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POPULATION GROWTH: INVESTIGATION OF A HYPOTHESIS

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April 1969

APR 29 1969

P-4056

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I. INTRODUCTION

The population explosion is a new and complicated part of the economic development problems and processes of most of today's less developed countries. Colombia is no exception. Indeed in recent years she has experienced one of the world's most rapid population growth rates -- more than three percent a year in the 1960s. Because of the population explosion almost all features of the Colombian economic, political and social scene have changed, are changing, and will change dramatically.

In later chapters we trace through some of these changes systematically. Suffice it to say here that because of the population explosion there are more children to be educated, more mouths to feed, more hands to be employed. And because of the population explosion, old institutions and policies no longer are able to cope with new problems.

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This is to be a chapter in a book on mechanisms of and constraints on the development process, which relies for illustrative purposes primarily on the recent experience of Colombia. This RAND study is written by R. R. Nelson, R. L. Slighton, and T. P. Schultz. The author has benefited greatly from the comments and criticisms of R. R. Nelson, J. P. Newhouse, R. Freedman, T. W. Schultz, F. C. Iklé, and other RAND colleagues.

Rapid population growth has fueled massive rural-urban migration. Growth of the urban modern sector has proceeded more slowly than has the growth of the migration-fed urban work force, and the urban poor, unemployed or employed at very low wages, are increasingly prominent. The regime of rapid population growth has manifestly complicated Colombia's problems.

The proximate cause of Colombia's population explosion was the abrupt decline in death rates following World War II, from about 25 to 15 per thousand. But to say this is not to understand the phenomenon, nor to be able to predict its future course, nor to be able to develop public policies which can better cope. The most salient issues that require answers are why has the birth rate not fallen more rapidly, what are likely future trends in the birth rate, and what variables (particularly ones that policy might influence) will affect these trends.

Historical experience with regimes in which the death rate has fallen sharply indicate that, almost invariably, the birth rate moves to offset changes in the death rate, sooner or later, and in varying degree. Developed countries experienced a fall in birth rates in concurrence with a series of other fundamental social and economic changes; industrialization, urbanization and the extension of universal education have therefore all been attributed a role in the reduction of birth rates in developed countries.

A closer look at today's less developed countries reveals that birth rates are already substantially lower among urban than among rural women. Similar rural-urban differentials in fertility are

prominent in developed countries, or were a few generations ago. Since the population explosion is contributing to a rapid shift of population from the countryside to the cities, this redistribution of population may help to dampen the rate of population growth by instigating a decline in the average birth rate. This sanguine interpretation of the effect of rural-urban migration on the birth rate has been discounted by some observers, but is generally accepted, nevertheless. This phenomenon is important enough to probe deeper to learn why rural and urban birth rates differ, and whether rural-urban migration will disturb these traditional differences. Perhaps by exploring this question one can sharpen one's understanding of the general determinants of birth rates, and also discover how public policy can influence birth rates. To develop such a model of reproductive behavior is the aim of this chapter.

Can differences in birth rates be interpreted partly as reflecting differences in the number of births parents want, and if so what aspects of the parent's environment are ultimately responsible for their different wants? Our model rests on the assumption that people tend to adjust their behavior for their own betterment when their environment affords them new opportunities and imposes on them new limitations. This tendency toward "rational" behavioral adjustment may be neither prompt nor complete, but it provides a working hypothesis regarding family planning behavior that is helpful in investigating the local environment for the possible determinants of local birth rates. This approach grows out of our belief that population growth is not, as economists and demographers are prone to assume, exogenous to the

development process, but it is itself endogenously determined by the social and economic environment of people.

The second section of this chapter elaborates the conceptual framework of the family planning hypothesis and explores its empirical implications. In the third section the Model is evaluated empirically, with reference to Colombia. Then with the aid of two additional case studies -- Puerto Rico and Taiwan -- for which the limitations of data are less severe than for Colombia, further implications of the model are tested.

II. THE FAMILY PLANNING HYPOTHESIS AND THE ECONOMIC CAUSES OF POPULATION GROWTH

The family planning model is built around three factors that are assumed to exert a systematic effect on the actual frequency of births in following periods: (1) a family size goal or a number of surviving children that parents want, which is determined by a host of environmental factors modifying the relative attractiveness of few versus many children; (2) the incidence of death, mainly among offspring, which necessitates a compensating adjustment in birth rates to achieve any particular family size goal; and (3) uncertainty in the family formation process where deaths, births, and remarriage are unpredictable.[1]

1. The Family Size Goal

Parents value children for themselves, but in less developed countries particularly, children also contribute to family resources from an early age. Balanced against the benefits of having children

there are also costs: opportunity costs of time parents spend with their children, and pecuniary costs of goods and services required to feed, clothe, shelter, and educate a child. Parents' resources, in terms of time and wealth, constraint the activities undertaken, including the number of children they can rear.

It is useful as an introduction to more formal and quantitative analysis, to discuss briefly several characteristics of a community that seem likely to affect the subjective or pecuniary net cost of having children and thus affect the number of surviving children parents desire. The following are considered central: (a) opportunity income of women and men, (b) the allocation of children's time between school and work, (c) institutions, (d) birth control.

a. Opportunity Income of Women and Men

To devote her time to her children, a mother forgoes the opportunity to earn additional income or undertake other activities; this opportunity cost of children is an important part of the total costs of rearing children, a a part that appears to grow as a society advances economically. When women can easily find good jobs outside of the home, they tend both to participate frequently in the labor force and to appreciate the opportunity costs associated with enlarging their family or lengthening their years of child rearing. One expects, therefore, and generally finds in an environment where women can earn more income (per unit time), higher female participation rates, lower birth rates, and shorter intervals between births, other things being equal.[2]

Typically the main source of family income is that of the male head of household. A change in his income may have a variety of effects on parents' desires for children. An unanticipated but permanent change in family income would appear to change, in the same direction, the number of children parents can expect to rear at their current standard of living.[3] However, in the long run, a permanent shift in income is usually translated into a new standard of living for parents and children alike. Though parents have some latitude in the standard of living they provide their children, the standards deemed socially acceptable rise with parents' income and status. Exactly how these countervailing effects of an unexpected permanent change in income and a subsequent change in child costs balance out cannot be predicted *a priori*.[4]

b. Child Labor and Education

Children may also be gainfully employed. Until children can earn more than they consume, they rely economically on the family. The extent to which potential child earnings are captured by the parent depends on the alternative opportunities for children to attend school or to assist their parents, and the social attitudes toward child labor practices within and outside the home. At a later age when children can earn more than they consume, a host of cultural and economic factors are likely to determine what fraction of this "net income" is claimed by parents. Regardless of the underlying determinants of child labor practices in the community, the prevalence of unpaid family workers should be associated with larger benefits or lower net costs for rearing children.

School for children, therefore, even when provided free by the state, imposes opportunity costs on parents. Even if children do not work outside the home, they provide help in the home by tending younger children and performing routine household chores. This help is restricted when they attend school. School attendance also adds as a rule to direct household outlays for better clothes, school materials, transportation, and support away from home. The parents' decision to send their children to school thus increases child costs and may be a strong determinant underlying the family size goal. Having more children or providing fewer with additional opportunities for schooling may be an important watershed in the transition from so-called "traditional values" where reproductive behavior was consistent with a regime of high childhood mortality and low social mobility, to so-called "modern values" where reproductive behavior adjusts to conditions of low mortality and higher mobility in accord with the individual's talents, training, and formal education. For investment in the productive capabilities of children to be attractive, the chances for child survival and opportunities must be good.

The schooling of parents may also, plausibly, affect their family size goal; for the education of parents is closely associated with their opportunity income, and thus with the opportunity cost of the parents' time spent attending to the needs of their children. And since children tend to be a relatively time intensive involvement, parents' education may underlie their relative evaluation of whether to have a large family or to allocate more of their time and resources to other activities. Schooling may give parents easier (cheaper) access

to birth control information, contributing to their earlier and more reliable adoption of family limitation. Behavioral patterns of better educated parents may be more flexible and capable of coping with environmental change, such as an unanticipated decline in death rates as has occurred in Colombia. Finally, the willingness of parents to invest in their child's education may hinge on how much schooling they had. It is possible, therefore, that the schooling of each generation paves the way for the increased educational opportunities enjoyed by the next, increasing respectively the costs of rearing children.

c. Institutions

Income and wealth transfers between generations and from active workers to inactive aged and infirm depends in part on the structure of the family. The extended family tends to shelter both the old and young; parents have socially approved claims on their offspring's future earnings if their own means of support are exhausted, just as young parents turn to the extended family for support of their children when their current earnings are deemed insufficient. The scope and necessity of these family production and redistribution relationships appear to be a function of the average level of wealth in the society and the specific activities undertaken by the state.[5] These family institutional factors are judged to be important by some observers in determining family size goals, but empirical evidence is scant, and Colombian data are not rich enough to specify this facet of the family setting.

d. Birth Control

The costs of birth control consist of first acquiring and evaluating information about alternative contraceptive methods and then outlays and inconvenience associated with using a method. Traditional methods of birth control are less reliable and less convenient than modern ones.[6] Where the range of alternatives is limited to traditional methods, large costs must be incurred to achieve a high degree of reliability, as in the extreme cases of continence, dissolution of marital unions, and induced abortion. For the individual living in a "traditional" community, it may be very costly to search independently for a more reliable and a more convenient (modern) method of contraception, whereas for a society as a whole, informational costs are perhaps more modest per capita because of economies of scale in disseminating information. It should be stressed, however, that the personal costs associated with the adoption and use of contraception are poorly understood and very difficult as yet to appraise empirically.

e. Other Factors

Many other factors undoubtedly play a role in determining the relative attractiveness to parents of having a few or many surviving children, but for the scope of this study this abbreviated list of more important factors provides a useful starting point for evaluating the predictive power of the family planning hypothesis for Colombia. It is assumed, of course, that the environmental variables that are omitted from the analysis are uncorrelated with those included. Having settled on a desirable number of surviving children, parents may then decide, prospectively and retrospectively, how many births are needed to achieve that family size goal.

2. The Incidence of Death

In exercising some control over births to achieve a certain surviving size of family, parents must take into account the incidence of death among their offspring. Neglecting for the moment the uncertainty of outcome that stems from the unpredictability of births and deaths within a particular family, the family planning hypothesis implies that parents try to compensate for the average incidence of death by seeking the number of births that will give them the desired number of surviving children. Two behavioral mechanisms may be involved in this compensating adjustment of birth rates to death rates: a long-run expectations mechanism that may work primarily via changes in accepted patterns of marriage, birth timing, and spacing, and a short-run replacement mechanism that may emerge several decades after the onset of the decline in child death rates.

First, the established regime of childhood mortality may influence parents in planning their lifetime reproductive behavior to compensate for what they expect to be the incidence of death among their offspring. If the death rate for children is high, this adjustment may take the form of earlier marriage and earlier initiation of child bearing and more frequent remarriage. Second, since mortality in childhood is concentrated in the first years of life, parents may make an added effort to have an additional child when they lose one of their children. This presumes that some still fertile women already have the number of living children they want, and without their child's death would seek to avoid further births. A decade or two after child death rates decline, when large numbers of parents reach their surviving family size goal before menopause, fluctuations in child death

rates are likely to exert a pronounced effect on the birth rate among this group of older women.[7]

Although these two behavioral mechanisms are distinct, it is empirically difficult to distinguish between them with the available demographic data because the usual expectation model and the replacement model imply similar adjustment equations for the purposes of empirical estimation. Regardless of the relative importance of these two mechanisms, the implications are clear that for a community current birth rates are likely to be influenced by recent past and future expected death rates.

3. Uncertainty

When parents desire a certain number of surviving children, they undoubtedly realize that they cannot assure the outcome they want. Rather, their actions influence only the range and probability of possible outcomes. This recognition of uncertainty in the family formation process may induce parents to aim for more or fewer children (births) than they would desire under a predictable regime of deaths and births. There is a close link between the level of death rates and the degree of uncertainty attaching to the family formation process. Where increased uncertainty has the effect of inducing parents to seek more births, both the direct effect of death rates and the indirect effect operating through uncertainty will tend to influence objective birth rates in the same direction. Separating these direct and indirect effects of death rates statistically may prove difficult in most contexts, and impossible in Colombia where reliable information of child death rates is altogether lacking.

In summary, parents' decision to seek a particular number of births is interpreted as a function of (1) the character of their environment that affects their revealed preferences for surviving children, (2) past or expected child death rates that necessitate compensating adjustment in birth rates, and (3) the uncertainty associated with births and deaths that may induce parents to increase or reduce the number of births they seek. This family planning hypothesis is next translated into a model that yields implications for reproductive behavior that are subject to empirical verification.

III. TOWARD EMPIRICAL EVALUATION OF THE MODEL FOR COLOMBIA

This section presents a formal model based on the preceding qualitative discussion, and some results of testing the model against Colombian data. The problem is to specify a relation between the number of births parents want and environmental variables that are not themselves determined simultaneously with or subsequently by the objective number of births. In this exploration of the implications of the family planning hypothesis, it is assumed that the factors determining birth rates are themselves predetermined.[8]

1. The Hypothesis and Implications

Our family planning hypothesis postulates a multivariate relationship between equlibrium birth rates and certain features of a parents' environment. Under plausible assumptions about the functional form, the model implies that current birth rates are a linear function of past gradually changing environmental constraints, and a distributed lagged adjustment to recent death rates.[9] From the earlier discussion,

it may be predicted that female opportunity income or its proxy the participation of women in the labor force, child schooling rates, and perhaps adult educational attainment will be associated with higher child costs from which we infer birth rates are likely to be lower. Conversely, the employment of child labor within the family will tend to have the opposite effect. Birth rates should be postively related to child death rates. The effect of uncertainty cannot be predicted a priori since it depends crucially on the asymmetry of parent cost functions, but it is plausible that in less developed countries a reduction in uncertainty will contribute to a reduction in the desired number of births.

2. Empirical Evidence for Colombia

The purpose of this section is to see if differences in birth rates across regions in Colombia are as predicted by our model, and more precisely what features of the Colombian environment are strongly associated with signs of retardation in the rapid rate of population growth.

Births and deaths are not reliably known at the regional level in Colombia. The major source of regional data is the Census of Population. While there is no complete registration of births or deaths, the age composition of the population is recorded in the Census at the municipality level.[10] These data do not permit one to estimate birth and death rates independently of one another,[11] but the age composition does provide a basis, albeit approximate because of migration flows, for estimating a measure of surviving fertility, or a proxy for the rate of natural increase of the regional population.[12] More

precisely, the proportion of young children in a regional population reflects two inseparable phenomena: the regional frequency of births and the regional incidence of child deaths. If, as appears to be the general case, the level of birth rates and child death rates are positively correlated across regions in Colombia, this synthetic measure of surviving fertility derived from child/woman and child/population ratios will vary less across regions than the actual birth rate, but will correspond approximately with both the long-run size of surviving family in the region and the rate of natural increase of the population, that is, the growth rate of population before migration.[13]

There are similar problems in obtaining indices of the "independent" variables. No Colombian data exist on a regional basis for wage rates for women. There is regional data on labor force participation rates for women. We assume here that women's participation in the labor force is predetermined by her income opportunities, and is a satisfactory proxy for women's opportunity wage.

The effect of the educational process is measured in two ways: school attendance among children and educational attainment of adults. Since child and adult schooling are thought to add to the costs of rearing children in different ways, directly and indirectly, these two measures of schooling are included together in the regression analysis.[14] No measure of age specific labor force participation is available for Colombia by municipality, and thus the effect of unpaid family employment of children or indeed any measure of the work experience of children is omitted in this analysis.

Departing from the central components of the model, several other variables may be worth considering, though their relations to

preferred size of surviving family are more problematic.[15] Under the plausible assumption that a rapid rise in real wages relaxes parents' resource constraint on having a larger number of children, it is plausible that the level and rate of growth (1952-1965) of local agricultural real wages may be associated with somewhat larger families, other things equal.

Internal migration may also account for some of the interregional variation in surviving fertility. Women in rural areas have more children, on the average, than women living in urban areas. Since the bulk of internal migration in Colombia consists of persons moving from rural to urban residence, the migrant may bring with him more than the urban average number of young children, or continue to want and have a larger number of children than is typical among urban-born residents.[16] In this case, regions in which a large proportion of the local population were in-migrants would tend to record higher levels of surviving fertility than regions, otherwise similar, but in which in-migrants represented a smaller proportion of the population. To test this line of reasoning, the proportion of men in the municipality who were born outside of the municipality is included in the regression model as an in-migration variable. In the next chapter migration and its determinants are the center of analysis.[17]

Finally we return to the rural or urban nature of a locality. However, characterizing an environment as urban or rural neglects more fundamental differences among environments that are only crudely described by this arbitrary dichotomy. Although urban as compared with rural residence frequently involves a number of changes in

family organization and environment that on balance appear to add to the costs of rearing children, and thus may foster lower birth rates among urban than among rural populations. Many of these changes are directly incorporated into our model.[18] For much the same reason, agricultural activity is often thought to be more conducive to higher birth rates than nonagricultural activity. Both the proportion of the population in rural residence and the proportion of the labor force employed in agriculture are considered as possible explanatory variables in our regression analysis of surviving fertility in Colombia.

Finally, the proportion of adult women married or living in free unions is often considered as an intermediate cause for variation in surviving fertility. It must be emphasized, however, that the marriage rate represents an institutional variable which is not likely to be exogenous to desired or surviving fertility, for the timing of marriage patterns are heavily influenced by the environmental constraints and opportunities that simultaneously determine the number of children parents indeed want.[19] Therefore, the inclusion of the marriage rate in the regression model may bias the estimation of the direct effects of environmental variables in surviving fertility.

The data examined are derived from a 15 percent random sample of 131 Colombian municipalities for which unpublished 1964 Census tabulations and published 1951 Census data are matched. Information from the two Censuses yield estimates of local patterns of population growth and internal migration.[20]

3. Empirical Findings for Colombia

The association between regional surviving fertility, from the decade before 1964, as defined earlier, and characteristics of the local population and environment is estimated in Table 1 by ordinary least squares. The principal variables of the model -- child and adult schooling rates and female activity rates -- account for about 22 percent of the interregional variation in surviving fertility in Colombia. The predictive power of the relationship is less important, for our purposes, than the significance and size of the regression coefficients. Child school attendance and female activity rates are significantly associated with interregional differences in surviving fertility, but adult education falls marginally below the 5 percent confidence level, its coefficient being only 1.8 times its standard error. The marriage rate, in-migration rate, and growth of real wage variables all have the expected sign in relation to surviving fertility, but none adds significantly to overall relationships or is attributed a regression coefficient that is significantly different from zero.

Though there is a tendency for rural and agricultural regions to record higher fertility rates, as was noted earlier, these differences are largely accounted for by the education and female activity variables and make no significant additional contribution to explaining interregional variation in surviving fertility in the Colombian sample.

If the relationship estimated in Regression 4 of Table 1 were valid, a number of probable changes in Colombia would contribute to a reduction in the rate of population growth. A doubling of the child school attendance rate for the age group 5 to 9 from the level of

Table 1

REGRESSIONS ON ESTIMATED MUNICIPAL SURVIVING FERTILITY: COLOMBIA 1964[a]
(Beneath regression coefficients are t statistics or ratios of coefficients to their standard errors)

Regression Number	Constant Term	Proportion with Some Primary Schooling: Aged 5-9	Proportion with Some Primary Schooling: Aged 15-59	Female Activity Rate	Proportion of Women Married	Proportion of Men not born in locality	Annual Growth of Real Wages	R^2
1	52.09	-.098 (-2.27)[b]	-.080 (-2.34)[b]	-.108 (-2.92)[c]	.037 (1.98)[b]	.028 (1.53)	.142 (1.34)	.266
2	52.31	-.086 (-2.02)[b]	-.084 (-2.46)[b]	-.112 (-3.03)[c]	.035 (1.87)	.028 (1.52)	NI	.256
3	52.32	-.095 (-2.24)[b]	-.067 (-2.07)[b]	-.116 (-3.12)[c]	.035 (1.85)	NI	NI	.242
4	54.46	-.109 (-2.59)[c]	-.059 (-1.81)	-.120 (-3.20)[c]	NI	NI	NI	.221

NOTES:

NI - variable not included in regression.

[a]Independent variables expressed in percentages, with growth of real wages measured in agriculture on an average annual basis from 1952 to 1965. Surviving fertility is expressed in terms of a crude birth rate per thousand population that is approximately associated with the proportion of children in the regional population to women and adults of childbearing age (see Footnote 12).

[b]Coefficient significantly different from zero at the 5 percent level of confidence.

[c]Coefficient significantly different from zero at the 1 percent level of confidence.

SOURCE:

T. Paul Schultz, Population Growth and Internal Migration in Colombia, RM-5765 The RAND Corporation, Santa Monica, California, 1968, Table 3. Sample size is 131.

22 percent in 1964 would imply tha many more children received some exposure to the primary educational system in Colombia, a not unreasonable goal. Such an expansion in educational opportunities would be associated with a 5 percent reduction in surviving fertility, and as the proportion of adults with some schooling increased from, say, 62 to 74 percent, this would be associated with an additional 1 percent reduction in surviving fertility. These findings are broadly consistent with those considered later for Puerto Rico and Taiwan: the school system appears to exert a stronger influence on fertility more because its demands on the time and energies of children are a burden to parents, than because of its delayed impact on the educational attainment of parents.[21] The participation of women in the labor force is likely to continue to increase in Colombia, and a doubling of the current low level of activity among women would be associated with a 4 percent decline in surviving fertility. Major changes such as these are likely to occur in the next decade or two, and according to the estimates presented here, these changes alone would be associated with a 10 percent reduction in surviving fertility and population growth.

PROSPECTS FOR THE FUTURE

If these factors, among others, influence the number of surviving children parents desire, the birth rate may also depend on the death rate for children. Though it is not possible to estimate the child death rate in Colombia on a regional level, historical evidence suggests that for birth rates to fall, the chances for child survival must first improve for an extended period. The Latin American countries that are experiencing a substantial decline in birth rates have also had an

earlier large fall in death rates.[22] The unanswered question is how long a lag will separate the decline in death rates induced in the less advanced areas of Latin America from the onset of the decline in birth rates.

Mortality among children in Colombia has undoubtedly decreased with the control of some infectious and microbial diseases, but childhood deaths are still much more common than in developed countries. Infant mortality is about four times greater in Colombia than in advanced countries, and death among preschool children (age 1 to 7) is probably thirty times higher. Protein-calorie malnutrition is thought to be responsible for the high death rate in Latin America, contributing to the susceptibility of children to the pneumonia-diarrhea complex of diseases. Essentially non-microbial, these diseases are not readily controlled by modern medical technology without a prior improvement in the child's diet and home environment.[23]

Since child spacing is a subtle form of family planning that is uncommon in less-developed countries, most persons seeking reliable birth control methods already have the number of living children they want. Consequently, the demand for birth control and the subsequent decline in birth rates may be expected to lag ten to fifteen years behind the decline in child death rates, and be most noticeable among women 30 years or older. Because of the reduction in child mortality that has already occurred in Colombia, one might expect a large number of women between 30 and 35 in the 1960s will desire the means to avoid additional births. Once the birth rate has begun to decline and there is a potentially fertile group of women preventing unwanted births through

reliable means of birth control, fluctuations in child mortality may become gradually associated with (replacement) fluctuations in birth rates, primarily among this older group of women, but with a much shorter lag, probably on the order of two or three years. The data are not available for Colombia to test these conjectures, but data for Taiwan considered later in this chapter permit us to probe these events in greater detail and precision. However, where means of reliable contraception are not available, abortion and dissolution of marital unions may become more frequent as is already evidenced in Chile and Peru as well as Colombia.

IV. PUERTO RICO AND TAIWAN: FURTHER EVIDENCE

From the limited information available for Colombia, strong indications are found that regional differences in surviving fertility are associated with characteristics of the local environment that are expected to influence the number of surviving children parents might want. But analysis has been limited to an indirect proxy for the birth rate which at best reflects the net surviving balance between the birth rate and child death rate. To examine directly and in greater detail the implications of the family planning model, Puerto Rico and Taiwan are examined in the remainder of this chapter.

A. THE CASE OF PUERTO RICO

Puerto Rican data are generally better than Colombian. In particular we have reliable observations on birth and death rates by municipality, so we can test directly more of the implications of the model.

The empirical analysis for Puerto Rico deals with 75 municipalities for seven consecutive years, 1951 to 1957. In this period death rates

were completing their fall which had begun a decade earlier, and birth rates were beginning to decline (see Table 2).

Environmental, vital and population statistics for Puerto Rico are derived from vital registrations, which were virtually complete in this period, and the U.S. Censuses of Population.

The association between birth rates and prior death rates conforms to expectations. The estimates are statistically significant for two years and of diminishing positive value for four years when analyzed together against current birth rates. Two education variables are investigated, as for Colombia, measuring this time school attendance rates for children 7 to 13, and median years of schooling for adults. Both are inversely associated with birth rates. Female activity in the labor force is again used as our proxy for the opportunity income of women and hence their opportunity costs of rearing children. In the opposite case, where family members work in the family without pay, some of the costs of rearing children are offset by their productive contribution to family resources. These two reflections of other costs entering into the family formation process are together included in Regression 1 of Table 3, which presents the generalized two-stage least squares estimates of the complete family planning model allowing for regionally specific correlation of errors.[24]

Although there is the frequently noted pattern of higher birth rates for rural and agricultural regions in Puerto Rico, Regressions 2 and 3 in Table 2 show that as in Colombia the particular aspects of

Table 2

CRUDE AND AGE SPECIFIC BIRTH
AND DEATH RATES IN SELECTED COUNTRIES

Country and Year	Crude Birth Rate	Age Specific Birth Rate 15-19	20-24	25-29	30-35	39-40	40-44	45-49	Crude Death Rate	Infant Mortality Rate
TAIWAN										
1921-1925	41.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	23.7	165[a]
1936-1940	43.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	19.7	140[a]
1950	43.3	62	247	298	269	192	112	30	11.5	44.7[a]
1955	45.3	51	274	342	296	219	103	25	8.6	44.8
1960	39.5	49	254	334	256	170	79	13	6.9	35.0
1965	32.7	36	261	326	195	100	42	6	5.5	24.1
1966[b]	31.3	39	269	320	184	88	37	5	5.4	21.7
PUERTO RICO										
1939-1941[c]	39.2	78	248	262	215	140	43	9	18.4	137
1950	39.0	99	280	260	200	143	53	12	9.9	68
1954	35.2	98	255	219	160	131	48	11	7.5	58
1958	33.2	104	291	203	133	104	42	10	6.9	53
1964	30.6	n.a.	257	193	116	88	34	7	7.2	52
COLOMBIA (estimated)										
1951-1964	47	95	299	339	302	239	168	30	14	115
UNITED STATES										
1964	21	73	220	179	104	50	14	1	9.4	25

Table 2 continued:

Notes:

[a]1920-1940, George W. Barclay, Colonial Development and Population in Taiwan, Princeton Univ. Press from U.N. Sources. 1950 entry is for 1952, 1954, tables 36, 39.

[b]Adjusted for shift in pattern of Enumeration in December 1966 associated with Special Census.

[c]Underregistration is probably substantial at this time in Puerto Rico.

Sources:

Taiwan - Demographic Reference Taiwan 1 56, Vol. VI and adjusted 1966 Crude Birth Rate Bimonthly newsletter of the Taiwan Population Studies Center, Jan.-Feb. 1968, p. .

Puerto Rico - UN Demographic Yearbook and US Vital Statistics.

Colombia - Estimates from T. Paul Schultz, Population Growth and Internal Migration, RM-5765, Appendix A, Table .

United States - Natality Statistics Analysis, United States 1964, Arthur Campbell, Alice Clague, Frank Godley, National Center for Health Statistics, Series 21, No. 11, Feb. 1967, Table 3, p. 8.

Table 3

TWO STAGE REGRESSION ON CRUDE BIRTH RATES IN MUNICIPALITIES OF PUERTO RICO, 1950-1957

(In parentheses beneath regression coefficients are their standard errors)

Regression Number	Constant Term	Education: Children Age 7-13 (% in School)	Education: Adults Age 25 over (years)	Women Participation (%)	Unpaid Family Workers (%)	Crude Death Rates: Lagged 1 year	Crude Death Rates: Lagged 2 years	Urbanization (%)	Proportion Active in Agriculture (%)	R^2
1	26.88	-.083 (.037)*	-1.451 (.296)**	-.179 (.030)**	.766 (.095)**	.835 (.171)**	.304 (.163)			.449
2	28.47	-.099 (.039)**	-1.627 (.324)**	-.185 (.030)**	.759 (.095)**	.817 (.172)**	.263 (.166)	.016 (.012)		.451
3	26.20	-.078 (.039)*	-1.382 (.352)**	-.177 (.030)**	.755 (.099)**	.831 (.172)**	.303 (.163)		.007 (.019)	.449

*Coefficient significantly different from zero at the 5% level of confidence.

**Coefficient significantly different from zero at the .1% level of confidence.

SOURCE: T[illegible]ul Schultz, A Family Planning Hypothesis and Some Empirical Evidence from Puerto Rico, The RAND Co[illegible]ration, Santa Monica, California, RM-5405, November 1967, Table 9. Sample Size is 525.

the rural-agricultural environment that are associated with birth rates are already adequately specified in terms of the central variables in the family planning model.

Further detail on the family environment can be obtained from the Puerto Rican material for testing other implications of the family planning model that were not available for Colombia. Most difficult to test is the hypothesis that parents react to the presence of uncertainty in the family planning process by altering their birth rate. Uncertainty involves both the timing and the arrival of family births and the timing and incidence of family deaths. No data are available on the frequency and intervals of birth given preferred birth schedules. The frequency of deaths, however, is known for the recent past within each community, and is assumed to be independent of individual preferences. The variability of death rates is used as a proxy for uncertainty stemming from fluctuations in the incidence of death but without finding a statistically significant association with regional birth rates.[25] Much greater refinement of our conceptual understanding and empirical measurement of uncertainty as it enters into the family planning process will be required before any firm conclusions will emerge as to the causal link between uncertainty and human reproductive behavior.

Differences in age, sex, and marital status of the population may also account for some part of the variation in crude birth rates across municipalities. To test this hypothesis, two variables are constructed to measure the effect of these compositional characteristics on birth rates.[26] Adding either or both of these variables to the central variables of the family planning model does not add to its explanatory

power, nor do these variables show a statistically significant association with birth rates or alter substantially the previous estimates of the model.[27]

One implication of these empirical results for Puerto Rico is of particular interest. The estimated association between death and subsequent birth rates shown in Table 3 implies that a change in regional death rates is associated within a few years with a fully compensating change in birth rates. A reduction in death rates in this period was not associated, therefore, with a significant change in the rate of population growth. If the association reflects causality, as the model postulates, reducing death rates by improving health and economic conditions in this period did not exacerbate the population growth problem in Puerto Rico, but on the contrary, directly facilitated the transition to a lower level of fertility and a lower rate of population growth. This evidence may foreshadow future trends in Colombia.

In summary, four environmental variables lagged one year and death rates lagged one and two years constitute the core of the Puerto Rican test of the family planning model. In contrast with the Colombian test of the model, family unpaid workers and directly measured birth and death rates have been added. Additional environmental and demographic variables again do not account for a significant portion of the remaining unexplained interregional variation in birth rates in Puerto Rico. The salient features of the family's environment -- mortality or health, education and economic activity of women and children -- account for almost half of the variation in Puerto Rican birth rates among 75 municipalities over seven years.

B. THE CASE OF TAIWAN

For Taiwan three new dimensions of the model can be examined. First, death rates may be translated into child survival probabilities, which permits one to specify the birth rate function multiplicatively, as was implied in the conceptual discussion.[28] Second, birth rates can be examined for women of various ages, to determine whether women are more responsive to the framework of the family planning model in their younger or older years. It was earlier conjectured that the effect of family planning constraints and opportunities would be more noticeable among older women, particularly as they might try to quickly replace the loss of their children. Third, it is possible in Taiwan to evaluate by means of our model the marginal effectiveness of public policy aimed at hastening the spread and use of modern contraception to reduce birth rates.

The Taiwan system of household registrations provides a rich and reliable source of certain types of demographic and economic data which have been compiled and published in the last few years for 361 administrative units of Taiwan -- precincts, townships and hsiangs.[29] From these data it is possible to estimate school attendance for children, educational attainment for adults as in Colombia, and also derive the occupational attachment for men.[30] Birth rates are analyzed for two years, 1964 and 1966. In the latter year the large-scale unofficial family planning program launched in 1964 may have begun to influence the regional levels of birth rates. It is initially assumed that the program's effect is uniform throughout the island, or at least uncorrelated with the exogenous variables, and later some adjustment for

the effect of the program on birth rates is explored.

Additional biological and behavioral information sharpens the implication of the family planning model for age-specific reproductive behavior. Most family planning is avoiding unwanted births after having the number of surviving children wanted. As noted before, spacing of births is a subtle and uncommon refinement, for two reasons.[31] First, as fertility declines, birth intervals do not increase, rather child bearing becomes increasingly concentrated in fewer years, usually while the mother is still in her 20s. It therefore appears that women prefer to have their children close together in their early years of marriage once reliable means of contraception are available assuming the family environment is relatively stable and predictable.[32] Second, spacing of births relies on foresight, which is difficult to fathom in a rapidly changing environment such as is common in developing countries, whereas avoiding further births when enough children are already living necessitates no forethought and involves obvious reinforcement mechanisms.

As fertility declines secularly, it is common for the relative decline in birth rates to older women to exceed the decline to younger women, as is evidenced for Taiwan in Table 4. The proportion married in Taiwan has fallen of late for women aged 15 to 19, but has not changed appreciably since 1959 for older women, though for older cohorts the secular trend has been toward an increasing proportion married. The postponement or early consummation of marriage is one form of family planning, and may, like others, adapt to environmental opportunities and constraints, such as a change in child mortality or an increase in returns to, and opportunities for, extended education. Consequently,

Table 4

PERCENTAGE DECLINE IN TAIWAN BIRTH RATES FROM 1955 TO 1966

Age of Women	Birth Rate per 1000 Women
15-19	-24
20-24	-2
25-29	-6
30-34	-38
35-39	-60
40-44	-64
45-49	-80
Total Fertility Rate*	-28
Crude Birth Rate	-31

*Sum of age specific fertility rates times five, that is the number of years in each cohort.

SOURCE:
See Table 2.

our model is designed to predict age specific birth rates and not age specific birth rates of married women. The extent to which the model accounts for regional differences in birth rates to women 15 to 19, two instruments of family planning are likely to be in operation: birth control within marriage and postponement of marriage itself. More generally, however, the model has greatest relevance to the age specific reproductive behavior of women over the age of 30, for whom birth control is likely to become increasingly common as demographic transition progresses.

The analytical treatment of child death can in the case of Taiwan be refined further than was possible for Puerto Rico where only the crude death rate was available. The model implies that the death of a child to a still fertile mother is likely to induce her to have a somewhat higher subsequent birth rate than would have otherwise been the case. Although the death of a child may motivate its mother to seek an additional offspring, this effect on her reproductive behavior may be difficult to distinguish in the short run if she is young and her age cohort is likely to be having additional children regardless of the incidence of child mortality. If on the other hand, the mother is older, say in her late 30's, when a sizeable proportion of her cohort intends to avoid further births, her behavioral response to the child's death may distinguish her from others in her cohort in a relatively short time.[33] Though it is not possible from published

data to trace the frequency of child death to mothers of a specific age, it is possible in each region to determine the age specific death rate for children in several years. Since age specific mortality is relatively low beyond age 14, the child death rate is defined from birth through age 14.[34] If parents compensated precisely for the probability of child survival implied by the given year's age-specific death rates in their region, then the estimated regression coefficient for the death factor would be unity (1.00). A regression estimate for the death factor greater than one suggests that as child death rates decline, the associated reduction in birth rates a few years hence will overcompensate, thus reducing the number of children a couple may expect to have reach the age of 15. An estimated coefficient less than one implies the number of children surviving to age 15 in each family will tend to be larger where the child death rate is lower, other factors held constant.[35]

One final issue is germane to our inquiry: how long is the lag likely to be between the death of a child and its subsequent observable effect on births? Research on the average length of birth intervals for women not practicing contraception suggests that an average two or three years will elapse.[36] For women between the ages of 20 and 29 when fecundity appears to be highest, two years seems more appropriate, at least for the United States, and perhaps three years for women 15 to 19 and over 29 years of age. To this biological lag, a decisionmaking lag may be added, but there is no empirical evidence to guide one on the appropriate length of this behavioral lag. Since we are restricted in Taiwan to a few years of collected and published death data, experimentation with various lags is limited to 1966, where it is found that

the three year lag is statistically strongest for the age standardized birth rate, although the two-year lag (not reported here) is marginally more powerful in accounting for the interregional variation in birth rates for women between the ages of 20 and 29. This result is consistent with the other direct evidence on birth intervals mentioned above. The results reported here are for a fixed three-year lag for both 1964 and 1966.[37]

Estimates of the logarithmic association implied by the family planning model between birth rates in 1964 and 1966 and appropriately lagged environmental variables are shown in Tables 5 and 6.[38] This formulation of the model accounts for 23 percent of the interregional relative variation in the age standardized birth rate in 1964 and 57 percent in 1966.[39] For the age specific birth rates from age 30 to 44 the model accounts for 20 to 38 percent of the variation, but for the age 20 to 29 cohorts only 6 to 20 percent of the variance can be understood in terms of these environmental variables. These over-all findings are consistent with our expectation that the model pertains primarily to the older age cohorts when birth control is practiced more widely.[40]

As before, the child death factor and child school attendance rates are the most powerful explanatory variables in the model. The association in both years between birth rates and the child death factor lagged three years is positive and statistically significant at the .1 percent confidence level, except for women in 1964 between the ages 25 and 29. As indicated earlier the reproductive behavior of this group is not likely to be influenced strongly by the determinants of the family planning

Table 5

REGRESSIONS ON REGISTERED FERTILITY IN ADMINISTRATIVE REGIONS OF TAIWAN, 1964[a]
(In parentheses beneath regression coefficients are their t statistics, or the ratios of the coefficients to their standard errors)

Regression Number	Dependent Variable	Constant Term	Percent of Children Age 7 to 15 in School 1961	Percent of Adults with Primary School Certificate 1961[c]	Percent of Labor Force in Agriculture 1965	Reciprocal of Child Survival probability 1961[d]	R^2
1	Birth Rate Normalized for Age and Sex Composition[b]	.112	-.100 (-4.2)	-.005 (-.12)	.017 (1.75)	1.218 (5.74)**	.225
	Age Specific Birth Rate per 1000 Women of age:						
2	15-19	1.246	-.094 (-1.08)	.273 (1.76)	-.086 (-2.37)*	4.050 (5.16)**	.107
3	20-24	2.418	-.056 (-1.85)	.025 (.47)	.008 (.60)	.953 (3.47)**	.074
4	25-29	2.689	-.047 (-2.05)*	-.070 (-1.70)	.023 (2.36)*	-.186 (-.89)	.055
5	30-34	2.545	-.144 (4.82)**	-.027 (-.51)	.017 (1.39)	1.238 (4.50)**	.202
6	35-39	2.441	-.224 (-5.01)**	-.109 (-1.37)	.052 (2.80)*	2.801 (6.96)**	.310
7	40-44	1.931	-.256 (-4.29)**	-.028 (-.27)	.077 (3.10)*	3.351 (6.22)**	.271

Table 5 continued:

*Coefficient significantly different from zero at 1% level of confidence.

**Coefficient significantly different from zero at .1% level of confidence.

NOTES:

[a]All variables expressed as logarithms (to base 10). Sample size is 361.

[b]Actual Crude Birth Rate divided by Normalized Crude Birth Rate derived by attributing the national age specific birth rates to the seven age cohorts of women in each region. Deviations from one (or zero in the log form), therefore represent deviations in local crude birth rate from that expected nationally from the regions age/sex population composition.

[c]Adults considered to be all persons over the age of 12, and out of school.

[d]This variable is defined as the reciprocal of the one minus the summed death rates for children from birth to age 15 in the region. Thus if d_i is the frequency of death per 1000 persons of age i in a region, the death variable is defined as

$$1/(1-(\sum_{i=1}^{15} d_i)/1000).$$

Table 6

REGRESSION ON ADJUSTED REGISTERED FERTILITY IN ADMINISTRATIVE REGIONS OF TAIWAN, 1966[a]
(In parentheses beneath regression coefficients are their t statistics, or the ratios of the coefficients to their standard errors)

Regression Number	Dependent Variable	Constant Term	Percent of Children Age 7 to 15 in school 1965	Percent of Adults with Primary School Certificate 1965[c]	Percent of Labor Force in Agriculture 1965	Reciprocal of Child Survival Probability 1963[d]	R^2
1	Birth Rate Normalized for Age and Sex Composition[b]	.371	-.185 (-10.3)**	-.075 (-2.18)*	.013 (2.06)*	1.928 (12.46)**	.566
	Age Specific Birth Rate per 1000 Women of age:						
2	15-19	1.756	-.198 (-2.31)*	.035 (.22)	-.054 (-1.73)	5.709 (7.71)**	.211
3	20-24	2.765	-.111 (-4.07)**	-.131 (-2.52)*	.021 (2.14)*	1.130 (4.81)**	.185
4	25-29	2.781	-.065 (-2.18)	-.138 (-2.42)*	.029 (2.70)*	.655 (2.53)*	.090
5.	30-34	2.695	-.211 (-6.61)**	-.087 (-1.44)	.009 (.76)	2.169 (7.89)**	.338
6	35-39	2.722	-.406 (-7.61)**	-.140 (-1.37)	.027 (1.36)	3.579 (7.74)**	.372
7	40-44	2.349	-.455 (-5.82)**	-.181 (-1.21)	.087 (3.05)*	4.458 (6.58)**	.312

Table 6 continued:

*Coefficient significantly different from zero at 1% level of confidence.

**Coefficient significantly different from zero at .1% level of confidence.

Notes:

[a]Birth rates in 1966 were adjusted for overregistration in the last quarter of the year due to the year end Census of Population. Unadjusted data yield very similar findings. For methodology and convincing rationale for adjustment procedures is the Taiwan Demographic Factbook 1967.

[b]Actual Births divided by Normalized Births derived by attributing the national age specific birth rates to the seven age cohorts of women in each region. Deviations from one (or zero in the log form), therefore represent deviations in local crude birth rate from that expected nationally from the regions age/sex population composition.

[c]Adults considered to be all persons over the age of 12, and out of school.

[d]This variable is defined as the reciprocal of the one minus the summed death rates for children from birth to age 15 in the region. Thus if d_i is the frequency of death per 1000 persons of age i in a region, the death variable is defined as

$$1/(1 - (\sum_{i=1}^{15} d_i)/1000).$$

model. The coefficient estimated for the child death factor in the age standardized birth rate equation in both years exceeds unity (i.e., 1.2 ($\pm$ .2) in 1964 and 1.9 ($\pm$ .2) in 1966), which implies that a lower regional child death rate is associated significantly with a reduction in the number of children parents in that region are likely to have surviving to the age of 15.

Educational opportunities are also associated with lower birth rates. But as before for Colombia the association is more consistent and statistically significant for child school attendance rates than for adult primary education rates. The relationship between child schooling and the birth rate is stronger among women over 30, but by 1966 even among the younger women this association is statistically significant at the 5 percent level or better. Adult education plays no noticeable role in 1964, according to these findings, but emerges as statistically significant among women 20 to 29 in 1966. This may be an indication that better educated women are beginning to space their births or practice birth control even during their 20s.

As noted in our consideration of Colombia, the proportion of the active population in agriculture is frequently linked to differences in birth rates, for it is plausibly reasoned that small-scale agriculture permits parents to utilize, to a great extent, the productive contribution of children's time. Examining this relationship in Taiwan we find it weak. In 1964 it does not satisfy the traditional test for significant at the 5 percent level and in 1966 it hardly passes this test, revealing slightly higher age standardized birth rates in areas of heavy agricultural dependence.[41] More interesting than the over-all effect is

the age-specific association. It appears there is a tendency in areas where agricultural activity predominates for birth rates to be lower for the 15-19 age cohort, and higher for later ages. With the scarcity of land in Taiwan, it is not implausible that there would be a systematic tendency for marriage and child bearing to be delayed until land ownership or operation were within reach of the younger generation.[42]

Though it is not now possible to consider in adequate detail the influence of the Taiwan Family Planning Program, one rightly suspects that this program may be operating to bias our estimates of environmental effects on regional births. A simple treatment of this factor is therefore better than none.[43] Other facets of this program are dealt with later in this study. One may interpret the family planning program as an input which reduces the cost of contraception to persons in the region and thus makes it more convenient to limit reliably their family size. Inclusion in Table 7 of the man months of medical and nonmedical manpower employed in the region's family planning program in 1964 per 1000 women in childbearing age shows that the program's inputs in that year appear to have had a small, but very significant, impact on birth rates only two years later; particularly among young (15-19) and older (30+) women. The inclusion of the family planning program manpower input improves the explanatory power of the regression (about 4 percent overall), and reduces slightly the size and significance of the other estimates. Nevertheless, the only variable for which the change in estimates deserves comment is the adult education variable, which is no longer statistically significant at the 5 percent level after the inclusion of the family planning program variable. The

significance of this result will become clearer when the policy implications of family planning programs is considered in a later chapter.

Table 7

REGRESSION ON ADJUSTED REGISTERED FERTILITY IN ADMINISTRATIVE REGIONS OF TAIWAN, INCLUDING A MEASURE OF INPUTS INTO THE FAMILY PLANNING PROGRAM, 1966[a]

(In parentheses beneath regression coefficients are their t statistics, of the ratio of the coefficient to their standard errors)

Regression Number	Dependent Variable	Constant Term	Percent of Children Age 7 to 15 in School 1965	Percent of Adults with Primary School Certificate 1965[c]	Percent of Labor Force in Agriculture 1965	Reciprocal of Child Survival Probability 1963d	Man Months of Effort Family Planning 1963[e]	R^2
1	Birth Rate Normalized for Age and Sex Composition[b]	.305	-.156 (-8.85)***	-.060 (-1.85)	.031 (1.97)*	1.630 (10.48)***	-.033 (-6.13)***	.607
	Age Specific Birth Rate per 1000 Women of age:							
2	15-19	1.586	-.121 (-1.39)	.076 (.47)	-.061 (-1.94)	4.906 (6.41)***	-.091 (-3.42)***	.238
3	20-24	2.729	-.095 (-3.37)**	-.124 (-2.39)**	..021 (2.09)*	.968 (3.93)***	-.018 (-2.10)**	.194
4	25-29	2.758	-.056 (-1.81)	-.134 (-2.36)**	.031 (2.74)**	.563 (2.07)*	-.010 (-1.01)	.094
5	30-34	2.624	-.180 (-5.56)***	-.072 (-1.21)	.008 (.65)	1.856 (6.51)***	-.010 (-3.55)***	.361
6	35-39	2.556	-.334 (-6.26)***	-.105 (-1.07)	.025 (1.29)	2.834 (6.04)***	-.082 (-5.03)***	.414
7	40-44	2.062	-.331 (-4.29)***	-.117 (-.82)	.081 (2.91)**	3.161 (4.66)***	-.145 (-6.10)***	.376

Table 7 continued:

*Coefficient significantly different from zero at 5% level of confidence.

**Coefficient significantly different from zero at 1% level of confidence.

***Coefficient significantly different from zero at .1% level of confidence.

Notes:

[a]All variables expressed as logarithms (to base 10). Sample size is 361.

[b]Actual Births divided by Normalized Births derived by attributing the national age specific birth rates to the seven age cohorts of women in each region. Deviations from one (or zero) in the log form, therefore represent deviations in local crude birth rate from that expected nationally from the regions age/sex population composition.

[c]Adults considered to be all persons over the age of 12, and out of school.

[d]This variable is defined as the reciprocal of the one minus the summed death rates for children from birth to age 15 in the region. Thus if d_i is the frequency of death per 1000 persons of age i in a region, the death variable is defined as

$$1/(1-(\sum_{i=1}^{15} d_i)/1000).$$

[e]This represents the number of man months of doctors, prepregnancy-workers, and village-health-education-nurses-allocated to each region in 1964 per 1000 women between the ages of 15 and 49. Since the equation is fitted in logarithmic form, and many regions received no manpower inputs in this initial year of the program, .1 man months per 1000 women in childbearing ages is arbitrarily added to the input for all regions; there being no logarithm for zero. The program input for the entire country increased from 1.47 in 1964 to 3.26 in 1965 and to 3.63 man months per 1000 women in 1966. The 1964 inputs should have an effect on birth rates in later years as well as 1966, and thus the effect estimated in this regression is <u>not</u> a long run estimate of the effect of the program inputs in this initial year.

V. SUMMARY AND CONCLUSIONS

Quantitative analysis of interregional variation in birth rates in Colombia and two other less developed countries suggests the organizing and explanatory power of the family planning hypothesis as a framework for guiding study of the determinants of population growth. However, the empirical counterparts for the conceptual variables discussed in section II are often difficult to specify and measure reliably: The death of children to still fertile parents; the economic time and resources of the family that grow out of the efforts of husband, wife, and child, each of whose contribution affects differently the relative attractiveness of children; the educational system that has a bearing on the cost of rearing children, influences the goals parents establish for their offspring, and may account for differential access to modern methods of birth control; and finally the web of social institutions and public policies that shape the function of the family and the role of children therein, altering the costs and benefits of rearing a large or small number of children.

Certain features of the parents' environment could be measured in each country, while other features could not, and their omission or indirect treatment by means of proxies introduce serious problems for our interpretation of these statistical findings. Nevertheless, the empirical evidence, though richer and perhaps more reliable for Puerto Rico and Taiwan than for Colombia, is for all three countries generally consistent with our model. General support is given to our working hypothesis that variations in reproductive behavior are the outcome of parent behavioral responses to the opportunities and constraints of

their environment. Several links between the environment and reproductive behavior emerge as quantitatively and statistically very significant, and later in this book their implications for the design of public policy will be explored in greater detail, but a word of summary may be worthwhile.

In Colombia, our proxy for the net balance between birth and child death rates, surviving fertility, should closely parallel the size of surviving family. The model postulates that to the extent that the number of surviving children parents indeed have is influenced by differences in parents' desires, the proxy for surviving fertility should be associated across regions with characteristics of those regions that make more or fewer children attractive to parents. Schooling for children is one such feature of the local environment that indicates parents bear additional costs in the rearing of children, which may contribute to their acceptance of a reduced family size goal. Education for the adult parent population also increases the opportunity value of a parents' time and may alter their preferences between goods and children, toward fewer children. Finally, where women participate in the labor force with greater frequency a higher value is attached to a woman's time, and consequently, child rearing becomes more costly.[44] Each of these features of the municipal environment and population in Colombia is associated with lower surviving fertility as implied by the model. No significant association remains after these variables are considered between the level of surviving fertility and rural-urban residence, growth of wages, or extent of prior local in-migration. What do these findings suggest for policy?

Increased income or urbanization may not necessarily reduce population growth by itself, though these changes may bring about a salutary reduction in both birth and child death rates without necessarily directly affecting population growth or migration rates. Rather the family environment must change to make more parents seek fewer surviving children. Furthermore, parents must be advised on the most humane and safe means to achieve their diminished family size goal. This may necessitate an active program hastening the diffusion of birth control innovations as has been mounted in Taiwan. The selective expansion of health, education, and welfare programs may do much to encourage parents to seek fewer children.

The association between surviving fertility and parents' environment, though statistically weak in the fragmentary and indirect data examined for Colombia, is revealed with greater clarity and richness when better data from Puerto Rico and Taiwan were examined.

Though much more research is needed to specify adequately a model of human reproductive behavior in terms that are appropriately simple but useful and estimate its parameters for a variety of populations, the analysis offered in this chapter points to important areas of interaction between a parent's environment and reproductive behavior. To control or cope with population growth these interactions must be understood. In addition to family planning programs that subsidize the spread of innovative modern means of birth control, slowing population growth in the less developed countries such as Colombia may depend in large measure on the priority given to promoting change in certain features of the family's environment.

Among these the extension of basic education and the improvement of child health may prove crucial.

FOOTNOTES

[1]The model is elaborated more fully in RM-5405. T. Paul Schultz, A Family Planning Hypothesis, RM-5405, RC/AID, December 1967, and in (forthcoming) "An Economic Model of Family Planning and Fertility," Journal of Political Economy, Vol. 77, No. 2 (March/April 1969).

[2]Each of these simple associations between women's earnings, activity, and fertility can be verified with U.S. data, and international comparisons also appear to be generally consistent with these direct implications of the opportunity income hypothesis. For example, see G. G. Cain and A. Weininger, "Economic Determinants of Fertility," mimeo April 1967; Cain, Married Women in the Labor Force: An Economic Analysis, University of Chicago Press, Chicago, 1966; United Nations, Population Bulletin, No. 7, 1963; Whelpton, "Trends and Differentials in Spacing Births," Demography, Vol. 1, 1964.

[3]Because children represent a long-term irreversible commitment, parents are not likely to respond to a change in income by adjusting the final number of children they want unless they view the change as permanent. The timing of births, on the other hand, might be altered in response to transitory changes in income.

[4]This issue is discussed at greater length in Schultz, "An Economic Model of Family Planning and Fertility," The RAND Corporation, P-3862-1, Santa Monica, California, July 1968.

[5]The government may, for example, proscribe child labor, enforce school attendance, institute support programs for the aged and unproductive persons, and provide compulsory insurance programs of disability, medical care, and retirement. Public policies further impinge directly on the costs and benefits of children versus other private resource uses by government tax and expenditure policies, which extend, on one hand, personal deductions and dependency allowances on taxes, and on the other hand, provide for public health, education, and welfare services.

[6]Though pregnancy rates differ among populations practicing similar methods of contraception, largely because of differences in motivation and understanding, the greater reliability of modern compared to traditional methods of contraception is on the order of 10 to 1. Costs and inconvenience also appear to favor modern over traditional methods of contraception.

[7]This implication of the model is confirmed by an analysis of Puerto Rican data reported by Schultz, "An Economic Model of Family Planning and Fertility."

[8]A later study of other developing countries will attempt to specify and estimate the more prominent simultaneous relationships among which will be family decisions relating to the frequency or number of births wanted. Neglecting interactions among family

behavioral decisions biases our estimates of the effects of environmental conditions on the frequency of births; but it is hoped this simultaneous equation bias is not large, and the findings of this partial analysis represent a tentative step toward understanding the complex of household decisions pertaining to participation, migration, and fertility.

[9] Since in the case of Colombia one is unable to consider more than one cross section of regional observation without reliable information of death rates, these dynamic aspects of the model are not further developed here. The assumptions and the entire econometric model implicit in this discussion is set forth in Schultz, A Family Planning Hypothesis, RM-5405.

[10] Three studies have attempted to examine for Colombia fertility, mortality and in some cases migration rates by Department. A UN study directed by Grauman sought to project demographic trends based on data for 1938-1951, and analyze some of the implications of these trends. Cuervo in a CELADE paper studied the differences in fertility across Departments, and demonstrated that the 1951 Census age compositions imply radically different fertility patterns from registered rates (which are grossly deficient in several Departments). Berry used Grauman's fertility and mortality estimates by Department, and suggests how these vital rates may be linked to various social and demographic characteristics. None of these studies utilized the 1964 Census materials, nor examined data at the municipality level. Alvaro Lopez is preparing a study of Colombian population growth based on the 1964 Census results, but it was not available as of 1968. See, Some Aspects of Population Growth in Colombia, prepared by the Secretariat of the Economic Commission for Latin America, Economic and Social Council, United Nations, E/CN.12/618, 10 November 1962; Lilia Ines Cuervo Gomez, Fecundidad Diferencial de Colombia por Secciones Politico-Administrativas, Centro Latinoamericano de Demografia, Santiago, Chile, E/CN.CELADE/C.21 B.61.1/5.Rev.1, 1964; R. Albert Berry, Breve Estudio de los Determinantes del Crecimiento de la Poblacion en Colombia, Centro de Estodios Sobre Desarrollo Economico (CEDE), Universidad de los Andes, Bogota, Colombia, March 1965.

[11] Even if the assumptions often advanced to proceed with quasi-stable population theory estimates of vital rates were granted, there is no general way to contend with interregional migration which radically affects the age compositions of regional populations. At the national level, it may be assumed that net migration flows into or out of Colombia in this period were negligible, and thus it is feasible to estimate Colombian national average birth and death rates. But regional estimates of vital rates must rely on less reliable evidence of the net balance between birth and child death rates, as reflected in child/woman and child/population ratios of the traditional sort. See T. Paul Schultz, Population Growth and Internal Migration in Colombia, RM-5765, 1969, Appendix B.

[12]Four linear estimates of the crude birth rate (uncompensated for the incidence of child death) are computed and averaged, based on the ratio of children (age 0-4 and 5-9) to women of child bearing age (15-49) and on the ratio of children (age 0-4 and 5-9) to total population. The linear estimates are borrowed from a cross-sectional analysis of some 50 countries by Bogue and Palmore. The average of the four 1964 estimates is designated our estimate of surviving fertility for each municipality for the decade before the 1964 census. For regression coefficients, see Donald J. Bogue and James A. Palmore, "Some Empirical and Analytic Relations Among Demographic Fertility Measures with Regression Models for Fertility Estimation," Demography, Vol. 1, 1964, Table 8, p. 325.

[13]The counterbalancing effects of interregional birth and child death rates and their impact on child/woman ratios are discussed by Warren C. Robinson, "Urbanization and Fertility: The Non-Western Experience," Milbank Memorial Fund Quarterly, Vol. 41, No. 3, July 1963, pp. 291-308. Puerto Rican data also reveal this interregional pattern. The family planning hypothesis, of course, implies that this pattern is behaviorally determined. See Schultz, "An Economic Model of Family Planning and Fertility."

[14]Multicollinearity is not as much a problem as might be expected in considering both child and adult schooling simultaneously in a regression model. For the Colombia sample the simple correlation coefficient between adult and child schooling variables is only .47 in the 1964 Census, for Puerto Rico from 1951-1957 it is .42, and Taiwan .39 in 1965.

[15](To be elaborated later - Housing Variable results.)

[16]Zarate has sought to show that urban immigrants to Monterrey, Mexico, only gradually reduce their fertility toward the level sustained by native-born residents of the city. However, he neglects to make allowances for the differences that undoubtedly distinguish the family environment for the urban in-migrant parents and city-born parents -- differences that may go a long way toward accounting for the different reproductive behavior he correlates with the two groups. Alvan O. Zarate, "Differential Fertility in Monterrey, Mexico," Milbank Memorial Fund Quarterly, Vol. 45, No. 2, Part 1, April 1967; and "Some Factors Associated with Urban-Rural Fertility Differentials in Mexico," Population Studies, Vol. 21, No. 3, November 1967.

[17]There are strong reasons for treating both migration and population growth simultaneously, but as noted later, this proved impossible given data limitations for Colombia.

[18]A number of factors could add, on balance, to the real costs of rearing children in the urban compared with the rural environment: (1) direct costs of food and housing are likely to be greater for a large family; (2) opportunities to use the productive talents of

children to add to family resources tend to be more limited; (3) the need to invest in children's schooling and skills is better understood in the urban environment, hence the associated costs are more often accepted; (4) opportunities for women to work outside of the home are greater, and consequently their potential contribution to family income that is forgone while children are young is larger.

[19]The postponement of marriage is the primary determinant of variation in the proportion of the adult female population married, and this form of institutional adjustment is commonly associated with the more fundamental changes in the environment already included in the analysis. To the extent that marriage is a response to the environmental constraints its inclusion biases downward the other estimates for the environmental constraints. Its omission or non-simultaneous consideration also biases the analysis in ways that are difficult to ascertain.

[20]The design and shortcomings of this sample and associated Census data are discussed in T. Paul Schultz, Population Growth and Internal Migration in Colombia, RM-5765, Appendix B.

[21]Schultz, A Family Planning Hypothesis: Some Empirical Evidence from Puerto Rico.

[22]Argentina, Uruguay, Cuba, Puerto Rico, and Chile.

[23]McDermott, "Modern Medicine and the Demographic/Disease Pattern of Overly Traditional Societies: A Technologic Mismatch," paper presented at the Institute on International Medical Education of the Association of American Medical Colleges, Washington, D.C., March 28, 1966.

[24]For full discussion and derivation of estimation procedure for dynamic relations of a time series of cross sections see Schultz, A Family Planning Hypothesis, RM-5405, Appendix D.

[25]Since death rates fell abruptly in this period, 1943 to 1956, and declines were due largely to irreversible improvements in health and economic conditions, it is plausible that the greater the deviations in death rates from their trend value, the greater parents' difficulty in anticipating future death rates and interpreting accurately trends. Uncertainty in death rates is therefore estimated as the variance from a linear time trend. How well this proxy represents the parents' expectations of the uncertainty which they face in forming their family is moot. No significant association was found between it and birth rates after including the other control variables.

[26]As a proxy for the share of the population subject to the risk of child bearing, the proportion of adults married was used. Age-specific marital status data was not available by region for the purposes of deriving a measure of the fertile population subject to the risk of child bearing. The women in each age group were attributed the appropriate national age-specific birth rate, and the estimated number of births for each municipality was then divided by the population to derive an estimate of the municipal crude birth rate. This

procedure assumes that age-specific birth rates do not vary appreciably across Puerto Rico, so that age/sex compositional differences will account for (some of) the observed interregional variation in crude birth rates.

[27]These demographic variables may not vary sufficiently across regions for us to identify their effect on birth rates, or their effect may have already been accounted for by underlying economic variables that themselves influence marriage rates and through their effect on migration, change the age structure. But regardless of the reasons, this simple test finds no support for the hypothesis that these compositional features of the municipal populations are helpful in understanding existing differences in municipal birth rates.

[28]See discussion later in footnote 35.

[29]These unique data for a less developed country are published by the Taiwan Department of Civil Affairs and reflect years of consultative effort on the part of the University of Michigan Population Studies Center under the direction of Ronald Freedman and the Taiwan Population Studies Center in Taichung under the direction of L. P. Chow. The Taiwan family planning program has become in recent years the prototype of a successful large scale, well run program in a developing country. This reputation is probably closely related to the fact that a large fraction of the program's resources have been used both to improve the design of the program with the aid of carefully evaluated pilot programs (the Taichung experiment is discussed in a forthcoming book by Freedman and Takeshita) and to collect the basic demographic and program statistics which allow for reliable evaluation of the program's success at each stage in its evolution. For a recent survey of this much-studied program, see R. G. Potter, R. Freedman, and L. P. Chow, "Taiwan's Family Planning Program," Science, 160: 848-853, 24 May 1968.

[30]Education and occupation data are available for only a year or two. Women's participation in the labor force was also examined (from unpublished tabulations of the household registry kindly provided by Paul Liu), but were not found to be significantly associated with birth rates. Liu finds from an evaluation check on the accuracy of the registry system that it performs well in measuring births, education and male occupation, but was exceptionally inaccurate when it comes to current work status of women in the community. Paul K. C. Liu (trans. W. L. Parish), "The Use of Household Registration Records in measuring the Fertility Level of Taiwan," Economics Papers, Selected English Series No. 2, The Institute of Economics, Academica Sinica, Taipei, Taiwan, p. 4. It has been pointed out to me by Ronald Freedman that the adult education measure published from the household registration material provides information only on the average educational attainment of all persons 12 years or older who are no longer in school. It would be distinctly preferable to have age specific educational data, since only the potential parent population's education is germane to the hypothesis we seek to test. With 1966 census materials, soon to be available, it should be possible to derive such a measure of age specific educational attainment.

[31]For example, in Taiwan among women accepting an IUD (Intra-uterine Device) in 1966 about 15 percent reported their objective was spacing as opposed to stopping further births. Among women over the age of 29, the proportion spacing births was only 5 percent. Demographic Reference -- Taiwan, 1967, Vol. V, Table 8.

[32]This pattern prevails in virtually all developed countries. One exception is the Netherlands, where fertility is still relatively high and the participation of women in the labor force is very low, particularly among married women. In the Netherlands one finds the unusual pattern of prolonged childbearing years, and thus a more uniform relative downward shift in age-specific fertility rates at all ages than in most other advanced industrial countries. The growing concentration of childbearing in the younger years appears to be also emerging in many of the less-developed countries that are experiencing a substantial decline in fertility.

[33]This implication of the family planning model allows us to discriminate between two possible causes for the association between child death rates and subsequent birth rates in a region. Some students of the subject have suggested that the statistical association may be due to a biological lag in the human reproductive process. The reasoning runs that when an infant dies which is breast feeding, the consequent cessation of lactation reduces the period of postpartum sterility (amenorrhea) and thus increases the probability that the mother will conceive again. In some cultures intercourse during lactation is taboo, just as various other customary and institutional arrangements work to increase birth intervals if the child survives, but are rescinded if the child dies. Were this the cause of the statistical association noted in Puerto Rico, the association should be significant for women of all ages, and perhaps diminish with advancing age and declining fecundity. The family planning model that attributes this association to a behavioral decision would lead us to expect that the statistical association would be stronger among women over 30 and weaker among women in their 20s when reproductive behavior is less immediately sensitive to child mortality.

[34]Age specific death rates are summed for the region from birth through age 14. Also the infant survival rate was investigated, but the statistical association was stronger when the child death variable was defined over the entire first 14 years of life. Beyond that age not only are death rates low, but an increasing fraction of the child deaths are likely to occur to parents who were sterile and could not, therefore, change their reproductive behavior.

[35]The death factor is defined as the reciprocal of the child survival rate (i.e., one minus the child death rate). For example, if 80 percent of the children survived to age 15, then the child death factor would be 1.25. Parents to have four surviving children would seek five births ($4 \times 1.25 = 5$). It seems probable, however, that uncertainty enters this decisionmaking process and when, say two decades ago, only 50 percent of the children survived to age 15 in the region, parents might still have only wanted four surviving children, but to hedge against the greater uncertainty implicit in such a heavy

regime of childhood mortality, they might have sought not 8 births (4 x [1/.5] = 8), but perhaps 9 or 10. In this case the reduction in child death rates would reduce the size of surviving (to age 15) family. The child survival rate considered here is not defined precisely the way life tables are ordinarily constructed, for it is simply one minus the accumulated child death rates. Thus our measure of the survival rate is somewhat lower than that recorded in a life table. Though there may still be a serious problem of underregistration of infant mortality in Taiwan, I may hazard the guess that there are few other countries with Taiwan's level of income that could compare favorably. In future research child death rates will be analyzed from age one to 15, in an effort to avoid the potentially larger margin of error that is thought to surround the registration of infant deaths in comparison to deaths of older children.

[36] Robert G. Potter, "Birth Intervals: Structure and Change," Population Studies, Vol. 17, No. 155, 1963, pp. 155-166.

[37] Using the two-year lag for the age specific birth rates between 20 and 29 did not change appreciably the other regression coefficients, and since the two-year lagged death rates were not available for 1964, comparability was preserved by using the three-year lag for all regressions reported in Tables 5 through 7

[38] Ordinary least squares estimates are interpreted, recognizing that such estimates have well known deficiences for considering one part of a simultaneous system of behavioral relations.

[39] The age standardized and normalized birth rate is defined for the ith region as:

$$B_i / \sum_{j=1}^{7} \bar{B}_j W_{ij}$$

where B_i is the number of births in the ith region, $\bar{B}_j$ is the national age specific birth rate per thousand women in the jth age cohort, and W_{ij} is the number of thousand women in the jth age cohort in the ith region. For instance, if the age specific birth rates in a region were identical to the national average age specific rates, then the age standardized birth rate would be unity. A possible source of error in our dependent variable is the adjustment procedure applied to correct regionally registered birth rates for the unusual effects of the 1966 Census which concentrated birth registrations at the end of 1966. The adjustment procedure, I am informed by Ronald Freedman, was later found to be unsatisfactory, and an improved procedure is being developed. The results reported here are not greatly affected by the shift from adjusted to unadjusted series. Table 6 and 7 are based on the adjusted figures as published in the 1966 Taiwan Demographic Factbook, table 17.

[40] All regressions are significant at the 1 percent level according to the F ratio test of the overall interrelation. In Tables 6 and 7, all satisfy this test at the .1 percent level.

[41]It should be noted that the quantitative magnitude of this relationship between agricultural activity and higher birth rates is small indeed. The association suggests if the proportion of active men in agriculture in a region increased 100 percent, the age standardized birth rates would increase 1.3 to 1.7 percent.

[42]A similar tendency was evident in England during the enclosures and industrial revolution, for the age at marriage fell more slowly in the rural setting than in the urban, where land, and support on the land, for a wife and children was generally not within the reach of young men. See P. G. Ohlin, "The Positive and the Preventive Check: A Study of the Rate of Growth of the Pre-Industrial Population," unpublished Ph.D. Dissertation, Harvard University, 1955.

[43]The restricted measure of the impact of the family planning program in Taiwan that is considered here is defined in Note e to Table 7. Numerous studies have over the last several years sought to evaluate the effect of the program on behavior of the population. Most studies have analyzed the program measures of output: the number of persons serviced or the number of IUD and pill acceptors. Island-wide surveys have also documented the changing patterns of contraceptive use. Consequently, our method is in no sense unique in implying that the program has had a distinguishable impact on birth rates in Taiwan, but it does use indirect procedures of statistical inference that have not been widely applied. A more thorough investigation of the impact of the family planning program on birth rates is presented in the author's "The Effectiveness of Family Planning in Taiwan," The RAND Corporation, Santa Monica, P-4069, March 1969.

[44]Not all forms of economic activity undertaken by women necessarily raise the cost of child rearing, for some types of activity may be undertaken in the home or in the company of one's children and thus not represent a conflicting claim on the mother's family rearing responsibilities.