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Assessing Family Planning Cost-Effectiveness: Applicability of Individual Demand-Program Supply Framework

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The optimal allocation of scarce public resources on social welfare programs (i.e., family planning, health and education) is an important question in all societies, but especially in developing countries. This research considers the distinction between two sets of factors that affect fertility - community supply of family planning services, and constraints on parent demand for births - and assesses how it guides the empirical design of family planning programs. Evaluating the effect of program activities on fertility requires that certain determinants of parent demand for births be held constant. Increases in supply are associated with reductions in "cost" of birth control. The supply-demand framework can clarify the segments of the population for which the program is likely to be more or less cost-effective, and how the effectiveness of various program activities may change with the scale of the program and interact with other program elements and population characteristics. Evidence from Thailand demonstrates that family planning expenditures are subject to diminishing returns and that marginal returns differ across elements of the program and segments of the population.

ABSTRACT

This paper considers the distinction between two sets of factors that affect fertility -- community *supply* of family planning services, and constraints on parent *demand* for births -- and assesses how it guides the empirical design of evaluation of family planning programs.

Evaluating the effect of program activities on fertility requires that certain determinants of parent demand for births be held constant. Increases in supply are associated with reductions in "cost" of birth control. The supply-demand framework can clarify the segments of the population for which the program is likely to be more or less cost-effective, and how the effectiveness of various program activities may change with the scale of the program and interact with other program elements and population characteristics. Evidence from Thailand demonstrates that family planning expenditures are subject to diminishing returns and that marginal returns differ across elements of the program and segments of the population. To improve the efficiency and equity of family planning programs, policymakers need estimates of the cost-effectiveness of family planning programs at the "margin" of various "mixes" of program activities, within distinguishable segments of the reproductive-aged population.

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I. Introduction

Many social equilibrating processes that use scarce resources to satisfy human wants are conceptualized in terms of meshing the *preferences* of people, or their *demands*, with the *technology* capable of satisfying them, or the *supply* of technical services and inputs. Social scientists have used this type of supply-demand framework to describe the role of family planning as a fertility determinant. This paper reexamines the supply-demand framework as a means for analyzing fertility in low-income countries with the objective of assessing the cost-effectiveness of family planning programs.

At least through the 1960's, observers tended to think that people in low-income countries would reduce their fertility substantially if only they were provided with modern means of birth control. Therefore, many believed the lack of modern *technology* to control fertility was primarily responsible for the often high level of fertility in developing countries. Others argued that although improvement in technological options for birth control might be an important ingredient in achieving a slower rate of population growth, couples in these societies wanted many births for other fundamental reasons. Until these underlying constraints motivating human reproductive behavior changed, they maintained, the delivery of a better technology of birth control would reduce fertility only modestly (e.g., Westoff, Moreno, and Goldman 1989). Forecasting the circumstances under which improvements in the *supply* of birth control methods would reduce fertility required an understanding of the constraints on people's *preferences* that shape the *demand* for children. This debate on policy and research priorities has continued (Bulatao and Lee, 1983; Lapham and Simmons), but at the same time, increasing numbers of studies analyze simultaneously the socioeconomic determinants of the demand for births and the supply of family planning services (Hermalin, 1975). In other words, to evaluate the role of family planning as a determinant of fertility, it may be necessary to control statistically for the potentially confounding effects of socioeconomic determinants of the demand for births that are not themselves affected by household behavior, i.e. exogenous. Otherwise statistical inferences regarding the effectiveness of family planning will be biased.

In addition, the World Fertility Survey and Demographic and Health Survey programs have measured with increasing accuracy the intermediate biological mechanisms that regulate fertility

(Bongaarts, 1978, 1982). These proximate determinants of fertility -- age at marriage or exposure to intercourse, use of contraception, and breast feeding practices -- provide a complementary framework for accounting for fertility variation among aggregate populations. Because these determinants are potentially self-selected in response to people's underlying reproductive preferences, fecundity, and birth control technology, they represent an intermediate level of individual and family choice variables that accommodate to people's lifecycle goals and environment. These proximate determinants are channels through which the socioeconomic background variables influence fertility. But as shown later, there is no simple way to separate preferences, fecundity, and technology, and disentangle how programs operate through intermediate choice variables. If the primary goal is to evaluate the fertility impact of family planning program expenditures, their impact is statistically estimated without bias by controlling for only the supply and demand determinants that are not affected by household choices and lifecycle behavioral strategies. A comprehensive set of supply and demand variables that are in this sense exogenous to household fertility decisions should by their inclusion as control variables improve the precision of estimates of a program's effect, even when the program intervention is designed as a randomized social experiment (e.g., Manning et al., 1982).

Section 2 of this paper describes and contrasts these various frameworks. Section 3 comments briefly on promising efforts to integrate them in empirical research aimed at evaluating the consequences of unexpected fertility. An analysis of Thailand survey and program data that estimates the effects of supply and demand factors on fertility is summarized in section 4. The concluding section restates several criteria for evaluating the impact of a family planning program.

II. Alternative Frameworks

A. Socioeconomic Determinants: Parental Demand and Program Supply

Researchers study variation in fertility across individuals (or couples) to learn how different socioeconomic situations, program environments, and personal characteristics influence fertility. It is possible to estimate this relationship without bias when the function relating the conditioning variables and fertility is correctly known (e.g., linear and additive); the relevant variables are observed without error; and the unexplained variation in fertility, or the error, is identically and

independently distributed in a convenient form (e.g., normal). The last condition implies that the errors are independent of the conditioning socioeconomic variables, or that these determinants are *exogenous* to the framework in which fertility is determined. If an explanatory variable is not exogenous, e.g., voluntary contraceptive practice by the individual couple, then single-stage estimates of the entire fertility relationship may be biased and inconsistent or tend to the wrong parameter values, even as the sample becomes very large and the measurement of the variables increasingly accurate.

To be more specific, assume that a couple's fertility -- lifetime number of children ever born -- is approximately a linear function of a set of individual household demand variables (E); a set of r variables (X_r) defined over regions, including inputs of family planning programs in the locality (X_f); and potential interactions between program supply and household demand variables, individual initial preferences (P), biological reproductive capacity (B -- i.e., fecundity), and a serially uncorrelated error (e_1).

$$F_i = a_0 + a_1E_i + a_2X_r + a_3X_f + a_4E_iX_f + a_5P_i + a_6B_i + e_{1i} \tag{1}$$

Where each parameter (a) is estimated from information on a sample of n individuals where i = 1, 2, , n. Preferences refer in this case to the *initial* variation in people's tastes for goods and activities -- tastes that are idiosyncratic or random and thus not related to their socioeconomic circumstances. Couples' self-reported responses as to their desired fertility are a subjective evaluation of their current preferences conditional on their circumstances. It reflects a combination of their initial or "axiomatic" preferences, as modified by their past experiences and current socioeconomic constraints on their range of choice. Initial preferences are, consequently, not an observed variable in this framework.

The flow diagram in Figure 1 illustrates the relationships among fertility determinants. The a parameters are mixtures of fundamental behavioral and biological-technical parameters, to the extent that the fertility determinants affect the parent demand and the program supply, as well as parent fecundity. Because initial preferences and fecundity are not generally observed, most empirical work on fertility tends to absorb then into the unexplained error in the model along with normal mistakes in learning to use competently a birth control technology, except insofar as this residual variation is correlated with included socioeconomic determinants of fertility. Since this

equation does not separate the mechanisms by which factors from the socioeconomic environment may influence fertility (e.g., delay of marriage, contraception, or abortion), but rather summarizes the total effects of these factors as they work their way through an underlying structural model including those control mechanisms, it is called a reduced-form equation.

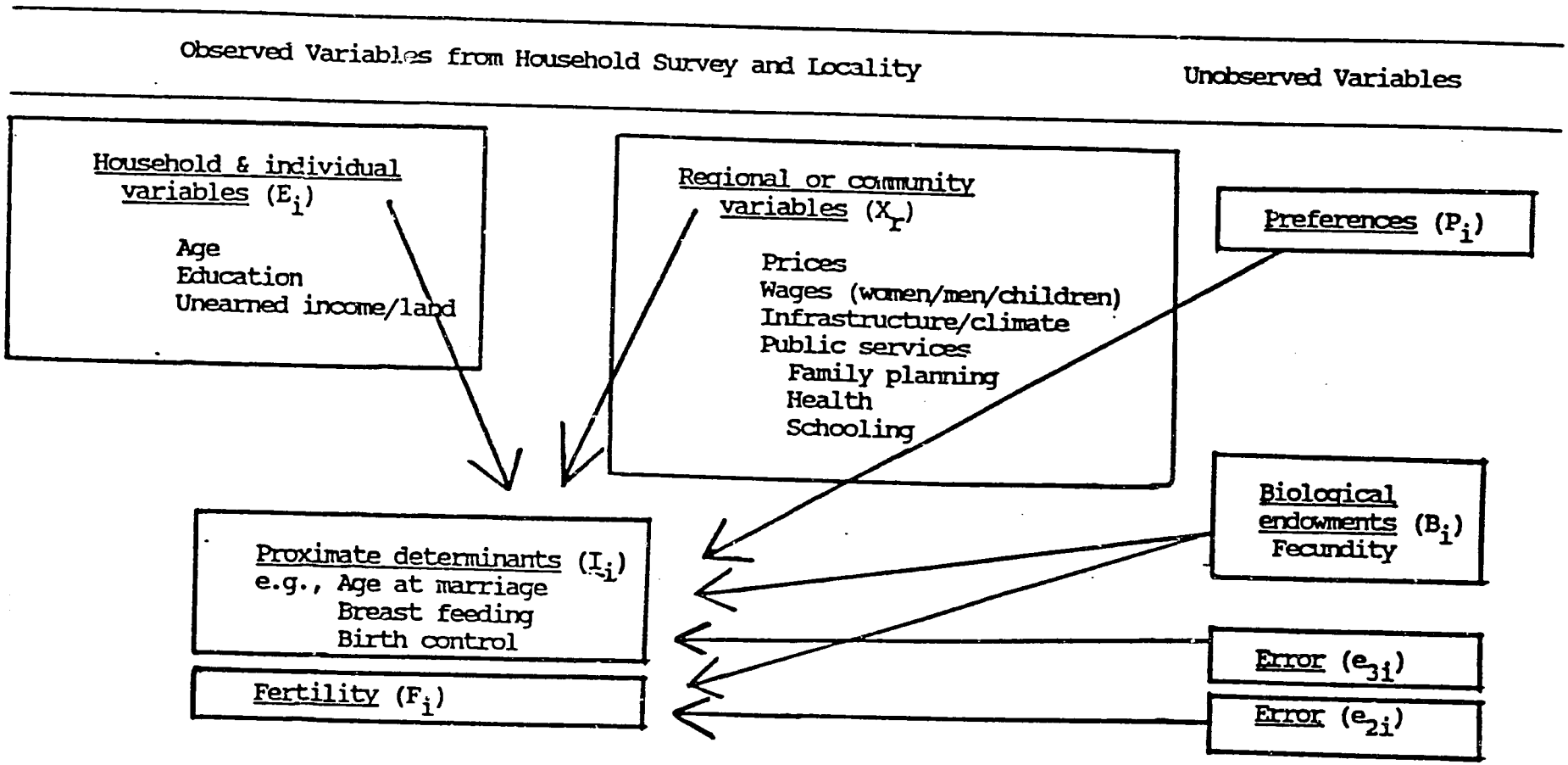
In this initial framework for assessing the socioeconomic determinants of fertility, different disciplines and researchers entertain distinct hypotheses to explain reproductive behavior; they therefore select different conditioning variables and often interpret the effect of the same variable differently. Regardless, the statistical working assumptions are the same. If equation 1 is estimated by standard single-stage techniques, the socioeconomic determinants must be independent of the error, which in practice includes the effects of preferences and fecundity (i.e., $a_5P_i + a_6B_i + e_{1i}$). In this context, the economic literature proposes statistical tests of exogeneity or model specification, although their power depends on obtaining identifying instrumental variables (Rosenzweig and Schultz, 1985, 1987). Consequently, the choice of identifying instruments that determine a potentially endogenous variable, but do not directly influence fertility, is of critical importance.

The strength of this analytical approach is that it can estimate the net impact on fertility of family planning program activity in the region by using transparent and efficient statistical methods. The researcher assumes that resources allocated to the program will reduce the cost of birth control to couples, including both the information cost of evaluating and adopting a suitable technology (typically a one time, fixed cost), and the cost of using that method (typically a continuing, variable cost). This reduction in the supply price of birth control will have its greatest effect reducing fertility where the amount by which reproductive capacity exceeds the demand for births is greatest, the alternative sources of birth control are most costly and least culturally desirable, and the demand for births is most elastic with regard to the effective price of birth control. The estimated effect of family planning program expenditures, say dF/dX_f, from equation 1 represents the inverse of the cost-effectiveness of the program supply subsidies. Estimating this equation, of course, entails simultaneously evaluating the net effects of demand factors, as well as any possible interactions between supply and demand factors, as discussed in section 4.[1]

In the case of the supply and demand determinants of fertility, interest focuses on the net fertility consequences of supply policies and socioeconomic investments that shift the demand determinants. These reduced-form estimates of equation 1 provide, therefore, the essential

Figure 1.

Flow Diagram of Fertility Determinants



WP/flowdiag

information needed for family planning and development policy choices. The working assumption is nonetheless critical -- that the allocation of family planning resources across regional segments of the population is independent of people's preferences and fecundity, and that the form of the function estimated is sufficiently flexible to capture important nonlinearities in the fertility effects and interactions among them.

A limitation of this approach is that if a socioeconomic determinant of the demand (or supply) of births (other than family planning) is omitted and it is correlated with measured family planning activity, a spurious bias will result. All empirical models of human behavior that are not derived from a randomized experimental design reflect this limitation. Inclusion of controls for the more important fertility determinants, particularly those that are correlated with family planning activities, should reduce the problem, hopefully to tolerable proportions.[2]

However, suppose that governments do, in fact, systematically allocate family planning expenditures to regions where preferences for fertility are particularly strong or weak. Take, for example, the possibility that at an early stage in the demographic transition, the demand for birth control may be relatively concentrated in the upper strata of society -- that is, among the educated urban elite. If family planning services at government clinics are responsive to the strength of local demands, outlays will be concentrated in urban regions that will exhibit lower fertility regardless of the level of program expenditures. To reduce the resulting spurious overestimate of the program's effect, controls might be introduced for such demand factors as the level of female and male education and the household's nonearned income, as well as other community services in health and education that might contribute to the difference between urban and rural fertility demands. Ultimately, the mechanism governing the local allocation of services and expenditures should be modeled, and that model would probably depend on community demands for birth control. Disentangling these processes may prove difficult.

Conversely, in a society where the initiative and funding for family planning comes from the central government (or abroad), and the program is designed to facilitate a fertility reduction in regions where fertility is relatively high, program activity may be positively correlated with local fertility demands. In this case, estimates of the program's impact on fertility from equation 1 would understate these effects.

Migration may introduce another source of bias in assessing program effects. If migrants have a tendency to move toward regions where family planning services are better funded, and if migrants have a relative preference for low fertility, with other conditioning variables held constant, the estimates of equation 1 could lead to an overstatement of program effects. Even though family planning services may be a small factor in the migrants' choice of destination, most rural-to-urban migrants benefit greatly from the improved combination in public services they receive in health, schooling, and family planning. All of these programs appear to contribute to reducing fertility by shifting demand and supply factors (Rosenzweig and Wolpin 1982, 1986; Schultz 1988b). This source of bias my thus be substantial.

Estimates of the reduced-form relationship 1 do not indicate *how* a background variable, such as the availability of family planning services, actually affects fertility and its timing. Does the variable increase the premarital use of birth control and thereby delay marriage, or increase birth intervals by encouraging the use of more effective contraception, or increase abortion, or increase breast feeding and thereby lower "natural" fertility? Decomposing the net effects of the socioeconomic determinants of fertility demands and the community program supply of family planning subsidies requires estimating the intervening biological structure (Davis and Blake 1956), and this is far more difficult than the literature would suggest.

B. Proximate Determinants of Fertility: Aggregate Decompositions

Biological models of reproduction mathematically approximate the distinct stages of exposure to conception, pregnancy wastage, and birth that are represented in a form that facilitates decomposition and simulation of average outcomes for an aggregate population (Sheps and Menken 1973; Bongaarts and Potter 1983). To simplify, it may be necessary to approximate exposure to intercourse by the duration of marriage (I_m), the duration of breast feeding, which may add to the length of sterility after a birth and increase birth intervals (I_b), and use of birth control that lowers the rate of conception for fecund exposed individuals (I_c) or contraceptive effectiveness. For illustrative purposes, assume these three (or more) proximate determinants linearly approximates fertility:[3] then each parameter (b) is selected from other studies that typically analyze how one biological subprocess at a time affects reproduction (Bongaarts and Potter 1983).

(2) $$F_i = b_0 + b_1 I_{mi} + b_2 I_{bi} + b_3 I_{ci} + b_4 B_i + e_{2i}$$

Combining these estimates in equation 2 and simulating the effects of various changes in I's on fertility requires several strong assumptions. First, the various forms of behavior must be independent of each other: individuals have no systematic tendency to substitute one form of behavior for another. The extreme assumption must be maintained that an individual does not view later marriage as a substitute for prolonged breast feeding or for better contraception, for example. The relatively greater use of contraception by certain individuals in a population is presumably uncorrelated with how long the same individuals breast feed, when controlling for background variables. Otherwise, the independently estimated effect of I on fertility, derived from population averages of the proximate determinants, will not represent accurately the effect on the aggregate level of fertility. Consequently, the standard decomposition of change in fertility may be misleading. These neglected covariance terms among the proximate determinants could, in principal, be empirically estimated jointly, if they were constant parameters, and then included in the simulation of the aggregate fertility level. I have not seen this strategy followed.[4]

More serious, perhaps, the proximate determinants, or at least the individual's use of birth control, may respond to fecundity. Thus, the omitted fecundity variable may be positively correlated with use of birth control, and the omission of the former from estimates of equation 2 tends to bias downward (toward zero) the estimated negative impact of more effective birth control methods that are then disproportionately used by relatively fecund couples. Analyses of U.S. and Malaysian populations (Rosenzweig and Schultz 1985, 1987) show such a downward bias in estimating the use-effectiveness of certain contraceptives (e.g., the pill).

Until the proximate-determinants approach is reconceptualized to allow for the endogenous and interdependent choice by couples of the various elements of their reproductive regime, it is difficult to see how the framework can be used to evaluate statistically the role of family planning as a determinant of fertility. Assuming that the prevalence of contraception induced by a program is equivalent to the contraceptive supplies that a program distributes could be even more misleading. The reason is obvious: in the absence of the program, many persons using public-subsidized supplies would use birth control provided from other sources of supply. The only change might be that program-supplied users pay a higher price for this service in the private market, and thus have a slightly smaller disposable income (Schultz 1988a).

C. Aggregate Intercountry Comparisons

Schematic approaches to explain changes in aggregate fertility during the demographic transition have also appealed to the supply-demand framework (Tabbarah 1971; Easterlin 1975; Easterlin and Crimmins 1985). The hypothesis has been advanced that at early stages in the demographic transition there is a relaxation of biological constraints on reproduction -- declines in child mortality, increases in fecundity due to improved health and diet, and declines in breast feeding -- that all might increase population growth and even fertility in the short run. These increases in the potential supply of births would lead to higher fertility until behavior changed to accommodate demands. Any effort by couples to modify behavior to control their additional reproductive capacity might reasonably require some period of adjustment.

Although this has been a popular framework within which to think about recent demographic trends, it has not yet led to the specification of a satisfactory statistical model of family planning programs. One difficulty is the assignment of child mortality to the biological supply side of the framework, when most recent research on child mortality confirms that it responds more strongly to family characteristics, such as mother's education, than to the local supply of health care or technologically exogenous developments, such as smallpox eradication (Preston 1985). The quantitative significance of diet on fecundity has also been difficult to confirm for populations above a starvation level (Menken et al. 1981). The above approach to fertility determinants, it should be obvious, does not rely on the same analytical distinctions between supply and demand factors that are outlined in this paper.

Several studies have assessed the influence of family planning on fertility by regressing aggregate fertility rates or contraceptive prevalence rates across countries on an index of population policies (Mauldin and Berelson 1978; Lapham and Mauldin 1985). This approach fits equation 1 to country aggregates rather than to individuals.

Aside from the more limited range of socioeconomic controls in these studies, two difficulties are notable. First, if the basic relationship is nonlinear at the individual level, it cannot be accurately approximated at the aggregate level by analyzing only population averages, for example, across countries. Second, the working assumption that interregional differences in family planning expenditures are uncorrelated with the demand determinants of fertility is defensible at the

individual level, but at the aggregate level this assumption is untenable. In some countries (e.g., Taiwan and Thailand), local family planning activities seem to be uniformly distributed across a population distinguished by socioeconomic characteristics (Schultz 1988a, 1989). However, analysis of national aggregates reveal that the changing constraints on families that increase the private demands for birth control also encourage governments to supply more family planning services. In other words, at the aggregate national level, the working assumption might well be reversed: the extent of family planning program activity should be treated as an endogenous variable that responds in part to private demands for lower fertility as well as peculiar factors that shift the budget constraint on public expenditures, such as exportable natural resources or the strategic importance of a country (e.g., Taiwan, Egypt) that increases the government's supply of foreign exchange or assistance. A simultaneous equation model is required that will explain family planning budgets, and then use that program budget variable for the nation as predicted within the model, along with private demand determinants, to explain fertility levels across countries. Changes in fertility over time within countries could then be studied analogously.

Again, the critical assumption required to estimate the supply-demand model at the aggregate level is the exclusion restriction that identifies the model -- namely, a variable that influences national population policy and public and non profit family planning expenditures, but does not determine private demands for births and birth control. One possible identifying variable would be foreign aid transfers or international assistance provided by non governmental population agencies that subsidize the domestic cost of family planning activities, such as the International Planned Parenthood Federation. Consolidated accounts are available that might support such an aggregate intercountry analysis (Ross et al. 1988; Nortman and Hofstatter 1978), but I have not seen an inter country analysis of fertility that grapples with this difficult issue of identifying an external forcing variable that could explain intercountry variation in family planning program subsidies.

III. Integrating Analytical Frameworks

Combining the socioeconomic-determinants approach, which distinguishes between supply and demand factors, with the proximate-determinants approach, which decomposes changes in aggregate fertility into the biological mechanisms, requires a suitable estimation of the intermediate

relationships between the exogenous socioeconomic determinants (E and X) and the proximate determinants (I_j). Where I_{ji} may be thought of as a vector of J relevant forms of behavior that biologically determine fertility, such as marriage age, breast feeding, and birth control:

$$(3) \qquad I_{ji} = c_{0j} + c_{1j}E_i + c_{2j}X_r + c_{3j}P_i + c_{4j}B_i + e_{3ji}\ , \quad j = 1, 2, J$$

These behavioral equations are presumably approximately linear in the c parameters. Equation 3 can be estimated by single-stage estimation techniques -- e.g., Ordinary Least Squares (OLS), probit, or Tobit -- because the observed conditioning variables are not correlated with individuals' preferences or fecundity, and thus the omission of preferences and fecundity in the equation should not introduce bias. Estimates of these equations would indicate whether family planning expenditures and activity in the residential area lead to changes in the age at marriage, to an increase in contraceptive, and, possibly, to a change in breast feeding. Parallel decompositions of the net effects of demand factors, such as the woman's education or the household's land holdings, are also possible from the estimates of equation 3.

The proximate-determinant behavior is then predicted for each individual in the sample on the basis of the estimates of equation 3, and these are by construction uncorrelated with a couple's residual fecundity (B) and the system errors (e_3). Therefore, equation 2 can now be consistently simulated without bias by substituting in the predicted input behavior for the individual to estimate the biological or technological parameters. Where $\underline{c}$ refers to the first-stage estimates of c in equation 3:

$$(2)^* \qquad F = b_0 + \sum_j b_{1j}(\underline{c}_{0j} + \underline{c}_{1j}E_i + \underline{c}_{2j}X_r) + b_2B_i + e_{2i}$$

These two-stage estimates of the biological effects of the proximate determinants on fertility are consistent estimates of the reproduction technology, and have been reported in two studies of the United States and Malaysia (Rosenzweig and Schultz 1985, 1987).

Unfortunately, neither of these studies using the integrated framework describes the role of family planning, because the information on family planning programs for the sample clusters is limited or not available. The overall consequences of family planning (X_f) on fertility can be decomposed as follows:

$$(4) \qquad dF/dX_f = \sum_j (dF/dI_j)(dI_j/dX_f) = \sum_j \underline{b}_{1j}\underline{c}_{2j}$$

The difference between the couple's actual fertility and that which is anticipated from the two-stage estimated model based on the couple's actual behavior is called the unexpected fertility (U). Where, again, $\underline{b}$ is a consistent estimate of b in equation 2* from a sample survey:

$$U_i = F_i - E_i = F_i - (\underline{b}_0 + \sum_j \underline{b}_{1j} I_{ji}) \tag{5}$$

This is a measure of how a couple's fertility deviated from what they could have expected, given their actual proximate-determinant behavior (1), had they known the estimated parameters of the reproduction function (2). This measure of unexpected fertility is similar to the demographic concept of unplanned or unwanted fertility except that it is symmetric and may be negative because it also includes couples experiencing a shortfall in their fertility, whether or not it is an unwanted shortfall. Unexpected fertility derived from estimates of this integrated framework can be used to identify individuals and groups in a population that incur a disproportionate share of the burdens of unexpected fertility.

One empirical measure of effective control over reproductive capacity in a population is the estimated variation in unexpected fertility. This measure represents not only the adequacy of family planning services in controlling excess fecundity, but also conditions that cause and alleviate subfecundity. It clearly is also dependent on the desired level of fertility. The standard deviation in unexpected fertility is 0.012 in the U.S. study mentioned above, whereas the monthly probability of a birth is 0.013; the standard deviation is 0.078 in the Malaysia study, where the monthly conception rate averaged 0.032. (See Table 1.) If a couple experiences (persistently) higher unexpected fertility, they may become more aware of their above-average fecundity or at least take account of their larger number of children. As a consequence, they are likely to adopt a more effective form of birth control, illustrated by the positive coefficient on unexpected fertility in the simple linear effects regression summarized in column 2 of the Table. But this behavioral contraceptive response appears to only partially compensate for the number of children ever born (column 1), which is still larger for couples with higher unexpected fertility. Only in the U.S. National Fertility Survey do the responses of the couples permit the calculation for each woman of her unplanned and unwanted conceptions, as summarized in columns 3 and 4. The unexpected births and unplanned and unwanted conceptions are, as expected, highly positively correlated in this

U.S. sample.

In both Malaysia and the United States, when a couple experiences a positive "shock" of unexpected fertility, those who are least educated tend to have the largest increase in their number of children ever born. This finding suggests that better-educated women are more capable in using birth control to compensate for their individual variation in fecundity. In other words, the more highly educated are "better" family planners, given their reproductive goals (Rosenzweig and Schultz, 1985, 1987).

The integrated structural framework draws our attention to biological heterogeneity in a population in one domain -- its reproductive capacity, or fecundity. People appear to respond to life cycle differences in fecundity as they become aware of them by adopting compensating behaviors, notably in their practice of contraception. Conventional estimates of contraceptive effectiveness measure the difference in fertility between groups of couples which have decided to use a particular contraceptive method or none. Controlling for a few observable characteristics of the couple, such as the woman's age and parity, this difference in conception rates will be a biased measure of contraceptive effectiveness for the average couple. Because of the heterogeneity in fecundity that evidently influences couples in the United States and Malaysia to self select themselves into different contraceptive use groups, the choice of contraception as well as the determinants of fertility must be analyzed in an integrated framework to eliminate the sample selection bias. The same sample selection bias could distort conventional estimates of the fertility-reducing effects of breast feeding, but perhaps to a lesser degree.

The covariation of fertility and many related household outcomes -- such as child health, nutrition and physical development, child school achievement, and women's welfare -- cannot be interpreted as direct evidence of the consequences of fertility on these family outcomes, because actual fertility embodies a couple's fertility preferences which are likely to be correlated with their other preferences and their choices for closely related lifecycle commitments, including child investments and women's employment. Because the couple's idiosyncratic preferences do not influence unexpected fertility, the latter can be related to other family outcomes (columns 5-8 of Table 1) and interpreted as an estimate of the consequences of unanticipated fertility shocks. In both countries the effect of an unexpected birth on a woman's wage is to reduce it by nearly ten percent (column 6), and the effect

TABLE 1
The consequence of a standard deviation change in unexpected fertility on family behavior and welfare: U.S. and Malaysia

	Reproductive behavior				Consequences relative to sample mean			
			Pregnancies		Wife's status		Average status of children	
	Children ever born (1)	Contraceptive efficiency (2)	Unplanned (now) (3)	Unwanted (ever) (4)	Labor supply (5)	Log weekly wage (6)	Birth weight (lbs.) (7)	Schooling (yrs.) (8)
United States 1970-74 (standard deviation .0188)								
Linear effect								
Individual effect (U)	.102*	.25*	.74*	.36*	-.20*	-.099*	n.a.	n.a.
Interaction Effects (including U × schooling)								
8 years	.30	.36	1.08	.51	-.12	n.a.	n.a.	n.a.
12 years (sample mean)	.14	.27	.82	.37	-.18			
16 years	.01	.19	.56	.24	-.24			
Mean of dependent variable	1.95	.0161	1.63	.62	.412	log.	n.a.	n.a.
Malaysia, 1971-76 (standard deviation .0776)								
Linear Effect								
Individual Effect (U)	.271*	.36*	n.a.	n.a.	n.a.	-.096*	-.0049*	-.019*
Interaction Effects (including U × schooling)								
0 years	.40	.76	n.a	n.a.	n.a	n.a.	-.014	-.035
4 years (sample mean)	.23	.27					-.0047	-.015
8 years	.071	.081					.0042	.005
Mean of dependent variable	4.84	.0172	n.a.	n.a.	n.a.	log.	6.76	10.9

Note:

n.a. not available.

*Statistically significantly different from zero at 5 percent confidence level.

(Source: Derived from Rosenzweig and Schultz, 1985, 1987.)

on her employment in the U.S. is evident for at least the first several years after the birth (column 5). In Malaysia, the unexpected birth is associated with significantly fewer years of schooling completed by the children in the family (column 8), and the average birth weight of the family's children is also slightly lower for the couple with greater fecundity.

In sum, the integrated structural framework provides a way to estimate not only the role of family planning in reducing the *level* of fertility, but also how family planning affects the *distribution* of the burden of unexpected fertility across families in the population, and the *consequences* of that burden within families for investments in the human capital of mothers and children.

The major limitation of the framework underlying the U.S. and Malaysia studies is the data required for its estimation: household economic characteristics; community characteristics, including family planning expenditures or activities; a reproductive history for each woman, including contraceptive use and breast feeding at least by birth intervals. Rarely are all of these data available from a single source. The second limitation is the existing empirical specification of reproduction function 2, which should be respecified in a more realistic form to reflect the non linear and interactive nature of the biological determinants of fertility. A third limitation of this approach is the current inability to control for the incidence of child, and possibly adult, mortality as it affects fertility. It is plausible that a reduction in high levels of child mortality contributes to the reduced demand of couples for births and hence increased effectiveness of providing better birth control technologies. But because child mortality is partially determined by many household choices that are related themselves to reproduction, child mortality cannot be included among the strictly exogenous control variables (i.e., E or X). The omission of such a potentially important determinant of fertility from the list of socioeconomic controls may also bias resulting estimates of the effectiveness of family planning programs in low income countries. Considerable work remains to refine the application of the structural biological-behavioral model of fertility to assess the role of family planning. Greater progress has been made in estimating the reduced form individual fertility equation 1 in which community level resources in family planning are included as an explanatory variable. Aspects of this research are illustrated in the next section by a case study of Thailand.

IV. Measurement of the Role of Family Planning: Thailand Case Study

Several issues arise in estimating the effects of family planning supply programs and the effects of constraints on parent demand that together determine fertility in a reduced-form relationship as represented in equation 1. First, a measure of the policy objective is specified, presumably in terms of recent or lifetime fertility rates. Second, characteristics of the program intervention are specified to guide policy and to help reduce the cost-effectiveness of the program. Third, the constraints on parent demand for births are specified such that these variables are outside of the control of the couples whose fertility is being studied. Fourth, a statistical model is specified to approximate the reduced-form relationship between fertility and the supply and demand factors.

Completed lifetime fertility of cohorts is an approximation for parent family-size goals and unwanted fertility, and the reduction in completed fertility is one indicator of program success. To avoid the delay of waiting until a cohort finishes its reproductive lifetime to evaluate the program's effectiveness, it is more common to evaluate recent age-specific birthrates and assume that they forecast synthetically changes that are likely to occur as the cohort completes its fertility. Analysis of program effects on contraceptive prevalence is a "second-best" and less-reliable evaluation strategy, because it depends on a subjective interpretation of the respondents' behavior and is not a direct measure of fertility. The least-satisfactory procedure assesses the role of a family planning program by measuring the birth control services and supplies that the program delivers by attributing to them a number of averted births. This last methodology does not usually measure how often the program services merely substitute for birth control practices that were in place before the program. The last two approaches incorporate uncertain estimates of contraceptive use-effectiveness when they translate practices into fertility (Schultz 1988a).

A. Specification of the Family Planning Program for Policy Analysis

Family planning programs are designed to help couples control their fertility. A program might affect fertility by disseminating *information* about birth control technologies and where to go to obtain particular methods; by subsidizing *clinic-based services* and supplies; and by subsidizing *outreach*, the distribution of birth control supplies and information by paramedics such as midwives, who canvas local communities to encourage adoption and use. Empirical assessment seeks to identify the conditions under

which these programs are most efficiently administered within the public sector, and to determine when nonprofit and profit-oriented private agencies are most efficient in using public subsidies to advance family planning program objectives (World Bank 1987).

Innovative programs that contribute to the diffusion of information and coordinate rural outreach activities may be best managed initially by the public sector, because monitoring the benefits and rewarding workers accordingly may be difficult in the private sector. Later in the evolution of family planning programs, routinized provision of birth control services and supplies should encourage several competing groups -- including the public health sector; private nonprofits; and private drugstores, nurses, doctors, clinics, and hospitals. If these groups are equally subsidized for performing equal services, the competition among them should improve program efficiency.

Several properties of family planning programs dictate how the supply factors might be specified in equation 1:

- Programs are eventually subject to diminishing returns to scale as they expand, where scale is defined as local program expenditures per potential beneficiary, i.e., per woman of childbearing age (Schultz 1988a). One simple way to evaluate this possibility is to include higher-order polynomials in program expenditures. For example, in the quadratic form the linear parameter would presumably be negative (on fertility), and the quadratic positive. To make program allocations efficient across activities or segments in the population, it is crucial to estimate the effectiveness of expenditures at the current *margins* of the program, typically summarized at the mean of the sample. Only in the case of a linear and non interactive specification of equation 1 is the average and the marginal program effect equal and constant as program scale varies. In the above example of the quadratic program function, the marginal effect is calculated by taking the derivative of equation 1 with respect to program expenditures, and evaluating it for a couple with the average sample characteristics.
- Separate program activities -- such as clinic subsidies versus outreach -- may be "substitutes" for each other. This implies that more use of one activity reduces the marginal payoff to the other in each local "market" area. Whereas each activity (e.g., X_{f1} and X_{f2}) might receive a negative coefficient in estimates of equation 1, the coefficient on an interaction variable, (i.e. $X_{f1}*X_{f2}$) would be positive if the two program activities were substitutes, or negative if they were complements. The potential for substitution declines to the extent that activities actually

serve separate populations. An example might be when the urban population obtains services from the hospital and clinic facilities, whereas the rural population benefits most directly from the paramedic outreach activities. If the population is highly mobile, such as within an urban area (e.g., Taichung City in Taiwan), spillover effects can make the statistical evaluation task much more difficult with data on small localities (Freedman and Takeshita 1969). Analysis of program inputs at a higher level of aggregation, such as a province, may then be advisable.

- Information activities may either complement or substitute for the effectiveness of the two service distribution networks. The same form of statistical tests that include additional interaction terms between possible program inputs is required to explore how and when during the demographic transition information campaigns influence the effectiveness of other program activities.
- If the family planning program has varying effects on fertility in particular segments of the population, its effects may be increased through a reallocation to those groups where the marginal effect is larger. This possibility should be considered along a variety of dimensions in the population to define who benefits most from the public subsidies to the various activities. Local program activity thus interacts with such exogenous characteristics of the population as women's education, husbands' income, or type of residential region.

The problem of public-sector management of a family planning program is somewhat analogous to that of a monopolist -- that is, one may assume for simplicity that the program's only objective is to maximize its effect in reducing fertility, whereas the monopolist's is to maximize profit. The latter varies sales of the firm's output across markets by reducing product supply where demand is relatively inelastic -- in other words, in markets where the price will increase by the largest proportion for a proportionate reduction in its supply. Similarly, the family planning program should increase its activity level (or its overall subsidy for information and services per woman) in those markets in which the demand for services is more price-elastic, or where the negative effect on fertility of an increase in subsidy is proportionately largest. Estimation of the relationship between the program supply variables and fertility in a *flexible* model specification that allows for nonlinear program effects and that includes interaction terms among program variables, and between program and demand variables, should

ultimately help to "fine-tune" funding to family planning and to increase the efficiency in future programs.

Figures 2 and 3 illustrate this interactive pattern between individual demand characteristics and program supply of effort. In Figure 2, a woman's level of schooling has a negative effect on her fertility before any program activity begins in the region, when the effects of her age and her husband's education or market wage opportunities are held constant. With family planning activities in the region, fertility declines on average for women in all education groups who are helped to avert some unwanted births. In the figure, the slope of the fertility function with respect to education diminishes, implying that family planning especially helps the least educated-women to evaluate new birth control technologies and to use them effectively. Thus, family planning and women's education are, in this sense, substitutes for one another. Expenditures on family planning have their greatest impact on aggregate fertility when they are allocated to regions where women are, on average, less educated.

The alternative possibility is that the demand for births declines most rapidly among better-educated couples, at least at the initial stages of the demographic transition, and consequently these couples benefit more by reducing their fertility when family planning is available. In this alternative scenario illustrated in Figure 3, family planning increases the slope; thus, family planning and female education are complements, each having a larger effect on fertility in the presence of the other. Several studies have found the substitution pattern in Colombia and Taiwan (Schultz 1988a). That the difference between actual and desired fertility is larger for less-educated women than for others in Latin America and Asia suggests that the less educated face a higher cost of acquiring and using reliable modern birth control, and they are the principal beneficiaries of family planning programs during the later stages in the demographic transition.

B. Controls for Parent Demand for Births

Household demand theories of fertility assign importance to the opportunity cost of the mother's time occupied by child care (Becker 1965; Schultz 1974). In Thailand, where women participate frequently in the market labor force and are primarily responsible for child care (Knodel et al. 1987), if they can earn a higher wage, their potential income and child care costs increase. The net effect of these offsetting income and price effects associated with an increase in women's wage rate has generally been found to reduce the desired and actual levels of fertility. Wage functions confirm that better-

Figure 2.

Family Planning as Substitute
for Female Schooling

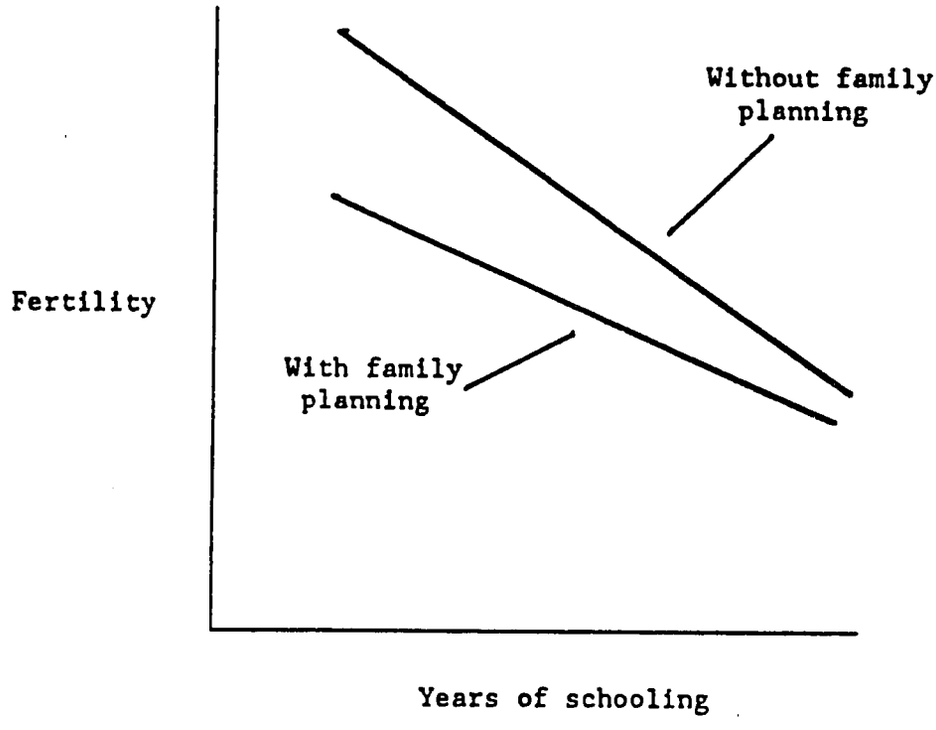
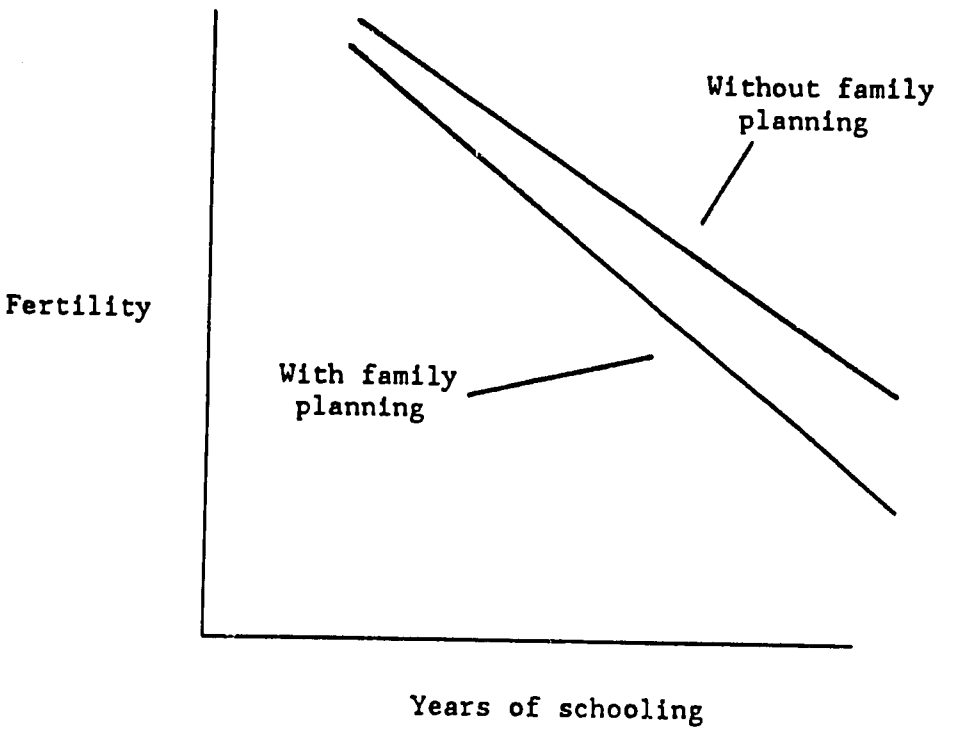


Figure 3.

Family Planning as Complement
to Female Schooling



educated women receive much higher wages in Thailand (about 25 percent higher for each year of secondary school completed, though increases are proportionally less at the university level). Years of schooling for women is therefore included in quadratic form in equation 1 as a measure of the price of women's time and a potential determinant of the demand for births.

Male wage rates and nonearned income exert a less-negative effect on fertility than do female wage rates. Indeed, in low-income agrarian societies such as Thailand, male and property income are generally positively associated with fertility, when female education or wage is held constant. In the 1981 Socioeconomic Survey (SES) of Thailand, analyzed here, the permanent male income of the household is measured by the household's total expenditures per adult. However, this income variable includes the effects of endogenous labor-supply decisions of the wife, and consequently it is estimated by instrumental variable methods, where the husband's age and education and nonearned income are the instruments.

Including a linear and quadratic term for the woman's age captures the biological capacity and behavioral tendency to have births in a concentrated period in the life cycle. Because better-educated women delay childbearing, the more flexible specification also allows an interaction between age and education.

Information is available on family planning expenditures in Thailand for the 62 provinces included in the 1981 SES (Kiranandana *et al.* 1984, appendix). Data are available separately for the Ministry of Health's National Family Planning Program and for the public subsidies to private nonprofit family planning associations. The public program under the Ministry of Health included the operation of hospitals, facilities for sterilizations, free-standing clinics, as well as outreach programs designed to serve rural communities. The private non-profit programs competed among themselves for a much smaller budget that emphasized outreach and information activities by paramedical personnel and relied heavily on community development organizations to reach remote rural populations. Expenditures are reported, however, for only a few years, including 1975 and 1980. Since expenditures can influence fertility only with a lag, the 1975 expenditures are more likely to be associated than expenditures in 1980 with the survey measure of fertility from 1976 to 1981. Empirically, the inclusion of the 1980 program expenditures in addition to those for 1975 did not improve statistically the model's fit. Consequently, the model reported below includes only the 1975 program expenditure levels.

It would be desirable to include expenditures on other local programs that might also affect the demand for children and could be correlated with family planning activity levels, such as health and education. Omission of such programs is likely to result in an overstatement of the effects of the family planning program on fertility.

Finally, a dummy variable is included to indicate whether the woman resides in a municipal area. A variety of prices and wage opportunities differ between rural and municipal areas of Thailand, and they might raise the cost and reduce the immediate benefits of a large family. The municipal variable is designed to capture the effects on fertility of these unobserved variables.

The measure of fertility examined in this paper is the number of children under the age of five living with their mother. This measure, based on a census or survey, is not uncommon when registration systems are incomplete (Cho, Rutherford, and Choe 1986). However, it presents problems when it is examined not at the aggregate regional level, but at the level of the individual woman between the ages of 15 and 49. These difficulties are considered elsewhere (Schultz 1989).

How should a statistical model be specified that links this count of own children and a series of covariates that are assumed exogenous, or estimated by instrumental variables if thought to be endogenous. The Poisson model is a statistical framework used to describe events that occur randomly and independently over a specified retrospective period of time (Maddala 1983). This characterization for the discreetness of counts of events observed over a fixed period has certain advantages over the OLS regression, but it still has limitations in describing fertility (Schultz 1989).

C. Empirical Findings

Table 2 reports the OLS linear regressions and the maximum likelihood estimates of the preferred Poisson model for the number of own children under age five per woman aged 15-49 in the 1981 Thailand SES. The table shows two empirical specifications. One allows for the hypothesized nonconstant returns to scale in family planning, the substitution between public and private program activities, quadratic effects of education, and education interacted with age. The second eliminates these five nonlinear and interaction variables that add flexibility to the model, although goodness of fit criteria appear to justify these added parameters to describe these data: they are jointly statistically significant. The Poisson parameters can be interpreted as proportional changes in fertility associated with a unit change in the explanatory variable.

TABLE 2

Number of own children less than age five per woman aged 15-49 - Thailand, 1981 SES[a]

Explanatory variables	Poisson model (1)	Poisson model (2)	Ordinary least squares (3)	Ordinary least squares (4)	Sample statistics[b] (5)
Intercept	-9.03 (20.4)	-11.0 (27.9)	-2.26 (13.5)	-2.69 (18.3)	.375 (.644)
Woman's age (years)	.496 (31.6)	.556 (36.4)	.134 (30.4)	.142 (36.9)	29.1 (9.83)
Age^2 ($\times 10^{-2}$)	-.891 (33.6)	-.939 (35.3)	-.230 (35.9)	-.237 (38.9)	9.42 (.614)
Woman's education (years)	-.231 (8.85)	-.0850 (15.9)	-.0357 (4.10)	-.0296 (16.2)	5.26 (3.37)
$Education^2$ ($\times 10^{-2}$)	-.459 (4.08)	---	-.113 (3.08)	---	.390 (.507)
Age times education ($\times 10^{-2}$)	.736 (9.58)	---	.0845 (4.12)	---	1.42 (.932)
Household monthly consumption per adult (log)[c]	.406 (7.66)	.453 (8.75)	.198 (8.96)	.210 (9.52)	7.00 (.269)
Family planning activity: (bahts per woman 1975)					
Public	-.109 (4.67)	-.0230 (4.21)	-.0496 (4.99)	-.00857 (4.21)	9.28 (2.72)
$Public^2$ ($\times 10^{-1}$)	.0289 (2.79)	---	.00138 (3.29)	---	.935 (.582)
Private	-.671 (3.94)	-.142 (4.59)	-.308 (4.39)	-.0576 (4.72)	.619 (.445)
$Private^2$ ($\times 10^{-1}$)	.841 (.76)	---	.505 (1.12)	---	.0581 (.0482)
Public times private ($\times 10^{-1}$)	.515 (4.58)	---	.226 (4.99)	---	.588 (.464)
Resident in municipal area	-.154 (4.48)	-.167 (4.88)	-.0568 (4.47)	-.0608 (4.84)	.354 (.478)
R^2	---	---	.1502	.1457	
Log likelihood	-8972.1	-9032.9	---	---	
Sample size	12,799				

_____ variable not included in specification.

[a]The absolute value of the asymptotic t ratio for the parameter estimates of the Poisson model are consistent even when there are certain types of specification error due, perhaps, to omitted explanatory variables that are independent of the regressors by use of pseudo maximum likelihood methods. Absolute values of t ratios reported in parentheses beneath OLS coefficients.

[b]Mean and standard deviation (in parentheses). The first entry is the mean and standard deviation of the dependent variable. Divide the OLS coefficient by the mean of the dependent variable to obtain the proportional effect on expected fertility that is estimated in the Poisson specification. For example, the OLS coefficient on public family planning activity (-.00857) in column 4 divided by .375 equals -.0229, or approximately the Poisson estimate of the proportional effect of a year of education of (-.0230) in column 20.

[c]Endogenous and estimated by instrumental variables, where the instruments are the husband's age, age squared, education, household unearned income, amount of unirrigated and irrigated land owned by household.

If a woman's education is one year higher than average, the flexible Poisson model implies that her fertility rate at the sample means is 7 percent lower -- or 9 percent lower in the noninteractive specification (column 2). A standard deviation increase in female education (3.4 years) is thus associated in the preferred flexible specification with a 22 percent decline in fertility. The percentage decline in fertility associated with an additional year of female education is not constant across school levels, but increases at higher levels of education as indicated by the negative sign of the coefficient on the education squared variable. A standard deviation increase (27 percent) in predicted expenditures per adult, the measure of male and noncarned income, increases fertility by 11 percent. No evidence indicated that at higher income levels, fertility declines with additional male income.

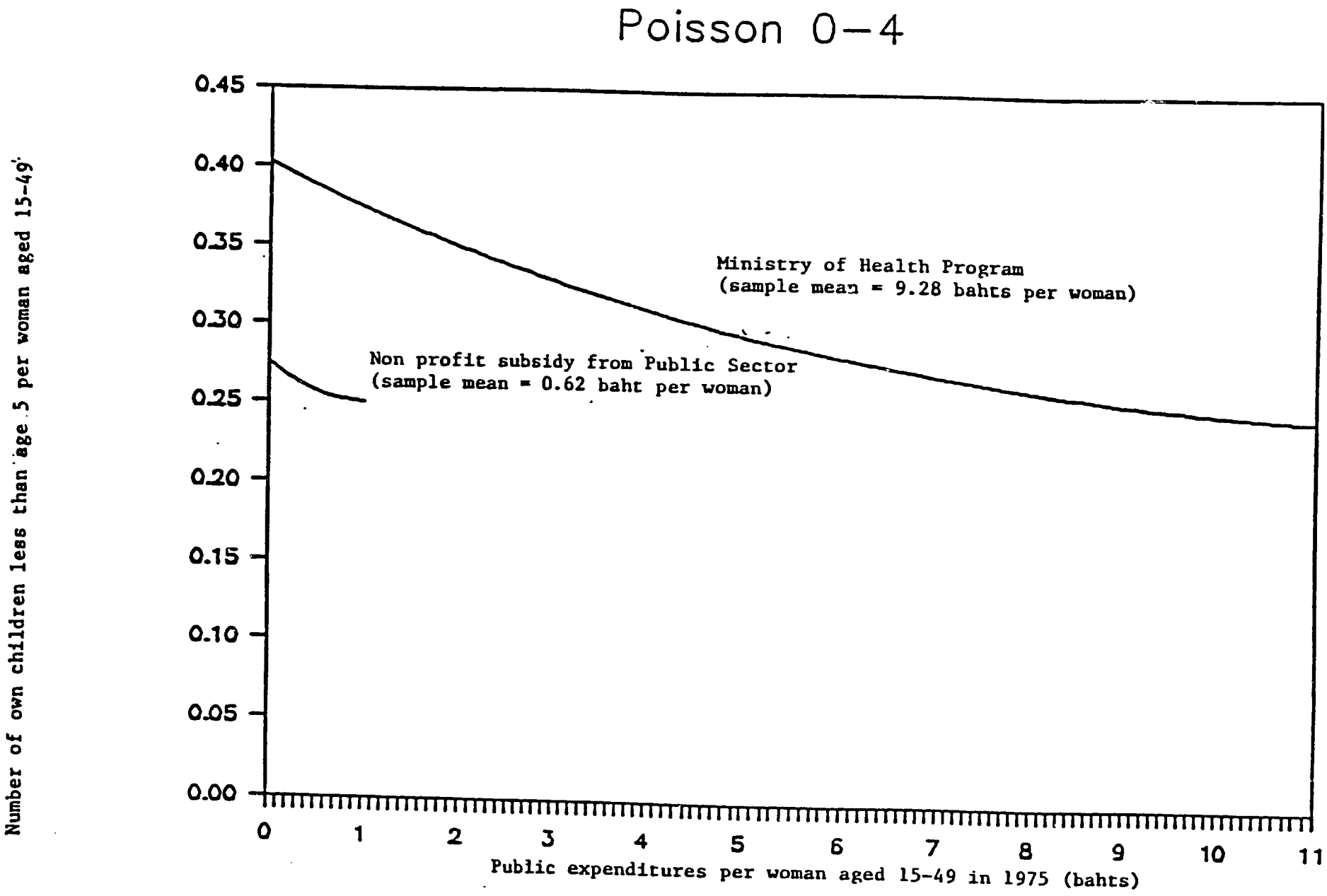
The two family planning expenditure coefficients in column 2 are individually statistically significant. A baht (the local currency, equivalent to U.S. $0.05) spent in 1975 in the public family planning program for every childbearing-aged woman in a province is associated, on average, with a 2.3 percent reduction in fertility. The same outlay is associated with a 14 percent reduction in fertility if it is allocated to the smaller, private nonprofit family planning associations. Expenditures on these programs may, of course, yield other benefits that are not measured here, and these relationships undoubtedly also include the effect of program expenditures in neighboring years that are positively serially correlated.

The flexible specification in column 1 confirms the hypotheses that the public and private family planning programs are substitutes for one another (i.e., interaction effects are positive), and that expenditures on the larger public programs are subject to diminishing returns to scale. The pattern of diminishing proportionate returns to scale is not statistically significant at lower levels of expenditure on the private nonprofit programs in 1975 (0.62 baht and 9.28 bahts per woman in the private and the public programs, respectively).

Figure 4 shows a simulation of the nonlinear relationship between family planning expenditures in 1975 and fertility in 1976 - 1981, using the preferred estimates of the flexible Poisson model specification column 1 of Table 2. The slopes of these fertility functions, evaluated at sample means, represent the marginal productivity of a baht spent per woman of childbearing age in a province on the public and private programs. The marginal product in the public program (of increasing expenditures from 9 bahts to 10 bahts) reduces the fertility level by 2.4 percent. In contrast, in the private program, an increase from 0.2 baht to 1.2 bahts reduces fertility by 8.9 percent. Thus, the payoff to allocating public resources appears to be almost four times as large as the current margin in the private versus the

Figure 4

Poisson Model Simulating Association of Province Family Planning Expenditures and Fertility



(Source: Table 2, columns 1 and 5.)

public sector. This is probably because previous expansion of the public program has already diminished its returns, whereas the small subsidy in 1975 to private nonprofit programs has not yet expanded sufficiently to reduce the returns. The data do suggest, however, that further expansion in the nonprofit programs will yield diminishing returns.

Taking the difference between the predicted level of fertility conditional on zero program expenditures and the observed mean level of fertility is one way to approximate the total effect of the 1975 program on Thai fertility in 1976 - 81. According to the flexible Poisson specification of equation 1, the public program is responsible for fertility's being 0.25 children per woman rather than 0.38 (intercept in Figure 4). The health ministry's activities thus account for a decline in Thai fertility of 34 percent. The private nonprofits account for an additional 7 percent decline. Thus, according to the simulation, the absence of the two programs would have increased Thai fertility 44 percent above that actually observed in the 1981 survey.

It should be emphasized, however, that these estimates of the *total effect* of the program are subject to much greater uncertainty than are the earlier comparisons of the *marginal effect* of program expenditure. This is because the estimated slope of the fertility function at the sample means is reasonably precise, and should be a locally unbiased second-order approximation of the marginal effect of program activity (Fuss and McFadden 1978). The hypothetical case of no program is, however, an extrapolation of the model outside of the range of sample observations. An extrapolation of this form is likely to be very sensitive to the choice of functional form embodied in the statistical model (i.e., Poisson or linear). This choice is quite arbitrary because it is not based on any economic theory or knowledge of the operation of family planning programs in general, or features of the program in Thailand in particular.

Another approach to estimating the program's total effect on fertility is to attribute the marginal product of factors at the current equilibrium (i.e., expenditures on the programs) to outlays of the program that may initially have had a higher payoff. This procedure is used in economics where other variables behave as inputs in a production process, and returns to all factors are distributed competitively. In this approach the public family planning program is responsible for a reduction in fertility of 22 percent (i.e., 0.024* 9.28 bahts per woman), and the private nonprofit program subsidy for 5.5 percent (i.e., 0.089* 0.62). The total fertility decline attributable to the two programs, according to this calculation, is still substantial -- or more than half of the nationally recorded decline.

Because of the apparent positive effect on fertility of the interaction of private and public program expenditures, the effect of expenditures in the private program triples if they are concentrated in areas that receive only half the national average level of public family planning outlays. Likewise, public program expenditures are 30 percent more effective if they are concentrated on the areas where the private program is at half its average national strength. Parallel patterns and magnitudes of the effects of the supply and demand factors on fertility can also be derived from the OLS estimates in columns 3 and 4 of Table 2.

An alternate means of measuring fertility is to count coresidential children under age 10 or 15 per woman, or analysis can focus on narrower age groups of women, without reversing any of the significant patterns discussed above (Schultz 1989, Tables 2 and 3). Interactions between family planning program variables and household and regional characteristics suggest that the private program had a larger effect among low-income households than among higher-income ones. The private nonprofit programs appear to have also had a greater impact in the nonmunicipal areas of Thailand. Therefore, Table 3 shows OLS regressions in the simplified linear specification for three survey strata. The impacts of women's education, male income, and public family planning do not differ dramatically from one stratum of society to another, though male income effects appear larger in urban than in rural or suburban areas. The private nonprofits, however, have their major effect on fertility in the suburban and rural areas, as suggested by the earlier noted interaction test.

V. Conclusions

Survey data from individuals on fertility, education, sources of income, and household expenditures can be merged with regional data on family planning activity or expenditures to estimate the role of local family planning as a determinant of fertility. It is clearly preferable to design the collection of these data around an "experiment" that randomly varies the level and mix of family planning activity by region. When this is not possible, it may be feasible to model the endogenous political and economic process determining the government's allocation of resources across regions. Even when family planning implementation does not follow an experimental design, holding constant for the principal factors that affect couples' demand for children should reduce bias in estimating the effect of family planning on fertility. Lacking experimental program data, it is

Table 3

Number of own children less than age five per woman aged 15-49: Stratified by region[a]

Explanatory Variables	Municipal urban (1)	Sanitary districts (2)	Rural villages (3)
Intercept	-5.71 (16.6)	-2.97 (8.11)	-3.03 (9.98)
Woman's age	.105 (14.1)	.118 (12.2)	.153 (26.2)
Age^2 ($\times 10^{-2}$)	-.182 (15.5)	-.201 (13.2)	-.254 (27.5)
Woman's education	-.0299 (11.7)	-.0248 (5.22)	-.0305 (8.21)
Household monthly consumption per adult (log)[b]	.672 (13.4)	.290 (5.15)	.247 (5.11)
Family planning activity (# per Woman in 1975)			
Public (Ministry of Health)	-.00787 (1.99)	-.00742 (1.41)	-.00893 (3.11)
Private (Nonprofits)	.00555 (.81)	-.0872 (2.75)	-.0914 (5.12)
R^2	.1370	.1326	.1485
Sample size	4,491	1,954	6,354

[a]OLS with absolute values of t ratios reported in parentheses beneath coefficients.

[b]Endogenous and estimated by instrumental variables, where the instruments are the husband's age, age squared, education, household unearned income, amount of unirrigated and irrigated land owned by household.

prudent to compare a variety of specifications of the reduced-form estimates, and to include numerous exogenous demand factors and combinations of supply program variables that describe the critical features of local family planning activities.

Among the characteristics of family planning programs that should be analyzed are the nonlinear returns to program scale in various specific operations, including clinic and hospital delivery units (for urban areas); paramedic outreach activities (for more dispersed and poorly served populations); and general information campaigns that may use different media to introduce people to the concept of family planning and to the actual techniques of birth control. The goal is to estimate as precisely as possible the fertility-reducing effect of changing the program resources allocated to each operation, evaluated at the *margin* where the program currently operates. Program managers can then either expand or contract activities so as to maximize the program's total effect on fertility. A change in one program activity will probably alter the cost-effectiveness of another. Consequently, these interactions between program subactivities should be specified in the fertility determinant equation, and their direct coefficients and interactions appropriately estimated. Two forms of family planning provided in a single region may be substitutes (positive coefficients) or complements (negative) in this reduced-form fertility equation. The impact of any one activity would then include both its direct effect and the multiple indirect effects it generates through the altered productivity of other program inputs.

Finally, the program should concentrate on reaching those segments of the population where the program subsidy has the greatest estimated effect on fertility, in order to again maximize its impact on national fertility. In the study on Thailand, available evidence suggest that the private nonprofit program had its greatest effectiveness among rural, poor households. According to evidence of differential responsiveness to this program, the overall impact could be increased if user fees were introduced or raised to recover more of the cost of services and contraceptive supplies delivered to urban, high-income households and these additional funds were then channeled into providing additional subsidized services to more remote, low-income regions.

In sum, analyses of existing survey data that combine economic and demographic information on households with regional accounts of family planning programs can address a number of allocation and financing issues in the efficient design and management of family planning programs . The resulting redistribution of public subsidies to family planning programs should enhance overall program efficiency and, perhaps even more important, contribute to reducing inequality in economic and social opportunities.

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1. An exception to this need to evaluate simultaneously demand and supply factors occurs if the variation in program supply is administratively designed to be random across the study population and is thus uncorrelated with the demand factors. Then, the association between the randomized supply variation and fertility is generally an unbiased source of information on the program's effect on fertility. But even in this case of a social experiment, controls for demand factors in the final statistical analysis can increase the precision of the estimates of the program's effectiveness or allow a reduction in sample size to obtain the same level of precision as obtained from a simple comparison of fertility means between the control and program treatment populations.

2. The classic example where an experimental design was implemented was in Taichung City, Taiwan, over 25 years ago (Freedman and Takeshita 1969). Unfortunately social experiments of this form (with randomized regional levels of activity) have not been used more widely to evaluate the impact of family planning. This gap in the evaluation literature on family planning may explain why there is little agreement as to the effectiveness of family planning worldwide.

3. The proximate-determinants model is generally multiplicative in its arguments. For the purposes of this example, the multiplicative indexes for the proximate determinants could be expressed in logarithms, as could the aggregate rate of fertility. This is clearly an aggregate representation of the population as a "representative agent" to simplify decomposition of the fertility rate.

4. Other decompositions of fertility focus on only marital fertility schedules, and express them essentially as a function of the effect of breast feeding on natural fertility and contraception (Cleland and Rodriguez 1988). Conditioning the dependent variable, marital fertility, on variables such as E and X in equation 1 will yield unbiased estimates of their effect on marital fertility <u>only if</u> age at marriage is not influenced itself by latent factors, such as preferences or unobserved elements in E and X. In other words, if age at marriage is endogenous to the socioeconomic and biological system that affects marital fertility, defining the dependent variable representing fertility as conditional on marriage may be misleading (Cleland 1985). To decompose the channels by which E and X affect completed fertility requires that the researcher impose an identification restriction on the structural model of marriage and marital fertility that is likely to be either controversial or, worse, arbitrary.