist, as Wesley Mitchell pointed out several decades ago (1937).

V. Other Dimensions of Fertility Behavior

The empirical results above lend support to the contention that more-educated couples achieve greater contraceptive efficiency. In terms of simple and partial correlations for each of the spouse's education levels, there appears to be a systematic selection of more effective contraceptive techniques by more-educated couples. Over extended periods of time and at high levels of efficacy, comparatively minor differences in contraceptive efficiency imply quite large differences in the risk of conception. If this is so, more-educated couples are exposed to lower risks of undesired conceptions, which would be expected to affect many other dimensions of their observed fertility behavior.

The influence on the completed fertility of more-educated couples is most straightforward. By lowering the costs of avoiding undesired conceptions, more-educated couples, on the average, exhibit lower completed fertility (if the problem of excess fertility dominates the problem of subfecundity in aggregate behavior). Not only may lower contraceptive costs reduce completed fertility, but they may also induce substitution toward quality of children, Q, and away from numbers of children, N, by implicitly raising the price of N relative to the price of Q. Since the shadow price of N is defined net of contraceptive costs, G, a reduction in G raises the price of N and induces substitution toward quality in the production of child services. The Becker-Lewis paper above explores this point in depth.

An effect of education on a couple's risk of conception could also be expected to influence the timing (over the life cycle) and spacing (by birth intervals) of their children. Economists have as yet not devoted much attention to these dimensions of fertility behavior, but the empirical evidence by sociologists suggests that more-educated couples (especially women) tend to marry later and to postpone childbearing longer after marriage begins (see especially Whelpton, Campbell, and Patterson [1966]). A recent (1968) survey of consumer anticipations conducted by the National Bureau of Economic Research and the U.S. Bureau of the Census contained information on the timing and spacing of children by couples in the relatively wealthy suburban households surveyed. These

data also suggest that more-educated couples—at relatively high levels of education—begin childbearing at a later age (see Michael [1971*a*]).

One explanation for this behavior may be that both schooling and child rearing are relatively time-intensive activities, especially for the wife. While engaging in the production of education, one's time value is relatively high, which effectively precludes simultaneously choosing to engage in childbearing. Thus, child production and education production are done sequentially. Add to this an assumption of asymmetry in the effects of the two stocks on the marginal product of time in the production of the other: assume that an acquired stock of education raises the marginal product of time in child rearing more than an acquired stock of children raises the marginal product of time in the production of education. Then one has, perhaps, the beginnings of a theory of the optimal timing of child production. As long as the optimal strategy involves postponement of child rearing, it is facilitated by contraceptive efficiency.

In addition to beginning childbearing later, more-educated couples also appear to space their children closer together (see, e.g., Bumpass and Westoff [1970], chap. 3; Michael [1971]; U.S. Bureau of the Census [1968]). Again, there is no well-developed theory of the optimal spacing of children, although the differential rates of increase in earnings profiles by education levels may be sufficient to imply a negative correlation between education and child-spacing intervals, other things (including child quality) held constant. Contraceptive efficiency is particularly relevant to the child-spacing issue, since a reduction in child spacing for a given number of children implies a longer period of subsequent exposure to the risk of an undesired conception.

Finally, it is of interest to note a tendency for more-educated women to space their children more evenly. Michael (1971) analyzed the absolute and relative variations within the household in the spacing of children and found that for age- and parity-specific groups, more-educated women exhibited a lower variation in the spacing of their children. That is, the standard deviation and the coefficient of variation in the spacing intervals among children within a given household decline, on the average, across households as the wife's education level rises. If the higher variation in spacing among less-educated women reflects outlying spacing-interval observations, these may reflect contraceptive "failures," although this argument is admittedly quite conjectural.

I have explored channels of influence from the couple's levels of education to various dimensions of human fertility in a relatively free format. Obviously, no tightly woven theory of the demand for fertility control or of the optimal timing and spacing of children has been set forth. While different aspects of fertility behavior surely interact with each other, the directions, nature, and magnitudes of these interactions have been considered only in passing. In short, this paper is a progress report on an

effort to understand the influence of education on several aspects of observed fertility behavior. I hope that it will help to convince other researchers of the viability of applying the household production function framework to the broad, interesting, and important area of human fertility.

Appendix

The constrained objective function, from equations (1)–(4) may be written

$$L = u[(Z_{it})] - \lambda[\sum_t \sum_i x_{it} p'_{it} - \sum_t \sum_j (W'_{jt} T w_{jt} + V_{jt})] - \sum_t \sum_j \lambda_{jt} [\sum_i (T_{ijt} + T w_{jt} - T_{jt})], \quad \text{(A1)}$$

where i, j, and t are indices over commodities, adult household members, and time, respectively, and where a prime represents an appropriate time-discounted value. For the purpose at hand, it will be assumed that all j adults are employed in the labor market at the discounted wage rate W'_{jt} and that the two constraints may thus be collapsed with the shadow price of time λ_{jt}/λ equal at the margin to the wage rate W'_{jt}.

Consider the optimal level of the goods input x_{P_k} in the production of the probability of conception P (see eq. [8]) in time period k. The first-order condition is

$$\frac{\partial L}{\partial x_{P_k}} = \sum_{t=k+1}^{h} \left(\frac{\partial U}{\partial Z_1} \frac{\partial Z_1}{\partial C} \frac{\partial C}{\partial N_{k+1}} \right)_t \frac{\partial N_{k+1}}{\partial P_k} \frac{\partial P_k}{\partial x_{P_k}} - \lambda \left[\sum_{t=k+1}^{h} \left(C'_{kt} \frac{\partial N_t}{\partial P_k} \frac{\partial P_k}{\partial x_{P_k}} \right) + \frac{\partial G'_k}{\partial x_{P_k}} \right] = 0, \quad \text{(A2)}$$

where C'_{kt} is the discounted total expenditure in period t on a child born in period k. The inelegant string of partial derivatives simply reflects the chain of influence through which x_P affects utility: x_P affects the probability P and in turn the expected number of children N, which alters the flow of child services and hence the production of Z_1 and, therefore, utility. Equation (A2) can be rewritten thus:

$$\sum_{t=k+1}^{h} \left(\frac{MU_1}{\lambda} MP_C \alpha - C'_k \right)_t \frac{\partial N_{k+1}}{\partial P_k} \frac{\partial P_k}{\partial x_{P_k}} = \frac{\partial G'_k}{\partial x_{P_k}}. \quad \text{(A3)}$$

The term in parentheses represents the benefits (in constant dollars) of an additional child in period t net of the costs of the child. Summed over time, the term represents the present value of the net marginal benefit of a child. The term will be designated B:

$$B_k = \sum_{t=k+1}^{h} \left(\frac{MU_1}{\lambda} MP_C \alpha - C'_k \right)_t. \quad \text{(A4)}$$

So the first-order conditions for x_P and T_{Pj} are

$$B\left(\frac{\partial N}{\partial P_k}\right) MP_{x_P} = p_{x_P} \quad \text{and} \quad B\left(\frac{\partial N}{\partial P_k}\right) MP_{T_{Pj}} = p_{T_{Pj}}, \tag{A5}$$

where p_{x_P} and $p_{T_{Pj}}$ are the prices of the goods and time used in the production of P.

The term B_k may be positive or negative. If, at time k, the present value of the gross benefit stream from an additional child exceeds the present value of the cost of the child, B_k will be positive. Presumably, the sign of the term B is the analytical analogue of the response to survey questions which seek to determine whether a given pregnancy was "wanted." Abstracting from the costs of fertility control, a child would be "wanted" if $B > 0$ and "unwanted" if $B < 0$. Since $\partial N/\partial P$, the effect of an increase in P on the expected number of children, is positive and the prices of time and market goods are also positive, equation (A5) implies that MP_{x_P} and MP_{T_P} will be positive or negative as B is positive or negative. That is, if $B < 0$, the couple will engage in fertility control by purchasing and using goods and time inputs to reduce P. If, instead, $B > 0$ and an additional child is "wanted," the couple may expend resources to raise P. Expressed differently, from the first-order condition for optimization with respect to P itself,

$$\frac{\partial L}{\partial P_k} = \lambda\left(B_k \frac{\partial N}{\partial P_k} - \frac{\partial G'_k}{\partial P_k}\right) = 0, \tag{A6}$$

or from equation (9),

$$B_k \frac{\partial N}{\partial P_k} = \Pi_{P_k}.$$

So equation (10) can be extended to indicate that if B_k is negative (or positive), P_k is less than (or greater than) P^*_k and Π_{P_k} is negative (or positive).

Comment

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I. Introduction

The basic assumption of Robert Michael's paper is that each family has a fertility objective and that decisions concerning it are made in the light of a set of constraints that are associated with education of the spouses. Fertility decisions are viewed as flowing from the weighing of benefits of child services against streams of costs. Empirical estimates presented of "education and fertility control" utilize data of the National Fertility Study of 1965, many findings from which are reported by N. B. Ryder and C. F. Westoff (1971). I comment briefly on each of the main sections of the paper and on tests of "wealth" constraints, the feasibility of which is inferred from information secured.

II. Theoretical Considerations

Household models provide an intriguing approach to any consumption analysis. Households are multiproduct firms with an exchange system within them and function in response to market and external nonmarket relationships. Interpretation of Michael's equation (2) fails to recognize activities related to the exchange system within households. All nonmarket activities are not inseparable from the enjoyment of the commodity produced. Failure to differentiate explicitly nonmarket activities of personal utility or enjoyment from those that provide products for another person, or for oneself that might be provided by someone else, is, in my opinion, a source of confusion in a general model of household production functions.

III. Channels of Influence of Education

The influence of education on fertility is assumed to flow through four principal channels, namely, utility, money wealth, a set of household

production functions, and time. Michael's review of these is a contribution to all analyses utilizing education as a behavior variable. The heterogeneity of the economic aspects of education is better documented than that of other influences.

a) Michael notes that "until a theory of the formation of preferences is available, little can be said, a priori, about the relationship between education and tastes or about the possible influence of education on the preference function." If knowledge affects preferences, then preferences are modified by exogenous change. Information theory predicts that diffusion of knowledge is affected by channels of information and theories of cultural norms and group identification explain resistance to change. The higher a person's education, the more accessible channels of information tend to be; hence, knowledge of new methods of contraception, such as the pill, will tend to be greater for better-educated couples. Knowledge and use of the pill as of 1965, less than 5 years after its introduction, could be expected to increase with education, to be greater for urban than for farm families, and to have restricted births after the second and third pregnancy intervals more than after the first. Cultural norms and group identification affect birth rates. Existing theories of lags predict that time tends to narrow the effect of their difference as well as that of knowledge among groups. Further innovation in contraceptive techniques may continue to cause differences in contraceptive behavior by education, access to channels of information, and cultural norms.

b) Michael comments briefly on the large literature on human capital. Theoretical models that relate fertility to education through wealth constraints seem well developed. Empirical investigators still search for reliable variables to fill boxes of the theory. So far, attention has concentrated on opportunity costs of time rather than on money costs of quality of children. Even so, money wage rates utilized are often very crude. Those of employed females have considerable measurement error. Even less is known of the supply wage of mothers out of the labor force because of home care of children. Better data on money wealth are, of course, not enough. Purchasing power of money must be considered. Money wages throughout the United States, and probably also within other countries, are likely to be positively correlated with the cost of living.

c) The effect of education on "production-function constraints" is appropriately viewed as "limitless." Economists are, as it were, warned of the maze in which they are likely to be entering in dealing with their ramifications. One production function explicitly dealt with is the effect on efficiency of fertility control due to knowledge and use of new techniques of contraception. Such differential efficiency may, however, be temporary. Diffusion of knowledge has been rapid, and utilization of new techniques calls for little expertise.

Education of mothers tends to increase efficiency of child care. Knowl-

edge of the effects of education awaits identification of quality. Could something be learned from infant mortality with respect to education of mothers, other conditions held constant? Or from the speed of learning of children during early years in school?

d) Discussion of the time constraint first deals with the positive correlation between education and age of marriage of women. This contributes to the negative correlation between education and fertility. This relationship is well documented by other studies. In this study, criteria imposed in testing the effect of contraception on fertility indirectly hold constant the age of marriage. Hence, its effect on fertility is not described.

The time constraint is related to life expectancy without consideration of its relevance to fertility. The discussion does, however, suggest an unexplored area of speculation. Do adults who expect a long life desire more children? They are looking forward to more years in which to enjoy them and their offspring. There are other conditions. For example, does having an additional child restrict leisure that contributes to health, so that parents, as it were, trade an extra year or two of life for themselves for an extra child?

A consideration of life expectancy seems to have been introduced by Michael in the hope of presenting further evidence that education increases efficiency of household production. It undoubtedly contributes. To isolate this effect is a matter of great interest. Attempts at its isolation through examination of longevity seem unlikely to bring much reward, and assuredly have little bearing on birth rates.

IV. Education and Fertility Control

Utilization of an estimate of probability of conception due to the contraceptive technique used is a unique feature of this study. It lends itself to simple and complex quantitative estimates of the type necessary for testing the model presented. The probability of conception is shown to be negatively correlated with the education of wife and husband and positively correlated with the number of children intended. The correlations shown among non-Catholic women by pregnancy interval, age, and race differ considerably between sets of all women and those using contraception. For the first and second pregnancy intervals, the correlation between birth probabilities and education of the wife is appreciably greater for all women than for those using contraception. What conditions account for this? Is effectiveness of contraceptive techniques related to wealth constraints? Wealth, knowledge, and effective use of contraceptive techniques are closely associated.