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HUMAN CAPITAL, POPULATION GROWTH AND ECONOMIC DEVELOPMENT: BEYOND CORRELATIONS

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Abstract

Empirical evidence on three assertions commonly-made by population policy advocates about the relationships among population growth, human capital formation and economic development is discussed and evaluated in the light of economic-biological models of household behavior and of its relevance to population policy. The three assertions are that (a) population growth and human capital investments jointly reflect and respond to changes in the economic environment, (b) larger families directly impede human capital formation, and (c) the inability of couples to control fertility is an important determinant of investment in human capital. The evidence suggests that widely-observed correlations among population growth, human capital and economic variables, which admit to alternative interpretations, are far stronger than are the estimates from studies whose objective is to quantify the causal mechanisms underlying the three assertions; however, there is empirical support for each.

The role of population growth in economic development has become a controversial issue in recent years. One of the principal relationships singled out by participants in debates about the consequences of population change is that between population growth and human capital formation. Indeed, one characteristic which distinguishes markedly low- from high-income countries is the extent to which families choose to allocate resources to increasing the number of children they have relative to increasing investments in the human capital of each of their children. Table 1 presents correlations among per-capita GNP, population growth, and school enrollment rates for 94 countries *circa* 1970-80. The broad picture they display is clear--high-income societies have low rates of population growth and high rates of schooling and literacy; countries with high rates of population growth are also characterized by low school enrollment and literacy rates. Within countries too, large families also tend to be families in which children have lower levels of schooling, health, etc. (National Academy of Sciences, 1971).

Debates concerning the appropriate policy mix for promoting economic growth can, I think, be summarized by three assertions about the meaning of the relationships among population growth, human capital and economic development, each of which is consistent with the correlational evidence:

Assertion (a): Population growth and human capital investment rates reflect the economic circumstances of a country; the observed mix of large families and low levels of health, nutrition and schooling are symptoms, not causes, of a lack of economic development. Governments and international development agencies should therefore focus on promoting (or removing impediments to) economic development and not on families' decisions about their size.

Table 1

Correlations Among Per-Capita GNP, Population Growth,

and School Enrollment Across 94 Countries

	Annual Population Growth Rate 1970-80	GNP Per-capita in 1980
GNP, 1980	-.18	-
Female school enrollment rates, ages 10-14	-.31	.49
Male school enrollment rates, ages 10-14	-.19	.44
Literacy rate	-.47	.54

Source: Jasso and Rosenzweig, (1986).

Assertion (b): Large families contribute directly to lowering the human capital of children; higher fertility--closer spacing of children, early childbearing, large families--impedes human capital formation, for given resources. Dissemination of information to families about the negative consequences of high fertility for their children and providing the means for controlling fertility should be high priorities for public agencies.

Assertion (c): The inability of families to control fertility reduces the resources families have for investing in their children. Improving access to fertility control resources thus is important for augmenting human capital formation.

The three assertions are not, of course, mutually exclusive, and each is consistent with the correlational evidence, such as presented in Table 1. This essay is concerned with evidence that goes beyond correlations and that can reject or support the three assertions--what is the evidence that population growth and investments in human capital jointly respond to changes in the economic environment, that altering fertility patterns causally affects the characteristics of the children born, or that the inability to control fertility is an important deterrent to human capital investments? I review empirical studies that I and colleagues have produced over the last decade whose objectives were to examine those issues by identifying causal--biological and behavioral--relationships between characteristics of the economic environment, fertility, and human capital investments.

Evidence cannot be interpreted without a theoretical framework. And in this case, the framework must simultaneously allow for all of the causal relationships proposed in the assertions. Section 1 of this paper, therefore, sets out a single economic model of the household incorporating both biological and behavioral mechanisms. The model embodies many features of household behavior that have been illuminated in recent work aimed at formulating economic models of the household. The household is an appropriate focus for obtaining and evaluating evidence on the determinants and consequences of population growth since that is ultimately where decisions about family size and human capital reside.

Sections 2, 3, and 4 of the essay describe, in the light of the model of Section 1, the kinds of evidence that are required to test the implicit hypotheses embodied in each assertion, and present evidence from a number of empirical studies using similar and appropriate (in light of the model) methodologies. In each section, and thus for each assertion, results from at least two empirical studies are discussed, as an important consideration in weighing evidence is the ability of results to be replicated, and replicated in different populations or environments, if not by different researchers.

In Section 5, I consider the question of whether the relationships between family size and human capital investments posed in assertion (b) and (c), if true, are pertinent to the question of whether public support of family planning efforts are warranted from an efficiency perspective. I also present evidence pertaining to the question of whether governments allocate resources in a manner which suggests that there is a complementarity between efforts to encourage human capital investments and reduce population growth and which is consistent with the findings on the relationships between population change and human capital formation.

Review of the evidence from studies I consider to have shed light on the empirical foundations for assertions (a), (b), and (c) suggests that each can be supported. But the quantitative evidence for any one is not overwhelming; there are only a few studies in each case that go beyond correlations and the estimated magnitudes of the causal relationships are small. On the other hand, the studies, based on data from countries as diverse as Colombia, India, Malaysia, the Philippines and the United States, are consistent with the general hypothesis that parents respond to increases in the relative returns to investing in human capital, by both lowering their fertility and increasing investments in each of their children. And this comes about whether the changes in relative returns are induced by alterations in the cost or efficiency of fertility control or via changes in rates of return to schooling that may accompany economic development.

1. A Model of Fertility and Human Capital Investment

In this section I set out a simple model of household decision-making incorporating fertility decisions and human capital investments.[1] The model illustrates the variety of relationships among population growth, income and human capital investments at the micro level and will be used in subsequent sections to translate assertions about these relationships into testable hypotheses. To simplify the presentation, I assume a one-period decision horizon and full information; hence, the stochastic and sequential nature of childbearing is abstracted from, although the dynamics of these processes will be discussed as they relate to the testing of hypotheses.

An essential feature of the determination of population growth is that fertility is a biological process; resources must be used by households to limit the supply of births rather than to increase supply, as for most other "goods." This can be expressed in its most basic form by using the construct of a reproduction function, as in (1):

(1) $N = \mu + n(Z), \quad n' < 0,$

where N = number of births (children), Z = resources used to control births, with $n' < 0$, and μ = fecundity, the number of births that would occur in the absence of control ($Z = 0$).[2] The household chooses its level of control Z, but fecundity is biologically determined.

Human capital (H) is also produced by the household. The function describing the effects of changes in household resources on the level of human capital invested in each child is given by (2).

(2) $H = V + h(t^c_H\ t^m_H, X, N), \quad h_1, h_2, h_3 > 0,\ h_4 \lesseqgtr 0.$

Here, there are four important human capital inputs highlighted: the time of the child t^c_H (in school, medical care), the time of the mother t^m_H, purchased goods and services X (e.g. books, medical care), and the number of children. The presence of the latter in (2) expresses the possibility that fertility may have a direct impact on human capital (assertion (b)); that is, a change in family size may affect H, for given levels of other human capital inputs.

The human capital production function (2) also contains a term V which reflects inputs influencing human capital not under the control of parents. The term captures, for example, the influence of environmental factors, such as the prevalence of disease, and biological factors, possibly genetically transmitted, which also directly, but exogenously influence H. As with fecundity, the human capital "endowment" may influence household decisions, as described below.

Human capital earns a return in the market. Thus,

(3) $E = \omega(H, V) \qquad \omega_1, \omega_2 > 0$

where E = (adult) child earnings. Parents also invest in their own human capital. For example, the mother may accumulate skills while working, such that her wage W will be a function of her work time, as in (4):

$$(4)\quad W = W(t^m) \qquad W' > 0$$

where t^m = mother's time at work.

The budget constraint of the households is:

$$(5)\quad F + W^c(\Omega - t^c{}_H)N + t^mW + \theta NE = p_zZ + p_xNX + p_yY$$

where F = non-employment sources of income, W^c = wage rate of children, Ω = time available, p_z = price of fertility control inputs, p_x = price of X, Y = household consumption, p_y = price of Y. The budget constraint incorporates the possibility that children contribute income to the household when not engaged in human capital accumulation (e.g., in school) and parents receive some fraction θ of the earnings of "grown" children.

Finally, the parental welfare function is described by (6);

$$(6)\quad U = U(N, E, Y).$$

Parents "care about" the number and adult earnings of their children, and the level of household consumption.

The parents maximize (6) subject to (1) through (5) by choosing the levels of Z, X, and Y and by allocating parental and child time across activities. In equilibrium, the marginal rate of substitution (mrs) between the number of children and the time each child allocates to human capital production (in school) is:

$$(7)\quad mrs_{N,t^c_H} = \frac{p_xX + Wt^m{}_H + W' - W^c(\Omega - t^c{}_H) - \theta E + p_z/n'}{((NW^c/\omega_1h_1) - \theta)}$$

The denominator of (7) contains the returns to time in school, or the ratio of the opportunity cost of school time W^c to the marginal increase in earnings associated with a unit increase in school time. In the numerator of (7) are the resource costs associated with addition of one child--the value of the purchased human capital inputs X, the value of the mother's time in "child care," inclusive of the foregone costs of her own human capital accumulation--less the value of children's contribution to household resources when young and when grown. Also in the numerator is the ratio of the per-unit cost of the fertility control resource to the "effectiveness" of control, the derivative of the control function (1) with respect to Z. Thus, reductions in the "costliness" of fertility control--decreases in the purchase price of contraception, p_z and/or increases in the effectiveness with which a given increase in the fertility control resource reduces fertility (a change in the absolute value of n')--influence in the same way the trade-off between fertility and investments in schooling. Both family planning interventions and the costs and returns to investments in children can thus potentially influence the allocation of resources between human capital and family size. In the next sections I address the questions of how and whether, empirically, the family size-human capital association is influenced by the economic environment and the costliness of fertility control.

2. Economic Development and the Schooling-Fertility Trade-Off

An important implication of the household model is that measures of the associations between household <u>income</u> levels and fertility and human capital investments reveal little about the influence of the economic environment on these decisions. This is because household income itself is determined along with family size and schooling investments. For example, how much time children spend at work time when young or the extent to which mothers participate in the labor market clearly influence the total level of household income, but are jointly determined with family size and other decisions in the model. To test the assertion (a) that the economic environment determines the observed association between population growth and investments in human capital it is thus necessary to ascertain how the relative returns to investments in family size and human capital are influenced by economic variables exogenous to the household. Testing proposition (a) requires, first, that there be a clear prediction with respect to the influences of a variable characterizing the economic environment and, second, that the variable be measurable and vary exogenously to family size and human capital decisions. Family income fails the second criterion, as noted; but so does the mother's wage rate, for example, since that is potentially influenced by her work time decision and thus both by the number of children she may want and her concern for their welfare.[3] Evidence on the effects of exogenous variations in fertility on the mother's wage rate is presented below.

One good candidate variable for testing the proposition that the economic setting in low-income countries is in part a cause of both the high-family size and low levels of school investment observed there is the child wage rate, W^c in the model. The 'wage' of children cannot be importantly influenced by human capital investments and wages of children are likely to vary spatially within a country, since it is unlikely that young children are mobile or that the returns from children constitute a sufficiently large proportion of total family income to make it worthwhile for parents to relocate in response to child wage differentials. In contrast, spatial differentials in gross returns to skill investments are likely to be arbitraged, since the costs of mobility for young adults are low.

Is the higher, more immediate economic value of children a reason for the larger family size and lower schooling investment rates in low-income compared to high-income countries--do higher values of W^c, all other costs the same, lead to higher levels of fertility and lower schooling levels? The effects of changes in W^c derived from the model are:

$$(8)\quad \frac{dZ}{dW^c} = n'[-S_{NN}(\Omega - t^c_H) + S_{NE}W_1h_1N] + \frac{t^c_H}{n'}\frac{dN}{dF}$$

$$(9)\quad \frac{dt^c_H}{dW^c} = S_{EE}N + S_{NE}(\Omega - t^c_H) + \frac{t^c_H}{W_1h_1}\frac{dE}{dF}$$

where S_{ii}, i = N,E are own compensated substitution effects, S_{NE} is the cross compensated substitution effect between the number and the per-child earnings of children, and di/dF is the income effect. Second-order conditions constrain the S_{ii} to be negative. Since the effects of a change in the child wage on the demand for fertility control Z and on child time in school depends on the <u>sum</u> of own and cross compensated substitution effects, as well as income effects, it can be seen that only when S_{NE} is positive, i.e., when adult child earnings E and family size N are Hicksian substitutes, can the model yield an unambiguous result (as long as income effects are small). In that case, higher levels of child wages will induce a lower demand for fertility control resources (higher fertility) and a lower demand for schooling (time) investments--where the economic value of younger children is high, an additional child is less costly <u>and</u> the opportunity cost of school time is higher.

If parents view family size and per-child earnings or well-being as substitutes (S_{NE}>0) then, definitionally, increases in the costs of having children or decreases in the costs of controlling fertility will not only reduce family size but increase per-child investments. The child-wage rate, representing the returns to younger children's labor, both offsets (reduces) the cost of an additional child and is a component of (increases) the cost (opportunity cost) of schooling. In contrast, a decrease, say, in the direct costs of human capital investments (p_x) or a rise in the gross returns to human capital investments (ω') increase the net returns to per-child investments but render having an additional child less costly as well. Suppose, as hypothesized by Schultz (1975), increases in the rate of technical change τ raise the gross returns to schooling; i.e., $\partial\omega_1/\partial\tau > 0$. Then the effects of a change in τ on fertility control and per-child school (time) investments are:

$$(10)\quad \frac{dZ}{d\tau} = n'\left[-S_{NN}\theta\frac{\partial\omega}{\partial\tau} - S_{NE}\frac{NW^c}{\omega_1 h_1}\frac{\partial\omega_1}{\partial\tau}\right] + \frac{\theta N}{n'}\frac{\partial\omega}{\partial\tau}\frac{dN}{dF}$$

$$(11)\quad \frac{dt^c_H}{d\tau} = -S_{NE}\theta\frac{\partial\omega}{\partial\tau} - S_{EE}\frac{NW^c}{\omega^2 h_1}\frac{\partial\omega_1}{\partial\tau} + \frac{\theta N}{\omega_1 h_1}\frac{\partial\omega}{\partial\tau}\frac{dE}{dF}$$

Here, own and cross-compensated substitution effects offset each other. When family size and child "quality" are substitutes and parents' total resources directly increase as a result of their investments in their children, technical change or other factors that raise the net returns to human capital have ambiguous effects on fertility and human capital investments. Both fertility and per-child resources spent on children may increase; total expenditures on children must increase. However, if transfers from children to parents either do not depend on investments in human capital ($\theta = 0$) or if such transfers do not depend on the number of children, then increases in the returns to schooling will lower fertility and raise investments in schooling, as the first terms disappear in (10) and (11).

The model thus suggests that if per-child investment returns and fertility are substitutes the development of an economy via technical change, which lowers the value of unskilled relative to skilled labor (lowering W^c, increasing ω'), is likely to induce a substitution by households away from large families and towards more investments per child, particularly where parents do not rely heavily on support from their adult offspring. What is the evidence? Table 2 reports results from three studies based on data from India and the Philippines that obtained estimates of the effects of variations in child wage rates, given adult female and male wages or earnings potential, on both fertility and child schooling. In all three studies, based on national surveys or aggregate data, fertility was higher and schooling lower where child wage rates were higher--family size and per-child investment returns do appear to be substitutes and to respond to the economic environment in a way consistent with the hypothesis that parents are attentive to the costs and returns to investments in children.[4] The estimates, while reasonably precise in each case, differ widely in magnitude--a ten percent increase in the child wage increases fertility by from .4 to 6 percent and lowers the schooling of children by .2 to 20 percent, with the most diverse estimates obtained from the same country, although at different levels of aggregation.

The "Green Revolution" in India also provides some evidence on parental responses to changes in the relative returns to human capital investments. An important feature of the Indian experience with respect to the introduction of the newer high-yielding grain varieties in the early to mid-1960s is spatial variability in the degree to which the "revolution" took hold. Cross-sectional data from India collected in 1970-71 suggests that where the HYV seeds were selectively introduced, fertility rates appeared to decline

Table 2

Estimates of Child Wage Elasticities for Measures of Child Schooling and

Fertility: India and the Philippines

	School Enrollment Rate			Fertility		
	India: District Mean Enrollment Rate, Girls 5-14[a,d]	India: Enrollment Rate, Children 5-14[b]	Philippines: Schooling attainment, children 10-20[c]	India: District Child-Women Ratio[a]	India: Children Ever Born[b,e]	Philippines: Children Ever Born[c]
Child wage elasticity	-2.02 (2.05)[f]	-.034 (1.70)	-.021 (1.61)	.59 (2.90)	.50 (1.71)	.036 (2.05)

a. Indian district-level data. From Table 3 in Rosenzweig and Evenson (1977).

b. Indian household data (NCAER ARIS-Survey), non-farm households, from Tables 3 and 4 in Rosenzweig (1982).

c. Philippines household data (1968 National Demographic Survey), from Table 3 in Rosenzweig (1978).

d. Child wage jointly significant and collinear with adult male and female wages in enrollment equation for boys.

e. Based on age-standardized measures of marital fertility control. Assumes no change in marital patterns associated with variations in child wages.

f. t-ratio in parentheses beneath elasticity estimate.

and school enrollment rates to increase relative to other areas and to their prior levels in the affected areas, for given levels of wage rates (Rosenzweig, 1982), although the pre-"revolution" baseline data are of lower quality than are the survey data.

The limited evidence from studies examining the economic determinants of both fertility and schooling, attentive to the behavioral and biological mechanisms highlighted in economic models of the household, thus do tend to support assertion (a)--increases in the level and pace of economic development, without direct family planning interventions, can lead to reductions in population growth and increases in human capital investments in children. But, the way in which economic development proceeds matters--rates of return to intensive and extensive investments in children must shift, as they are likely to do as a consequence of technical change and/or (exogenous) capital deepening. If so, parents appear to respond, in ways consistent with proposition (a).

3. Biological Effects of Fertility on the Human Capital of Children

The effects of relative price changes on the division of resources between fertility resources and per-child investments depends crucially, as was shown, on parental preferences, in particular, on parents' subjective view of the substitutability between family size and child quality in terms of household welfare. Assertion (b) which posits the existence of deleterious direct effects of larger families on the human capital of children pertains, however, to biological relationships between fertility and human capital. The question here is: will a woman who bears more children or more closely spaces her children reduce the average human capital (health, intelligence) of her children even if she spends the same resources on each child? In terms of the model this is a question about the characteristics of the human capital production function (2). Testing this proposition therefore requires that the influence of changes in measures of fertility--the number of children, spacing, timing of births--on measures of children's human capital (H) be obtained controlling for all other <u>inputs</u> that also may directly influence H.

Lack of controls for other H inputs that may be correlated with fertility may lead to misleading inferences. For example, fertility and mortality may be positively correlated because parents living in unhealthy environments expect their children to die more frequently. They thus invest less in each child and bear more children. Accounting for the influence of all relevant human capital inputs, including the possibility of environmental or other factors directly affecting human capital outcomes that are beyond the control of parents but taken into account by them, makes it difficult indeed to obtain evidence on the question posed in proposition (b).

Consider the case in which data are available describing all of the inputs in (2), but there is no information on the V term, the endowed or environmental component of child human capital. Attempts to fit some parameterized form of the function with least squares or some other curve-fitting method will result in consistent and unbiased estimates only if the inputs, inclusive of the fertility variables, are not correlated with the unobserved V term. If parents know V and V varies in the population, will the human capital inputs, in particular fertility, vary with human capital endowments? Rosenzweig and Wolpin (1982) treated the special case in which the production function (2) contained only X as an input. They showed that with an identical household welfare function as (6) and a comparable budget constraint, the effect of V on fertility is given by

$$(12) \quad \frac{dN}{dV} = \frac{p_x}{h_x} [h_x \omega_1 S_{NE} + \frac{dN}{dF}].$$

In that model, even without N directly affecting the human capital outcome, variations in endowed human capital induce variations in fertility as long as parents care about the relationship between N and E. In particular, with the simplified production function, parents with more endowed children bear more children when the number of children and quality per child are Hicksian substitutes, so that higher fertility would be positively correlated with H, controlling for X, even though fertility, in this case, actually has no direct influence on human capital. In the more general case of (2), the result is less clear, depending on how fertility directly affects human capital, i.e., on h_N and h_{NN}. Estimates of fertility effects on H are thus likely to be biased if there is variation in unobserved factors influencing human capital that are known to parents.

Regardless of whether or not the existence of unobserved exogenous factors is accounted for in estimating (2), it is still necessary to account for all relevant inputs directly affecting human capital that are under the control of parents. This information is most likely to be complete for early indicators of child development, such as birthweight and infant morbidity and survival. The number and variety of "inputs" that could have directly affected an adult's accumulation of human capital, aside from his/her number of siblings and sib intervals, is large indeed. It is not likely therefore that measures of associations between fertility variables and adult levels of human capital can shed much light on the question posed in assertion (b).

A number of recent studies have estimated the biological determinants of early human capital indicators employing econometric methods that take into account parental responsiveness to unobserved (by the researcher) human capital endowments. Rosenzweig and Schultz (1983, 1987) estimated the effects on children's birthweight of birth order, maternal age at birth and other direct determinants using instrumental variables, namely proxies for input prices, based on random samples of all legitimate births in the United States. They found that estimates of the effects of inputs on birthweight are sensitive to whether or not the unobserved factors are taken into account. Because in the United States in recent years almost 40 percent of births are first births, and family size is low, they could not find any direct effects of birth order on birthweight, beyond a (negative) first birth effect.

Olsen and Wolpin (1984) used a family fixed effects procedure to estimate the biological determinants of child survival based on a national probability sample of households in Malaysia. They looked at how differences across children <u>within</u> the same family in birth order, spacing, maternal age and other variables were associated with differences in survival. This technique purges out the family human capital endowment, and they found that their results were quite sensitive to whether or not differences across families in inherent child survival propensities were taken into account.

The <u>family</u> fixed effects procedure used by Olsen and Wolpin assumes that parents do not respond to exogenous differences across individual children. That is, dynamic behavior is assumed away. It is a procedure faithful to the static model described in section 1 in which all children have the same (family) endowment V and there are no unanticipated events. However, if parent's fertility decisions do respond to unanticipated events or the individual characteristics of their children, the family fixed effects estimates will also be biased and inconsistent. For example, if parents have an additional child more quickly because their last child dies (the so-called "replacement" effect), it will appear that shorter post-birth intervals increase the risk of death even when in fact they do not.[5] Similarly, the mother may less intensively breastfeed a child who is ill and who is thus more at risk of death, leading to overestimates of the true, if any, mortality-reducing effects of breastfeeding.6

Table 3 presents estimates of the effects of three fertility variables on birthweight from two studies, based on data from Malaysia and Colombia, that were obtained using a combination of within-family estimators, to take into account _family_ endowment (and input) differences, and instrumental variables, to take into account parental responsiveness to individual endowment differences across children within the family. The estimated effects (in elasticity terms) are remarkably similar across data sets from two very different economic environments, a result to be expected if biological relationships are being measured, as is the goal. Both studies indicate that the postponement of births, wider intervals between births, and fewer births increase _biologically_ the weight of children at birth, an important determinant (or correlate) of infant mortality and subsequent child development among surviving children.

The two studies that appropriately control for unobserved child and family specific variability in human capital endowments in estimating the direct human capital effects of fertility behavior thus support the contention that lowering fertility directly benefits those children born, when all other parental behaviors are the same. The magnitude of these direct effects appears to be small, however--a _doubling_ of the intervals between births (2.3 years to 4.6 years) increases birthweight only by from 2.6 to 5.6 percent; the birthweight of a fifth child is from four to six

Table 3

Estimates of Birth Spacing, Birth Order and Maternal Age Elasticities for Birthweight, from Within-Family, Instrumented Production Function Analyses: Malaysia and Colombia

Variable	Malaysia[a] Elasticity	Malaysia[a] Mean	Colombia[b] Elasticity	Colombia[b] Mean
Birth Order	-.16 (1.17)[c]	2.5	-.24 (2.08)	4.6
Prior birth interval (months, order>1)	.026 (1.62)	27.3	.056 (1.83)	27.6
Maternal age at birth (years)	.63 (1.50)	22.5	.76 (1.35)	23.5
Number of children	1458		238	

a. From Rosenzweig and Schultz (1987), Table 7. Based on children of order two and three only.

b. From Rosenzweig and Wolpin (1987), Table 2.

c. t-ratio in parentheses beneath the elasticity estimate.

percent lower than his/her immediately preceding child; postponement of births by one year, for given spacing and number, increases birthweight by from 1.4 to 3.2 percent.

4. The Human Capital Consequences of Costly Fertility Control

The assertion (c) that the inability of couples to control fertility is a principal cause of lower levels of investments in human capital requires two kinds of evidence. First, there must be evidence that the costliness of controlling births is an important determinant of the actual number of births. Second, it must be shown that parents or households respond to "excess" births by diverting resources from per-child human capital investments. For after all, parents with larger families could choose to reduce their leisure time or purchases of, say, transistor radios.

A seemingly-straightforward means of ascertaining both the prevalence and consequences of imperfect contraceptive control is to obtain information from parents on unwanted or excess births. Attempts to relate parental reports of the number of unwanted births or pregnancies to measures of their human capital investments (Rodgers (198_) are, however, problematical. First, that a child or pregnancy is unwanted <u>ex post</u> may be due to reasons other than a couple's inability to control fertility perfectly. In particular, <u>ex post</u> (post-fertility) "unwantedness" may be a function of unrealized expectations, expectations formed when fertility decisions were originally made, regarding economic circumstances or the "qualities" of the as yet unborn children. In societies in which returns to large families have been diminishing over time, <u>ex post</u> reports of excess births may thus be high, but do not necessarily signal a fertility control problem.

A second problem with using reports of excess births to measure the costliness of fertility control is that couples' willingness to bear "excess" children will clearly depend on the net cost of children (Michael, 1973). Both "excess" births--the number of additional births that would have been averted if fertility control were costless--and desired births are functions of the costs of children. Thus, in societies where the shadow price of children is low, actual, desired (under costless control) <u>and</u> excess fertility will be high. In an environment having identical costs of fertility control, but in which the relative returns to (costs of) large families are low (high) however, excess births will be lower (as will as actual births and desired births).

Finally, if excess births as well as human capital investments are likely to be correlated with economic circumstances, it is necessary to look at the consequences of variations in "excess" births controlling for those circumstances. But why should observationally identical couples facing the same economic environment report different numbers of unwanted children? One reason is that couples differ in their preferences--households in which smaller per-child human capital investments are preferred may be more willing to control fertility less perfectly, and <u>vice versa</u>.

In sum, direct, subjectively ascertained measures of excess fertility confound the costliness of control with (i) <u>all</u> discrepancies between couples' expectations and realizations, (ii) the costs and returns to investments in children, and (iii) couples' preferences. The association between such reports and human capital investments in children thus do not provide reliable evidence on how, or whether, decreasing the costs of controlling fertility would affect levels of human capital. There are alternative methods that can be used to assess the consequences of the costliness of fertility control, however. One is to estimate the effects of variation in p_z, the cost of contraception, on human capital investments i.e., estimate the cross price effect S_{NE} by estimating dX/dp_z or dt^c_H/dp_z. Studies of the effects of family planning programs (which either reduce p_z or increase (in absolute value) n'), usually focus on births, or worse, "acceptances" of contraceptive services. A number of studies have examined the "cross"-price effects of family planning, however.

Table 4 presents estimates from three studies which have estimated the effects of various measures of programmatic family planning efforts on measures of child survival and children's nutritional status. In all three studies, the effects of family planning are measured net of the effects of health programs and parental schooling levels. Each confirms the evidence presented in Table 2--raising the net costs of increasing family size, in this case via reductions in p_z (or increases in n') induces increased human capital investments; N and E are substitutes. The quantitative effects are, again, small--a doubling of expenditures per capita on family planning would reduce child mortality rates by from .7 to 3.7 percent (urban Colombia); children in families fully exposed to a local family planning clinic are 3.4 percent heavier than children residing in an area with no clinic (Philippines); a 20 percent increase in the proportion of villages with a family planning clinic would reduce child mortality by 4.4 percent (rural India).[7]

The principal difficulty with using community-based data on programs to estimate the effects of those programs on the behavior of households is that the program distribution may not be orthogonal to unmeasured variables influencing household behavior. For example, programs may be placed where the demand for program services is high, where the environment is least

Table 4

Elasticity Effects of Family Planning Interventions on Measures of Child Human Capital: Colombia, India and the Philippines

	Measure of Human Capital		
Country and Measure of Family Planning	Normalized Child Mortality[a]	Child Mortality Rate	Weight for Age[c]
<u>Colombia</u> (national, urban): Expenditures per capita in municipios.			
Mother aged 30-34	-.037 (1.78)[d]	-	-
Mother aged 35-39	-.022 (1.21)	-	-
Mother aged 40-44	-.007 (.038)	-	-
Mother aged 45-49	-.034 (1.90)	-	-
<u>India</u> (national, rural): Proportion of villages in district with clinic			
	-	-.22 (2.42)	-
<u>Philippines</u>: (20 barrios) Proportion of child's life exposed to clinic			
	-	-	.034 (2.76)

a. Ratio of family's actual child mortality rate (deaths/live births) to that predicted on the basis of birth histories in urban areas of Colombia. Source: Rosenzweig and Schultz (1982), Table IV.

b. Child deaths/live births. Source: Rosenzweig and Wolpin (1982), Table 3.

c. Weight divided by weight predicted for child of given age from national Philippines age standards. Source: Rosenzweig and Wolpin (1986), Table 3.

d. t-ratio in parentheses beneath elasticity estimate.

healthy etc. (Rosenzweig and Wolpin, 1986a). Conversely, households may move to localities that provide services they prefer or can use most efficiently (Rosenzweig and Wolpin, 1986). I consider some of these program distribution issues in somewhat more detail in the next section.

A third strategy for assessing the consequences of imperfect fertility control for human capital investments is to exploit the "natural" experiment associated with the variability in fecundity in the human population, μ in the model. Because fecundity is likely to be orthogonal to preferences and robust to at least small changes in the environment, this "variable" mimics the ideal randomized experimental intervention of varying births exogenously. Moreover, if and only if fertility control is costly can the variability in fecundity influence the variability in family size and, possibly, human capital investments. To see this, consider the effect of a change in μ on, say, school time, allowing the household to adjust all of its resources optimally. Rosenzweig and Schultz (1987) show that:

$$(13)\quad \frac{dt^c_H}{d\mu} = \frac{p_z}{n'}\left[n''S_{NE}h_1\omega_1 + \frac{dE}{dF}\right]$$

Expression (13) indicates that; first, if $p_z = 0$; i.e., fertility control is costless, or $n' = \infty$; i.e., fertility control is perfectly effective, variations in fecundity will not affect children's human capital no matter how parent's perceive the substitutability between family size and the well-being of each of their children. In that case, fertility can be costlessly adjusted so there are no consequences. Second, with $p_z > 0$, the association between fecundity and schooling will be negative if family size and per-child human capital are substitutes. The results in Tables 2 and 4 thus imply that couples experiencing exogenously a higher "supply" of births will invest less in each child if control is not costless.

Two methods have been used to measure fecundity. Rosenzweig and Wolpin (1980 and 1980b) proposed that the behavior of couples experiencing a multiple birth could be compared to those couples not experiencing such births to obtain unbiased estimates of the effects of "excess" births. Since "twinning" is uncorrelated with preferences and not subject to choice, such comparisons would not require any information on the economic circumstances of the couples, only information on birth histories and the behavioral outcomes of interest. Since the probability that <u>a couple</u> experiences a twin birth rises with the number of pregnancies, Rosenzweig and Wolpin (1980a) studied the consequences of imperfect fertility control for child schooling by using a measure of twins per pregnancy. A better method, implemented in Rosenzweig and Wolpin (1980b), compares couples with a twin on the first pregnancy to other couples. The "twins first" method is preferred since at which pregnancy the multiple birth occurs may matter. Indeed, in a regime of costless fertility control, and where couples desire at least two children, couples having a twin on the first birth should not behave very differently from other couples, unless the timing of births is important. Couples experiencing a twin on their last (planned) pregnancy, however, cannot adjust their family size no matter what the cost of contraception.

A major practical shortcoming of the twins first method is that less than one percent of all first pregnancies result in multiple births. Thus very large sample sizes are needed to exploit the natural twins experiment. Rosenzweig and Schultz (1985) have proposed a method which also exploits the variability in fecundity but does not require unusually large sample sizes.

In this approach μ is measured by estimating the reproduction function (1). If the parameters of (1) are known, then the difference between a couple's actual number of births and that predicted on the basis of their use of fertility control (and all other relevant) inputs in (2), the "residual," represents that part of fertility which, definitionally, is beyond the couple's control; i.e., for couple i,

(14) $\mu^i = N^i - n(Z^i)$.

The Rosenzweig-Schultz residual method requires detailed information on couples' contraceptive use and conceptions. Moreover, estimation of the reproduction function is not straightforward. Couples will adjust their contraceptive use to realized births, and thus to μ, just as, as was shown, couples allocate resources in response to human capital endowments. As a consequence, the unobserved μ will be correlated with Z in (2) and the estimation procedure must take into account the correlation. Rosenzweig and Schultz (1985, 1987) used instrumental variables to estimate the reproduction function using data from the United States and Malaysia. Thus, another data requirement of their procedure is information on the (exogenous) determinants of contraceptive control Z. In both countries, variation in fecundity was found to account for some portion of the variability in actual births, although the proportion was small - ten percent in the United States, three percent in Malaysia.

Table 5 reports estimates of the effects on children's schooling attainment of an <u>exogenous</u> increase in fertility by one birth, from a study (Rosenzweig and Wolpin, 1980a) applying the twins per pregnancy method, to rural Indian data, and from a study (Rosenzweig and Schultz, 1987) based on the residual method, applied to Malaysian data. Both estimates indicate,

Table 5

Estimates of the Percentage Change in Children's Schooling Attainment due to One Unanticipated Birth Using Two Methods: India and Malaysia

Method	India Age-Standardized Schooling Index[a]	Malaysia Mean Years of Schooling[b]
Twins per pregnancy[c]	-34.0 (3.22)[e]	-
Residual fecundity[d]	-	-8.3 (1.62)

a. Source: NCAER-ARIS. Mean of actual schooling of (non-twin) children of age i in family divided by average schooling for all persons aged i in population.

b. Source: Malaysian Family Life Survey. Includes expected schooling attainment for households in which children are still attending school. Original specification also includes mother's schooling attainment, mother's age, husband's earnings.

c. Estimate assumes 7 pregnancies for average family, from Table 2 in Rosenzweig and Wolpin (1980).

d. Fertility of couple net of age of mother, breastfeeding and use of contraceptive methods. From Tables 5 and 6 in Rosenzweig and Schultz (1987).

e. t-ratio in parentheses beneath coefficient.

consistent with the estimated child wage effects of Table 2 and the estimated family planning effects in Table 4, that per-child human capital and family size are substitutes. Assertion (c) is confirmed--the inability to control fertility perfectly lowers, on average, the human capital of children.

To obtain comparable quantitative effects across the two methods, the residual measure of fecundity obtained from the Malaysian data was converted into excess births using the estimated effect of a change in μ on cumulative births in that study, i.e., an estimate of $dN/d\mu$; since $dt^c_H/dN = (dt^c/d\mu)(dN/d\mu)^{-1}$. This procedure can also be used to examine the impact of variation in (exogenous) fecundity and thus excess births on the mother's wage rate, to assess the effects of costly fertility control on the accumulation of skills by married women. Table 6 presents estimates of the residual measure of fecundity on the log of the weekly wage rate of married women in the United States (Rosenzweig and Schultz, 1985) and in Malaysia. Both sets of estimates indicate that the costliness of fertility control also results in lower wage rates for married women.[9]

Interestingly, while the direct wage effect of variations in fecundity is larger in the U.S. than in Malaysia, the computed excess birth effect is larger in Malaysia than in the United States. This is because the estimated effect of a change in fecundity on births obtained in the U.S. study is greater than in the Malaysia study. It appears that the estimated fecundity effects on both births and wage rates are smaller in absolute value in the Malaysia study compared to those estimates obtained using the same methodology applied to the U.S. data set. One possible reason for this is that, because any measurement errors in the reproduction function inputs and in births are impounded in the residual measure of fecundity, estimates of

Table 6

Estimates of Uncontrolled Fertility on the Log of Weekly Wage Rate of Married Women: the United States and Malaysia

Variable	United States[a] Coefficient	United States[a] Unanticipated Birth Effect	Malaysia[b] Coefficient	Malaysia[b] Unanticipated Birth Effect
Residual fecundity[c]	-5.28 (3.20)[d]	-.14	-1.24 (3.80)	-.36
Mother's schooling	.0648 (4.36)		.117 (6.80)	
Husband's income ($x10^{-4}$)	-.134 (2.72)		.841 (1.91)	
Rho	-		-.901 (8.41)	
Proportion of sample with mother reporting wage	.64		.22	
Estimation procedure	OLS		Maximum-Likelihood Selection Correction	

a. Source 1975 National Fertility Survey. From Table 7, Rosenzweig and Schultz (1985). Other regressors include wife's age and husband's religion affiliation. Unanticipated birth effect computed for mothers aged 36.

b. Source: Malaysian Family Life Survey. Fecundity computation described in Rosenzweig and Schultz (1987). Other regressors include wife's age and race (Malay, Chinese, Indian).

c. See note c, Table 3.

d. t-ratio in parentheses beneath coefficient.

fecundity effects on behavior are likely to be biased to zero. The retrospective contraceptive information in the Malaysian data set used (the Malaysian Family Life Survey) is substantially less detailed than that provided in the U.S. data (the 1970 and 1975 National Fertility Surveys), and the estimates of the reproduction function used to construct the fecundity measure less precise. It is thus likely that the fecundity measure in Malaysia contains a larger measurement error component than does the comparable U.S. measure. Estimated fecundity effects, measured using the residual based on the reproduction function estimates, are thus likely to be biased more strongly to zero in the Malaysia than in the U.S. study. The more negative excess birth effect on child schooling based on the twins method in Table 4 and the less negative excess birth effect on the wage in Table 5 are likely to be better estimates than the comparable estimates obtained from the Malaysia data set. The studies from all three populations using both methods, however, do indicate that there is a loss of per-person human capital among children and mothers as a result of fertility control costs.

5. Externalities and the Optimality of Family Planning Subsidies

Evidence of the existence of imperfect fertility control and its deleterious consequences for human capital investments and evidence on the success of family planning programs in augmenting such investments are not sufficient to justify the allocation of public monies to the subvention of fertility control, at least on efficiency grounds. If the price of fertility control reflects its social resource costs then the actual level of "excess" fertility, defined, arbitrarily, in terms of the complete absence of such costs, is optimal in the sense that no one in society could be made better off without someone also being made worse off through the reallocation of resources.

Justification for governmental family planning interventions (inclusive of their financing) based on efficiency criteria requires that the total private cost of raising children borne by households not appropriately reflect the total social cost. As embodied in (7), the tradeoff faced by parents between having an additional child and investing more resources in each child depends on the costs and returns to human capital investments as well as on the costs of controlling fertility. Discrepancies between parental private and social returns to family size decisions can be sought, therefore, not only in terms of the externalities associated purely with population size or growth; e.g., crowding, but also in terms of human capital externalities. The desirability of the subvention of fertility control does not, therefore, require the existence of direct negative externalities associated with population, using purely efficiency criteria.

To test assertions about the efficiency of family planning interventions would require quantitative evidence on externalities, on the private and social resource costs of rearing children, but there is little, if any evidence. However, there appears to be an almost universal belief in the desirability of directly subsidizing human capital investments, as evidenced by the pervasiveness of public expenditures on schooling and health. Do the presumed externalities associated with human capital investments also justify, on efficiency grounds, family planning interventions in the absence of evidence on population size externalities? This question was investigated in Rosenzweig and Wolpin (1986a). In that study a model similar to that described by (1) through (6) was modified to incorporate a human capital externality and the possibility of cross-household transfers contingent on behavior.

Suppose that, for some ("wealthy") households the human capital production function (2) includes as an input the (average) human capital of other "poor" households. For simplicity, as in Rosenzweig and Wolpin's study, assume that the purchased good X and fertility (of the household) are the only other human capital inputs; i.e.,

$$(15)\quad H = h(X,N,H^*),$$

where H^* = mean human capital of the children in poor households and $h_i > 0$, $i = X,N,H^*$. There is thus a positive externality associated with human capital in the production of human capital, and poor households do not take into account the (positive) impact of their human capital investments on wealthy households. (For additional simplicity, the possible impact of their human capital investments on each other is ignored). Of course, there may be other kinds of externalities associated with human capital. Lucas (1986), for example, embodies externalities from education in the technology of goods production, which plays a central role in the process of development.

The wealthy households could (selfishly) subsidize the human capital inputs of the poor to induce them to increase their investments in human capital. If so, such an arrangement would be Pareto optimal; both types of households would be better off. The budget constraint of the wealthy households, incorporating (i) subsidies to fertility control to poor households, s_z, and (ii) subsidies to human capital inputs, s_x, is then:

$$(16)\quad F = p_zZ + p_xXN + Ts_zZ^p + Ts_xN^pX^p.$$

where F = the number of poor households, and the superscript p indicates that the variable is controlled by the poor households.

If it is assumed that Z is used in proportion to the number of births averted, μ-N, the optimal ratio of the fertility control subsidy to the market price of the fertility control input, in equilibrium, is:

$$(17)\quad \frac{s_z}{p_z} = -T^{-1}\,\frac{p_x N X \epsilon_{HH^*}}{p_z N^p \epsilon_{HX}}\,[\epsilon^p_{HX}\,\frac{\eta^p_{X,p_z}}{\eta^p_{N,p_x}} + \epsilon^p_{HN}] - (\eta^p_{N,p_z})^{-1}\,(\frac{\mu - N^p}{N^p})p_z$$

$$+ s_x\,\frac{X^p}{p_z}\,[1 + \frac{\eta^p_{X,p_z}}{\eta^p_{N,p_z}}],$$

where ϵ_{Hi} = elasticity of H with respect to human capital input i, from (2) or (15); $\eta^p_{ip_i}$ = price elasticity of input i (i=X,N) with respect to the price of i among poor households.

Expression (16) indicates that if there is no human capital externality (ϵ_{HH}*=0) and, therefore no subsidy to human capital inputs (s_x=0) there is no positive level of the family planning subsidy that is optimal, no justification for "family planning" subsidies no matter what the magnitude or direction of cross price effects or the biological effects of fertility on human capital. Conversely, if ϵ_{HH}*>0 and there are subsidies to human capital, family planning subsidies are also optimal. The intuition for this result is clear--since the human capital subsidy is paid for each child born, the fewer the number of children born the lower the total cost of the human capital subsidy; expenditures on family planning decrease the costs of increasing average human capital levels. Moreover, (16) indicates that the family planning subsidy is larger if (i) family size and human capital are substitutes (η_{Xp_z}<0), and (ii) increasing family size lowers human capital directly (ϵ_{HN}<0). Thus, the estimates reported in Tables 2, 3, 4 and 5 provide evidence that supports higher levels of family planning subsidies for the purpose of raising avearage human capital levels, but are not evidence of the optimality of such subsidies. Such evidence is not sufficient to justify the existence of public family planning interventions.

Does the actual distribution of family planning programs and institutions suggest that governments use such programs primarily to more efficiently induce greater human capital investments? The model suggests that (i) where human capital programs (health, schooling) exist, there would also be family planning subsidies; i.e., there would be few examples of human capital programs unaccompanied by family planning. On the other hand, family planning subsidies can substitute for human capital subsidies since family size and per-child human capital appear to be viewed as substitutes by parents; family planning programs without human capital programs might be observed.

Table 7 presents information on the actual distributions of public family planning and health facilities across communities in one province of the Philippines, Laguna, from Rosenzweig and Wolpin (1986a), and from the Malaysian Family Life Survey (Butz and DaVanzo, 1978), which included 50 communities (out of 52 surveyed) with information on both types of institutions. Both distributions conform to the notion that family planning programs complement efforts to augment human capital (health)--75 and 86 percent, respectively, of the communities in Laguna and in Malaysia either had both types of facilities or neither. In Malaysia, of those 7 communities with one program, it was a family planning facility in six. In

Table 7

Joint Distributions of Family Planning and Health Facilities:

Laguna, Philippines and Malaysia

	Laguna, Philippines[a] (Barrios)		Malaysia[b] (PSU villages)	
	Number	Percent	Number	Percent
Total localities	20	100	50	100
With both fp and health or neither	15	75	43	86
both	10	50	37	74
neither	5	25	6	12
With only one facility	5	25	7	14
only fp	2	10	6	12
only health	3	15	1	2

a. Source: Rosenzweig and Wolpin (1986), from 1979 Laguna Survey.

b. Source: 1976 Malaysia Family Life Survey (Butz and DaVanzo, 1978).

Laguna, only 3 of the 20 barrios had a health facility but no family planning program.

These patterns describing the spatial distribution of family planning and health facilities suggest the extent to which governments are concerned with human capital development. They also suggest that evaluations of the effects of family planning must take into account the effects of other programs, whose placement is highly correlated with that of family planning. Rosenzweig and Wolpin, for example, report that the (Spearman rank) correlation between the initiation dates of the two programs in Laguna was 0.62. The correlation between the proportion of villages with family planning facilities and with health clinics across the 300 kabupaten in Indonesia in 1980 was .45 (Pitt and Rosenzweig, 1987). The purposive placement of public programs also opens up the possibility that the distribution of programs over space and over time may be correlated with characteristics of the environment or the population that are not measured by the researcher, but which are important determinants of both fertility and human capital investments, e.g., V in (2). Correlations between program efforts and household decisions may thus not constitute reliable evidence on program effects when such programs are allocated efficiently by public agencies.

6. Conclusion

In this essay I have reviewed a number of empirical studies that have attempted to move beyond the correlational evidence usually brought to bear in policy debates on population and development. These studies have sought to quantify the causal mechanisms that underly the observed strong associations among population growth, human capital investments and economic development and that have been asserted to be important by policy advocates. The methods used in and the empirical findings from the studies discussed illustrate both the difficulties of establishing a solid empirical foundation for these issues, in the absence of experimentally-based data, and the frailty of the actual evidence pertinent to the extreme, but not mutually exclusive, positions assumed by participants in debates about the role of population growth in economic development.

Certain regularities emerge, however. Evidence from studies, based on data from countries as diverse as the United States, Colombia, India, Indonesia, Malaysia, and the Philippines and informed by models of household behavior incorporating many of the biological processes associated with human reproduction and development indicate that fertility, human capital investment behavior and economic development are linked in several ways. In particular, (a) returns to investments in skills appear to directly affect both the levels of investments in skills and family size decisions, such that in most cases fertility falls and human capital investments per person rise when such returns increase, (b) rapid, early and prolonged child bearing directly diminish the human capital of children, even when all other resource allocations are unchanged, presumably due to biological mechanisms (but mechanisms yet unsupported by a biological model), (c) difficulties in controlling fertility contribute to lower levels of human capital and, relatedly, attempts to lower the costs of fertility control appear to increase human capital levels, and (d) governments appear to treat human capital and population control programs as complementary, seemingly because of a concern for promoting human capital formation.

None of these empirical findings are surprising; what is important, however, is that the magnitudes of all of these causal relationships appear to be relatively small. The observed correlations among fertiliity rates, human capital investments, and levels of development thus appear to overestimate considerably the various causal connections between these phenomena that are asserted to be important by policy advocates. In any event, the relationships quantified do not provide a justification for any particular governmental intervention on efficiency grounds, although they do suggest the consequences of interventions, ranging from attempts to encourage technical change to family planning initiatives. In that regard, empirical studies that would attempt to clarify and quantify the relationships between the levels of physical investment and population growth, informed by considerations similar to studies that have addressed human capital-fertility issues, would also be useful in anticipating some of the consequences of economic development policies, but these appear to be almost entirely absent from the literature.

Footnotes

1. The model embodies the interaction between child quantity and quality in the household budget constraint (Becker and Lewis, 1973), the role of the mother's time (Willis, 1973), the economic value of children (Rosenzweig and Evenson, 1977), the production of human capital by heterogeneous households (Rosenzweig and Schultz, 1983), and the biology of reproduction (Easterlin, et al., 1980 and Rosenzweig and Schultz, 1985) emphasized in prior studies formulating models of the household.

2. Other reproductive inputs--e.g., age, breastfeeding--can readily be incorporated.

3. Of course, there may be exogenous forces determining the wage rate of women; if these can be identified, and vary over the sample space, they can be used to test assertion (a). Schultz (1986) makes use of exogenous shifts in the relative prices of commodities that are produced via technologies more or less intensive in female labor to identify the effects of changes in maternal wage rates on fertility based on Swedish time-series data. The prediction of the model with respect to the effects of exogenous variations in women's wages on human capital investments or schooling are, however, less clear than that for the effects of child wage rates, as discussed below.

4. In the study (Rosenzweig and Evenson, 1977) making use of aggregate data, the possibility that higher fertility rates or lower school enrollment rates might lower child or adult wage rates was taken into account using such instrumental variables as rainfall and industrial infrastructure to predict wages.

5. Wolpin (1983) formulates and estimates a dynamic stochastic model of fertility incorporating survival risk which calls into question the simple replacement hypothesis.

6. Evidence on responses by parents to individual endowments of children is presented in Rosenzweig (1986) and Rosenzweig and Wolpin (1986b).

7. In the Colombia study (Rosenzweig and Schultz, 1982), no evidence of the effects of family planning expenditures or health clinics on either fertility or morbidity could be found in rural areas.

8. The Rosenzweig-Wolpin (1986a) study of the effects of family planning on child development in Laguna, Philippines did attempt to take into account the endogeneity of program placement; results were sensitive to whether or not placement was "controlled for."

9. In the Rosenzweig and Schultz (1985) study based on U.S. data, no evidence was found of selectivity bias resulting from using a sample of working women to estimate wage determinants. In the Malaysian sample, a far lower proportion of women was participating in the wage labor market (in part because of the possibility of self-employment) and sample selectivity was significant. Note that because it is assumed that prior work time influences current wages, it is difficult to find (exogenous) variables influencing whether or not a woman is currently in the wage labor force that is also not a determinant of her current wage. In both exercises involving the effects of exogenous fertility variation on the maternal wage rate, the role of selectivity is essentially identified based on the assumption of a bivariate normal distribution for the unobservables.

References

Becker, G. S. and Lewis, H. G. (1973) Interactions between Quantity and Quality of Children, Journal of Political Economy 81: S279-S288.

Butz, W. and DaVanzo, J. (1978) The Malaysian Family Survey: Summary Report, RAND Report no. R-2351-AID. Santa Monica: The Rand Corporation.

Easterlin, R. A., Pollak, R. A., and Wachter, M. L. (1980) Towards a More General Economic Model of Fertility Determination: Endogenous Preferences and Natural Fertility. In Population and Economic Change in Developing Countries, (R. A. Easterlin, Ed.). Chicago: University of Chicago Press.

Heckman, J. J. (1979) Sample Selection Bias as a Specification Error, Econometrica 47: 153-161.

Jasso, G. and Rosenzweig, M. R. (1986) What's in a Name? Country of Origin Influences on the Earnings of Immigrants in the United States, Research in Human Capital and Development 5: 75-106.

Michael R. (1973) Education and the Derived Demand for Children, Journal of Political Economy 81: 128-164.

National Academy of Sciences (1971) Rapid Population Growth: Consequences and Policy Implications. Baltimore: Johns Hopkins University Press.

Olsen, R. J. and Wolpin, K. I. (1983) The Impact of Exogenous Child Mortality on Fertility: A Waiting Time Regression with Dynamic Regressors. Econometrica 51: 731-749.

Pitt, M. M. and Rosenzweig, M. R. (1987) Consequences of Infant Morbidity for the Household Allocation of Time. University of Minnesota, mimeo.

Rosenzweig, M. R. (1978) The Value of Children's Time, Family Size and Non-Household Child Activities: Evidence from Household Data. Research in Population Economics 1:

_____ (1982) Educational Subsidy, Agricultural Development and Fertility Changes, Quarterly Journal of Economics 97: 67-88.

_____ (1986) Birth Spacing and Sibling Inequality: Asymmetric Information within the Family. International Economic Review 27, 55-76.

Rosenzweig, M. R. and Evenson, R. E. (1977) Fertility, Schooling and the Economic Contribution of Children in Rural India, Econometrica 45: 1065-1079.

Rosenzweig, M. R. and Schultz, T. P. (1982) Determinants of Fertility and Child Mortality in Colombia. Journal of Health Policy and Education.

_____ and _____ (1983) Estimating a Household Production Function: Heterogeneity, The Demand for Health Inputs, and Their Effects on Birth Weight. Journal of Political Economy 91: 723-746.

_____ and _____ (1985) The Demand For and Supply of Births: Fertility and Its Life Cycle Consequences. American Economic Review 75: 992-1015.

_____ and _____ (1987) Fertility and Investments in Human Capital: Estimates of the Consequences of Imperfect Fertility Control in Malaysia. Journal of Econometrics, forthcoming.

Rosenzweig, M. R. and Wolpin, K. I. (1980a) Testing the Quantity-Quality Fertility Model: The Use of Twins as a Natural Experiment. Econometrica 48: 227-240.

_____ and _____ (1980b) Life Cycle Labor Supply and Fertility. Journal of Political Economy 89: 1059-1085.

_____ and _____ (1982) Governmental Interventions and Household Behavior in a Developing Country. Journal of Development Economics 10: 209-226.

_____ and _____ (1985) Migration Selectivity and the Effects of Public Programs. University of Minnesota, mimeo.

_____ and _____ (1986a) Evaluating the Effects of Optimally Distributed Public Programs: Child Health and Family Planning Interventions. American Economic Review 86: 470-482.

_____ and _____ (1986b) Heterogeneity, Intrafamily Distribution and Child Health. University of Minnesota, mimeo.

Schultz, T. P. (1985) Changing World Prices, Women's Wages and the Fertility Transition. Journal of Political Economy 93: 1126-1154.

Schultz, T. W. (1975) The Ability to Deal with Disequilibria. Journal of Economic Literature 13: 827-846.

Willis, R. J. (1973) A New Approach to the Economic Theory of Fertility Behavior. Journal of Political Economy 81: S14-S64.

Wolpin, K. I. (1984) An Estimable Dynamic Stochastic Model of Fertility and Child Mortality. Journal of Political Economy 92: 852-874.